DOMESTIC ENERGY FOR THE FALKLAND ISLANDS

A MANUAL FOR THE RESIDENTS OF THE CAMP

PREPARED BY
PETER FRAENKEL AND SARAH LANCASHIRE
OF I T POWER LTD

FOR THE FALKLAND ISLANDS
DEVELOPMENT CORPORATION

APRIL 1990

it Power

CONTENTS

1.

Introduction

1. INTRODUCTION

Scope of Handbook

This handbook is intended to provide information about methods by which people living in areas remote from an electricity supply grid may improve the availability of power in their homes and reduce the costs of their power supply. The book is divided into several sections. The first sections deal with methods by which existing equipment can be used more efficiently so that fuel consumption is reduced. Subsequent sections deal with methods of increasing the availability of power.

An important and vital bit of information to be aware of is that, nearly always, it will be cheaper to increase the efficiency with which an existing power supply is utilised so as to make it go further than to simply increase the availability of power to meet an increasing apparent demand. Only when all possible sensible steps to use an existing power source as efficiently as possible have been taken should a user generally consider increasing the size of the power supply. So this handbook will deal virtually as much with saving power as with generating it efficiently.

It is not possible to cover topics in great depth in a book of this size; therefore we have provided interested readers with references to other more specialised publications, suppliers and organisations. The final section gives product information together with sources of supply. The product list is not exhaustive. Wherever possible, at least three sources of supply are given for a product. However, since *I T Power* has not got first-hand experience of many of these products, the inclusion of any particular product is not an indication that the product is approved by *I T Power*. All information is taken directly from suppliers' literature. In exactly the same way, the exclusion of any product does not imply that we consider it unsuitable or inferior in any way.

Some important definitions

Throughout this book (and also in the more technically sophisticated literature) various terms will be used which are often misunderstood. Some of the most important are:

Work

Work in the simplest technical sense is when a force is used to move something. If you push the back of a car but fail to move it, although it may feel like "work", unless some actual movement takes place, no work is done; a force is merely being applied to no effect. However if you push a car and succeed in moving it, the work done is technically the product of the force used and the distance travelled. The same principle applies to other applications; eg. electrical work requires a flow of electrons (current) to be pushed by an electrical force (voltage); hydraulic work requires a liquid to be pushed by some force.

Power

Power is the *rate of doing work.* The quicker you do a certain finite amount of work the more power is required. In the case of electricity the work consists of forcing electrons, in other words an electric current, to move through a circuit and hence perform some useful function like making a filament glow white hot (in a light bulb), or making electro-magnetic fields turn a rotor which may, for example, pump refrigerant through a freezer's heat exchanger coils to remove heat from the food. So the more current you force through some electrical device the more power is needed. A 100W light bulb uses exactly twice the current and hence twice the power of a 50W bulb.

Power used to be measured in horsepower, the rate at which a horse could do work, but the modern unit is the Watt, abbreviated as "W". There are 746W in 1 hp, so the watt is rather a small unit and it is therefore more common for many practical purposes to use Kilowatts "kW" which are units of 1000W.

Energy

Many people confuse the meanings of the words "Energy" and "Power". Energy is the total work completed; so its units are a combination of power and time. The basic unit of energy is the kilowatt-hour "kWh" (or sometimes the watt-hour "Wh") which is the energy involved in delivering 1kW for 1 hour (or 2kW for 30 minutes, or 500W (0.5kW) for 2 hours, for example).

The basic unit by which electricity is commonly sold is the kWh. As fuel is burnt to generate electricity (or heat which is another form of energy) a can of fuel represents a "package of energy". One litre of diesel fuel, for example, if completely burnt produces approximately 10kWh of heat. But because no process for converting the energy of fuel into electricity is even near to being perfect, only some fraction of the energy in the fuel will be converted into *useful* energy output and the rest will be wasted as various losses such as waste heat and noise.

Efficiency

Efficiency is an important concept for any discussion about energy. It is defined as follows:

Efficiency = (Useful work done by device)÷(Energy supplied to device)

For example, a diesel generator may typically be described as 30% efficient. This means that of the diesel fuel burned by the engine, only 30% is converted into useful electricity. The other 70% is wasted as heat, noise and incompletely burned fuel lost in the exhaust gases. So instead of 10kWh from each litre of diesel fuel, the best that is likely is 3kWh of electricity (often written as 3kWh(e)) and 7kWh of waste heat and noise.

No device is ever 100% efficient – some energy is always wasted whenever energy of one type is converted into energy of another type. However, it is obviously desirable to be as efficient as possible when using energy, and therefore it is often worthwhile to pay a little extra for a more energy-efficient piece of equipment. In the long run, this equipment will use less energy and hence cost less to operate.

Efficiencies based on the definition just given will be referred to throughout this handbook as a measure of the "quality" of different devices.

Power and Energy

The power rating of equipment and the energy used or produced by the equipment are important values. Power is a measure of how quickly the equipment can do work, whilst energy is a measure of the total amount of work completed or fuel used. A simple example illustrates this:

Consider two electric kettles. One kettle has a power rating of 3kW whilst the other kettle has a power rating of 2 kW. The 3 kW kettle is therefore more powerful than the 2 kW kettle and will boil a litre of water more quickly. However, both kettles will consume the same amount of energy in boiling the litre of water, assuming they are equally efficient. The amount of energy consumed is calculated as:

$$\text{(Energy used)} = \text{(Power rating)} \times \text{(Time)}$$

If it takes 4 minutes for the 3 kW kettle to boil a litre of water and 6 minutes for the 2 kW kettle to boil the water, the energy used is calculated as:

$$\text{Energy used by 3 kW kettle} = 3\ \text{kW} \times 4/60\ \text{h}$$
$$= 0.2\ \text{kWh}$$

$$\text{Energy used by 2 kW kettle} = 2\ \text{kW} \times 6/60\ \text{h}$$
$$= 0.2\ \text{kWh}$$

Annex 1 gives more information about the basic units of power and energy for those readers who are unfamiliar with them.

Electric Current and Voltage

In some of the chapters of this book, reference will be made to the electrical parameters of current and voltage. A brief explanation of their relationship to energy and power is included here for readers who are unfamiliar with the physics of electricity. Most electrical equipment is designed to operate at a particular voltage. In simple terms, the voltage is the amount of electrical pressure or force needed to push the electricity through the equipment, whilst the current is the amount of electricity flowing. The power, voltage and current of a device are related as follows:

Power in watts (W)	=	Voltage in volts (V)	x	Current in amps (A)

Conversely, if an appliance is rated with its power and voltage, the current that it will take is given by:

Current in amps (A)	=	Power in watts (W)	÷	Voltage in volts (V)

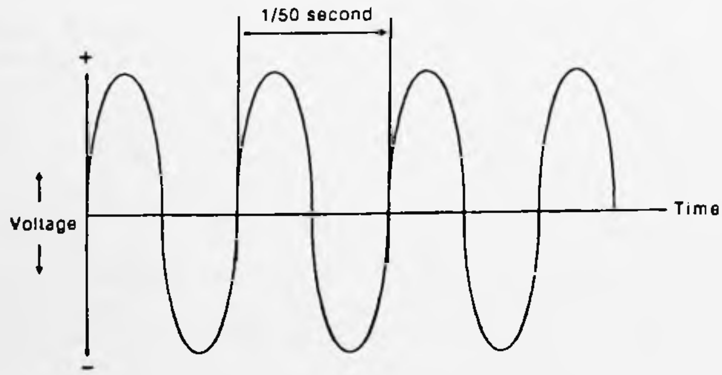
If the 3 kW kettle is for use with a 240 V electrical supply then the current that it uses is calculated as follows:

Current = 3000 ÷ 240 (Note: 3 kW = 3000 watts)

= 12.5 A

Alternating and Direct Current

Mains power throughout the world is delivered as AC (alternating current) in which the voltage goes from zero to some peak value, back to zero, to a negative value and so on as indicated. This commonly happens 50 times per second, and the frequency is said to be 50 Hz, as illustrated in the following diagram.



In effect the current rushes backwards and forwards down the wire to produce power.

The European and UK standard common to appliances generally used in the Falkland Islands is 220 – 240 Volts (this is the average voltage as of course it continuously fluctuates) and 50 Hertz. In the USA and many South American countries, the US standard of 110 Volts and 60 Hertz is common. Alternating current has the advantage that the voltage can be easily and inexpensively changed by using a transformer.

The power delivered by batteries and some specialised types of generating equipment is DC (direct current). In this case, the voltage is constant and the current flows steadily in one direction only. DC is often used in low voltage equipment. For example, a torch commonly uses two dry cells of 1.5 V each.

High voltage DC is uncommon because it is more hazardous than AC to human life and also it is not so amenable to being stepped up or down to different voltages, it needs heavier and more expensive conductors. Also AC appliances are mass-produced, almost universally used and therefore more easily and cheaply obtained.

Virtually all electronic devices, such as radios (both transmitters and receivers), computers, tape-recorders or videos depend primarily on low voltage DC although they are usually equipped internally with a what is called a "power supply" which transforms mains voltage AC down to low voltage DC. Televisions and computer monitors also have an additional high voltage circuit to power the tube.

Transformers, Rectifiers and Inverters

AC voltages can be converted by using transformers which for example can change 220-240V to 12V or 120V when this is needed. AC can then be converted to DC with devices called rectifiers. Most modern cars for example, have AC generators (often known as alternators) as these are cheaper, more powerful and trouble free than the traditional DC generator (or dynamo), so the output from the alternator is rectified by a set of diodes (solid state electronic devices) to feed DC to the car battery (AC will ruin a battery).

Similarly if you want to store electricity in batteries you have to rectify any AC supply and feed the battery DC at a suitable voltage.

If a DC supply, such as from batteries, is needed to power standard AC mains appliances, it is possible to convert the DC back to AC. The traditional method was a so-called rotary inverter, which is a DC electric motor driving an AC generator or alternator. Such devices are noisy and inefficient and the modern alternative is a solid-state electronic device called a static inverter.

Three-phase and single-phase AC

So far we have only talked about single phase AC where two or three wires, the supply one known as the "live" and usually coded with brown or red insulation and the return one known as the "neutral" (coded blue or black) (plus usually a third green/yellow "earth" cable which is vital to ensure safety) are used and the voltage and current fluctuate 50 times per second (usually) to average 240V. For power levels greater than around 5-10kW (i.e. most industrial and many agricultural and workshop applications) it is common to use 3-phase AC. Here there are three "live" cables from the supply generator each of which behaves like a single phase "live" line except the current and voltage fluctuate so that each line is one third of a cycle out of phase with its neighbour. A single fourth "neutral" line normally serves all three phases. The individual phases are sometimes coded with yellow, blue and red insulation (or terminal tags).

Three-phase power, for reasons that are not important at this stage, is more efficient and cost effective for larger power applications and it is therefore only used in the Falklands in the larger settlements. Small applications on three phase systems are usually shared between the phases to try and put approximately the same electrical load on each phase. It is quite important, to ensure safe, reliable and efficient operation, that the phases are generally kept as evenly loaded as possible.

2.

Reducing Diesel Consumption

2. REDUCING DIESEL CONSUMPTION

2.1 Diesel Engine Efficiency

A diesel engine will be rated to produce a certain amount of power under optimal running conditions. For example, a Lister – Petter diesel generating set TS2 is rated at 7.1 kW. If the generating set is used at altitude, at high temperature or in very humid conditions it will not produce as much power. It must be derated. For example, every 300m of altitude above 150m reduces the maximum power output by 3.5%.

Normally the full power output of a diesel generating set will not be required. The engine is then said to be running on part load. For example, 5kW from a 7kW TS2 represents 70% part load.

Part load (%) = (Actual load in kW)÷(Maximum output in kW) x100%

It is usual to size a diesel generating set to run at 70 to 80% of part load. This means that the set has some spare capacity to cope with occasions when a higher than usual load is needed. However, it is important that the generating set is not oversized so that it is often running at a small part load of 50% or less. Small part loads are bad for the engine and bad for the pocket of the owner. The engine will suffer from excessive soot deposits and will require more frequent overhauls. Its life will be significantly reduced. The efficiency will be low making the cost of electricity high.

For example, a diesel generating set run at 25% part load will consume about 70% more fuel per unit of electricity than the same engine running at 75% part load (producing three times as much power) or about 40% more fuel than a smaller engine running at 75% part load (producing the same amount of power). Figure 2.1 shows diesel generator set efficiencies versus part load for two sets. Diesel generating sets are typically 25 – 30% efficient at full load. Larger sets are usually more efficient than smaller ones as in the example. At small part loads the efficiency drops off rapidly.

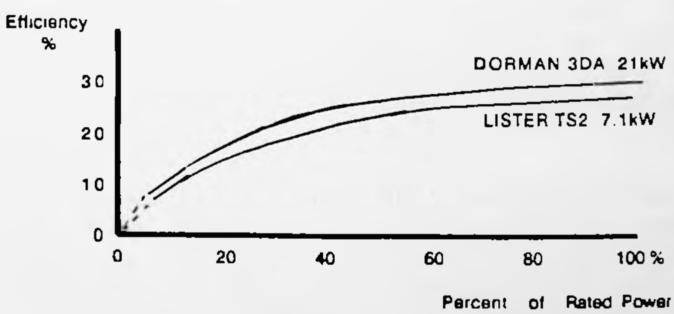


Fig 2.1: diesel generator set efficiencies at part load

When running a diesel generator set it is worthwhile keeping the load as close to full load as possible, but without wasting the electricity produced, and to run the generator for as few hours as possible each day. For example, if some washing is to be done in a washing machine it would be better to do this at a time when other electrical appliances are also needed, such as lights, television, etc, rather than to run the generator specially for it. (Unless the generator is small enough for the washing machine rating to be close to the generator rating.)

If your diesel generator set is often run on a small part load of less than 50%, it may be worth your while to consider one of the following options to rectify this situation:

- Examine your use of electricity and try to use more appli–ances simultaneously, so increasing the part load, but you will then need to run the generator for fewer hours.

- Buy a new, smaller diesel generator set which more closely matches your power needs. You may then be able to run the small set for small loads, or the older, larger set for larger loads, or both together for very large loads. You have greater flexibility. However, before deciding on this option you should examine the costs and benefits using the method described in Section 5.

- Install a battery to backup the diesel generator set. The set is then run at full load for a few hours when all the larger appliances have to be used (eg. washing machine, vacuum cleaner, iron, etc) and any surplus power generated is used to charge up batteries. The batteries are then used when the engine is switched off to power the smaller electrical loads through the rest of the day, such as lights, television, central heating pump, etc. The savings made by running the generator set at higher efficiency and for fewer hours, may offset the cost of the battery charger, batteries and inverter in some circumstances. More information on this possibility is given in Section 4.

  It is often more expensive to use batteries than to run a diesel generating set at small part load. However, there are other advantages which may justify the extra cost. The most significant advantage is that there is power avai–lable at all times, so lights or central heating pumps can run whenever necessary and refrigerator and freezer motors can run more efficiently, intermittently on their thermo–stats.

  Detailed information on battery systems is given in chapter 4. If a battery system is used there is then the further possibility of using a small wind powered turbine to charge the batteries. The diesel engine need be used only occasionally then. Chapter 4 also describes the use of wind turbines.

Anyone who decides to buy a new diesel generator set or to use a battery connected to the set should seriously consider the energy efficiency of electrical appliances. Section 2.2 gives some limited information about energy efficiencies of common AC appliances. Anyone who intends to use a battery may find it worthwhile to use some or all DC appliances. Batteries store direct current (DC) whereas most common electrical appliances use alternating current (AC). Therefore, in order to run AC appliances from a battery, an inverter is needed. The inverter converts DC electricity into AC. However, inverters are expensive and therefore it is sometimes a better option to use DC appliances. This is discussed in more detail in Section 4.

Since a small to medium sized diesel generator set is at best 30% efficient, there is a large amount of energy in the fuel which is generally not accounted for. Some of this energy is used to overcome friction, to move parts of the engine or is wasted as incompletely burned fuel in the exhaust gases or as noise, but far and away the most of it is turned into heat. Usually this heat is wasted. It is possible to recover some of the heat that escapes in the hot exhaust gases, and in water cooled diesel engines it is also possible to recover some of the heat transferred to the cooling water.

The exhaust gases from a small diesel engine are typically at 400–500°C. The temperature tends to be higher in larger engines and when they are working under full load. Figure 2.2 shows the flow of exhaust gases from a selection of Lister engines working under full loads. Some of the heat from the exhaust gases may be extracted with a simple water–filled heat exchanger. This could then be used to supplement domestic hot water, or for green house heating, for example (see also Chapter 3 and Figure 3.1).

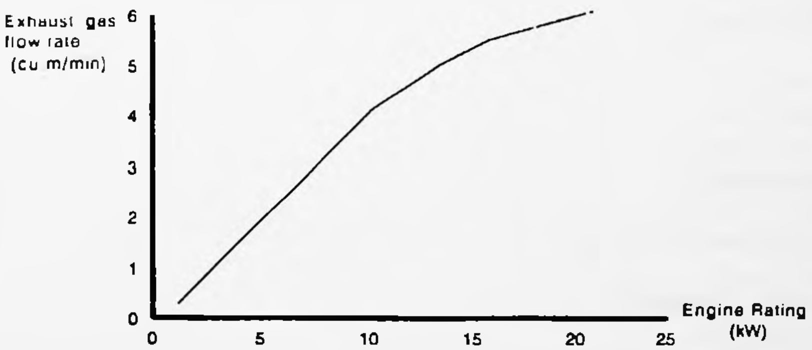


Fig 2.2: the flow of exhaust gases from a selection of Lister engines working under full loads

In a water–cooled diesel engine, water circulates around the various parts of the engine and extracts heat from it. The hot water then passes though a radiator where it loses its heat to the atmosphere. The cooler water leaving the radiator returns to the hot engine to extract heat once more. Instead of losing the heat from the hot water via a radiator it could be used more usefully, either to supplement hot water heating (although care must be taken that the water can be cooled sufficiently before it is returned to the engine) or to warm a greenhouse or a polytunnel.

The use of both exhaust heat and cooling-water heat as described above is generally not worthwhile for very small engines because the complexity of integrating both systems simultaneously is too great in relation to the amount of heat recovered, but simple exhaust heat recovery may be worth considering in many cases.

The fuel efficiency and breakdown frequency of a diesel generating set will depend very much on the quality of maintenance that is carried out, as well as its running load. It is most important for long engine life and good reliability that the maintenance schedule recommended by the manufacturer is carried out. Regular changes of oil, oil filters, fuel and air filters within the recommended time periods will have a bearing on fuel economy, the life of the engine as well as its long term reliability and therefore good reliable maintenance is an excellent and important investment.

2.2 More Efficient AC Appliances

If you use more energy-efficient electrical appliances, you may be able to reduce your diesel fuel consumption. However you must be careful not to reduce the electrical load so much that the diesel engine will run on a small part-load (see previous section). By using more energy-efficient appliances you may be able to run more equipment off your existing generator, or you may then have surplus power which you can use to charge a battery. If you are intending to buy a new generator you may be able to buy a smaller size if you also invest in more energy efficient equipment. In this section, information is given about the energy efficiencies of common household appliances.

If you are interested in the efficiencies of other electrical equipment, you may be able to obtain it from Consumers' Associations, or from suppliers. In Canada, all electrical equipment has to be labelled with its energy consumption and the label must also state the energy consumption of the most efficient similar device. Some useful addresses are given in Section 7.

Refrigerators and Freezers

There are quite large differences in the efficiencies of different models of refrigerators and freezers. The differences are large enough that the cost of electricity used to run one model can be several hundred pounds more than for another similarly sized model, over the lifetime of the freezer or refrigerator. The difference in running costs is often larger than the difference in the first cost, but tests show that the more expensive models do not necessarily have the lower running costs. If you are buying a new refrigerator or freezer, it is well worth your while to obtain information about the running costs of all suitable models.

The differences in electricity consumption are largely due to the quality and thickness of the insulation used. Better, thicker insulation has two advantages:

- it reduces the running costs
- the refrigerator or freezer takes longer to warm up if its power supply is cut

and one disadvantage:

- the refrigerator or freezer will have larger external dimensions for a given internal capacity. In other words, it will take up more space.

There is a strong correlation between electricity consumption and time to warm up. A more energy efficient refrigerator or freezer is usually able to withstand a longer power outages (i.e. when the diesel is off) without any damage to the food.

Other design factors and the ways in which the appliance is used also affect electricity consumption such as:

- the detailed design of the door and especially the door seal. If the door does not seal all the way round, warm air will leak in. The door seal should be checked regularly and replaced if it becomes damaged or perishes.
- refrigerators and freezers should be placed somewhere cool, not near a cooker or radiator.
- air should be able to circulate freely round refrigerators and freezers.
- refrigerators and freezers should be kept as full as possible. This will reduce the electricity consumption and will allow less warming up when the power is off.
- excessive frost should not be allowed to build up on refrigerator ice boxes and in freezers. Frost build up will tend to be reduced if food is always stored in sealed containers, and the door is opened infrequently. Frost and ice prevent the cooling coils from working properly.
- whether it is chest or upright. In general a chest freezer should be slightly more economical to run than an upright freezer because cold air sinks. When the door of an upright freezer is opened, the cold air will tend to fall out. The door of any refrigerator or freezer should be opened as infrequently as possible.

The electric current required to start the compressor motor of a refrigerator or freezer is generally much higher than the current that it uses once it is running. This high start up current may cause a problem to some users, especially those who use battery back up. It is possible to limit the start up current with a "soft starter". These are discussed in chapter 4.

Lighting

Some lamps are more efficient than others; they give more light for each watt–hour of electricity consumed. Table 2.1 summarises the types of lamp available and their relative merits. In particular the amount of light they produce for each watt–hour is given as a relative value in the range 1 to 10, with a score of 10 for the most efficient, and hence cheapest to run, lamp. Table 2.1 shows the wattage of ordinary incandescent light bulbs and fluorescent tube lamps which produce the same amount of light.

Fluorescent lamps	Ordinary bulbs
9–13 W	60 W
15–18 W	75 W
20–25 W	100 W
28–32 W	150 W
36–40 W	200 W

Table 2.1 : Approximate equivalent lamp ratings for the same light output

A few points which may be relevant to choice of lighting in certain circumstances are listed below:

- the light output of fluorescent tubes and compact fluores–cent bulbs gradually decreases and may be reduced by as much as 20% by the end of the life. The power consumption does not fall correspondingly so it may be worthwhile to replace bulbs or tubes before they actually fail.

- the life of a fluorescent bulb or tube depends on how often it is turned on and off. Typically if the lamp is on continuously it will last 1.5 x normal life but if it is turned on and off every 5 minutes it will last only 0.2 x normal life.

- the light output of all types of fluorescent lamp is much reduced at low temperatures (but increases as the light unit warms itelf up). At 0°C the light output is about 0.4 x normal output. If these lamps are used in unheated places, the lamp should be well enclosed. Some compact fluorescent bulbs will have difficulty striking if they are at below freezing temperatures.

- in practice the amount of useful light from a lamp is affected by how clean the lamp and lampshade are, by the colour and type of lampshade, and by the colour of the walls and ceiling.

- fluorescent tube lights are often considered to be ugly and to give a "cold" light. Many of the new fluorescent bulbs and newer types of tube light are much improved in this respect.

People who choose to continue to use incandescent light bulbs may be able to reduce the electricity consumption of these bulbs because higher wattage light bulbs are more efficient. Table 2.2 illustrates this point. It gives the light output (in lumens which are a standard measure of light) for two types of ordinary light bulb.

Watts	Light output in lumens	
	Single coil bulb	Coiled coil bulb
15	110	-
25	200	-
40	325	390
60	575	665
75	780	880
100	1160	1260
150	1960	2040
200	2720	-

Table 2.2: Comparison of filament bulb types

Where a light fitting uses more than one bulb, it is energy efficient and cost effective to replace them with a single bulb of higher wattage. For example, three single coil 40 W light bulbs give less light than one single coil 100 W bulb (see Figure 2.3).

Some people may be used to leaving all their lights on in order to increase electricity consumption so that the diesel generator is operating near full load. In practice, it would be better, if it is possible, to use the over capacity of the diesel generator to greater

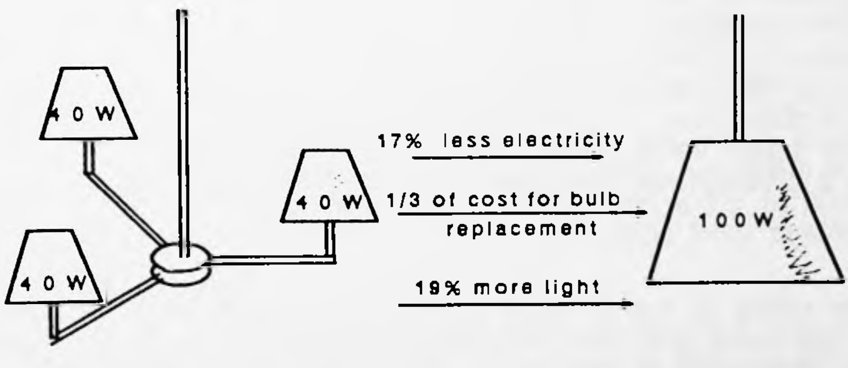


Fig 2.3: three single coil 40 W light bulbs give less light than one single coil 100 W bulb

advantage as is discussed earlier in this Chapter. If a new generator is to be bought it is well worth considering whether a second smaller engine for use exclusively with more efficient lights and other small appliances while the old larger engine with a change over switch is used less frequently purely for the few heavier loads. If back up battery storage is to be used, it is imperative to use high efficiency lamps to reduce the battery size needed (see Chapter 4).

Television Sets

Television sets are often used for about 6 hours per day on average. As a result the annual electricity consumption can be as much as 300–400kWh. However, the electricity consumption of television sets varies widely and therefore it is worth choosing a model with a low consumption. The most efficient ones use about half as much electricity as the least. In general smaller sets use less electricity than larger ones and black and white sets use less electricity than colour ones. Video recorders tend to use a lot less power than a television, often only around 30 to 50W.

Washing Machines

Washing machines vary a lot in their power consumption depending on:

- maximum spin speed
- maximum weight of clothes
- whether they take in cold water and heat it, or take in hot and cold water
- whether they are front load or top loading.

It is usually best to have a machine which can take in both hot and cold water. If it is fed with hot water, the machine will then adjust the temperature of the water by only a small amount, and hence use only a little electricity in water heating. The wash will also be faster because less time is needed to heat the water. The other factors which affect power consumption may be more influenced by personal circumstances. For example, although power consumption is significantly higher for a machine with a high spin speed, if drying clothes is a problem the high spin speed may be considered important.

Irons

The power rating of normal sized irons varies in the range 1.0 to 1.6kW. The rating will affect the speed with which the iron heats up but is not dependent on the type of iron. Steam irons do not necessarily have a higher power rating than ordinary irons, and similarly cordless irons may have a rating anywhere in this range. Unless speed is important, it is likely to be a better option to choose an iron with a power rating at the lower end of the range.

Vacuum Cleaners

Vacuum cleaners may be either of the cylinder or upright design, as shown in Figure 2.4. Usually an upright design has a higher power rating and uses more electricity than a cylinder design. Typically, it will use 20% more electricity. The best and worst vacuum cleaners, from an energy point of view, are rated from 800W (best) to 1200W (worst).

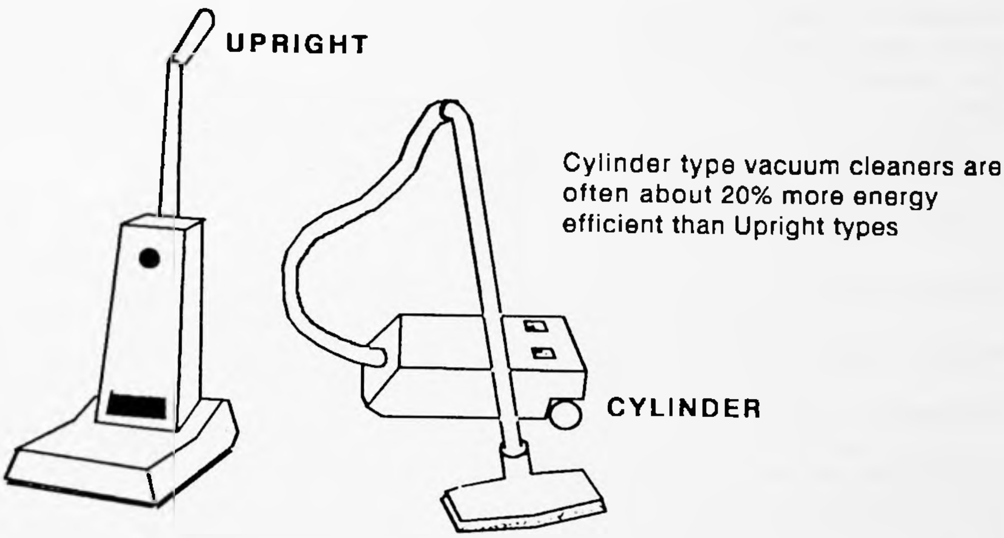


Fig 2.4 upright and cylinder type vacuum cleaners

Table 2.3 which follows details the pros and cons of different types of lighting in more detail. The Efficiency factor shows how much light you get for a given electrical energy consumption compared with a standard "long-life" 60W filament light bulb.

Figure 2.5 illustrates various forms of high efficiency domestic fluorescent light which are becoming available (a few types have been stocked by suppliers in Port Stanley already). Some comments on these are worth making. Most of the folded tube or compact fluorescents can be obtained either to fit directly into standard bayonet or edison screw light sockets or they have adaptors for this purpose. So a 15W compact light can substitute directly for a 60 or 75W conventional bulb. The compact light will use less than a quarter as much electricity for the same amount of light but will cost quite a bit more in the first place. Most folded tubes have a life of around 5,000 hours compared with 1,000hrs (if you are lucky!) from modern filament bulbs.

The best value compact fluorescents seem to be those with a detachable tube fitting into a special adaptor like the Lynx and the 2D (Figure 2.5). This is because typically with the Lynx, for example, the whole lamp with the adaptor costs much the same (approximately £12 to £15) as the types like the Philips and the Osram which plug straight into a light socket and the lives of the tubes are much the same. But the Lynx tube can be replaced separately for around £4 as its adaptor has a claimed life of 50,000 hours (more or less for ever) while the integrated compact fluorescents need complete replacement, to the tune of around £15 everytime they burn out (because their choke and starter get thrown away with the tube). It should be noted that these lamps are likely to get cheaper as they get more widely used and already significant discounts may be negotiated with wholesalers if they are bought in quantity.

So over a 10,000 hour operating period taken as an example (maybe 7 years regular use averaging about 4 hours/day) the following comparison would apply if a fresh unit is procured at the very end of the period:–

	Tungsten filament 60W bulb	Standard compact 15W tube	Detachable compact 15W tube
Number of replacements	11	3	1 & 2 tubes
Purchase cost	£5.50	£27.00	£17.00
Electricity consumed	600kWh	150kWh	150kWh
Cost of electricity			
a) in UK (1990)	£ 36.00	£9.00	£9.00
b) Stanley @ 13p/unit	£ 78.00	£19.50	£19.50
c) Camp gen.set @ 50p/unit	£300.00	£75.00	£75.00
Total cost for 3 years:			
a) in UK @ 6p/unit	£ 41.50	£36.00	£36.00
b) Stanley @ 13p/unit	£ 83.50	£46.50	£36.50
c) gen set @ 50p/unit	£305.50	£102.00	£92.00

In reality, although generating set electricity will usually cost in the region of 50p/kWh the savings from using more efficient lighting or other appliances are not as good as this might indicate as it doesn't cost that much less to run a diesel at part load. The biggest savings can be had either from being able to use a lower powered generator in the evenings or by being able to reduce generator running hours through the use of battery backing for the lights (which is only economically feasible with high efficiency lights). But it can be seen from this that folk in Stanley and the larger settlements who get metered electricity can obviously make genuine savings from investing in high efficiency lighting, and so for that matter can their community since most settlements in Camp where metered electricity is provided have to subsidise the cost of generation as 13p is considerably less than cost.

Annex 2 gives some typical power and energy requirements for a variety of electrical appliances which enable the reader to estimate the likely costs of using different types of electrical equipment.

Description	Efficiency (relative)	Pros	Cons	Life (hours)	UK Price (£)
Ordinary light bulb - tungsten	1	Standard bulb which will fit into existing fittings in most houses	Expensive to run	1,000	0.50
Long life standard light bulb - filament	1	Longer life than standard bulbs	Produce less light than standard bulbs usually	2,000	0.60
Reflector light bulb - tungsten filament, half silvered glass	1	Good for spot lights	Expensive	1,000	1.20
Spot or floodlight	1.5	Can be used outdoors		2,000	3.50
Incandescent strip	1	Often used in or under cupboards, at bed-heads. No ballast needed so cheap to install.	Poor buy for most uses	1,000	1.25
Halogen bulb	2	Maintains brightness all its life. Good for places needing a lot of light.	Bulb becomes very hot. Bulbs damaged by finger grease - use gloves.	2,000	4.00-6.00
Compact folded tube fluorescent with built in ballast	5	Good value, especially where lights are left on for long periods, so long as size and weight allow	Lamps heavy so can only be used where strong secure fittings exist. Takes a few minutes to reach full brightness	6,000 built-in ballast	9.00-13.00
Compact folded tube fluorescent with separate ballast	6	Good value, especially where lights are left on for long periods, so long as size and weight allow	Require special fittings which incorporate the ballast. Adaptors available. Takes a few minutes to reach full brightness	5,000	3.00 (tube) 10.00 (fitting)
Standard fluorescent tube	8	Cheap way of having lots of ight.	Difficult to install. Separate ballast necessary, usually included in fitting.	8,000-10,000	2.50
Triphosphor fluorescent tube	10	Most efficient type of white lighting and provide better quality light than standard fluorescent tubes.	Unattractive to look at. Difficult to install. Separate ballast and starter necessary, often included in fitting.	8,000-10,000	5.70
Low pressure Sodium lamp	8-12	Most efficient type of lighting but orange only. Very long life. Ideal for outside lights	Orange light distorts colours. Needs special luminaires & starter. Takes 10 mins to reach full output	10,000+	15.00 (18W tube) fittings cost varies

Table 2.3: Pros and Cons of different types of lights

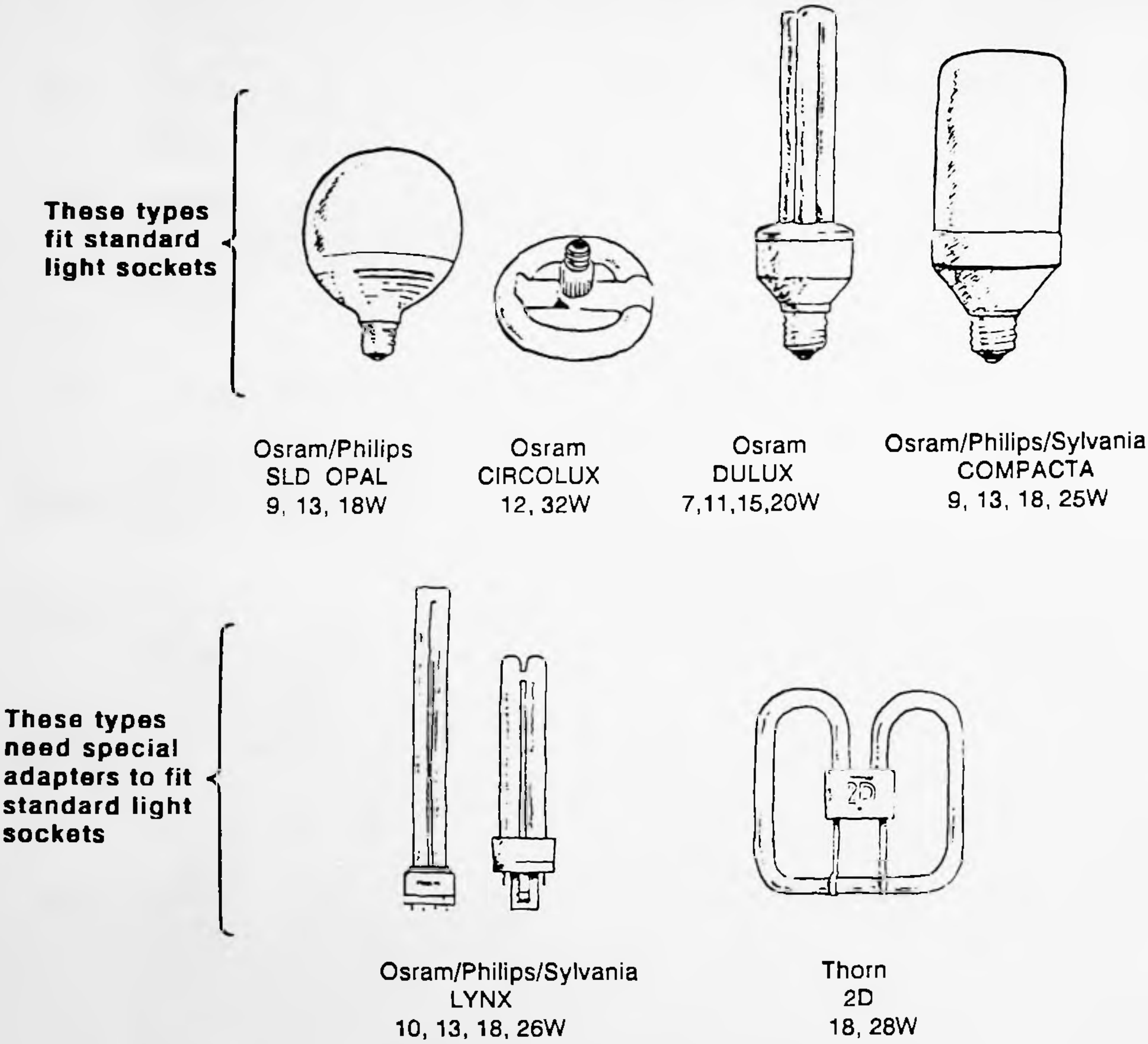


Fig 2.5: High efficiency compact fluorescent lights

3.

Reducing Peat Consumption

3. REDUCING PEAT CONSUMPTION

3.1 Heat Recovery from Diesels

Most residents of the Camp use diesel generating sets and generally these get used every day for a number of hours. All the time that your engine is operating it pumps out waste heat from both its exhaust and from its cooling system. In fact for every kWh (kilowatt-hour) of electricity generated, typically *three* kWh of heat are wasted.

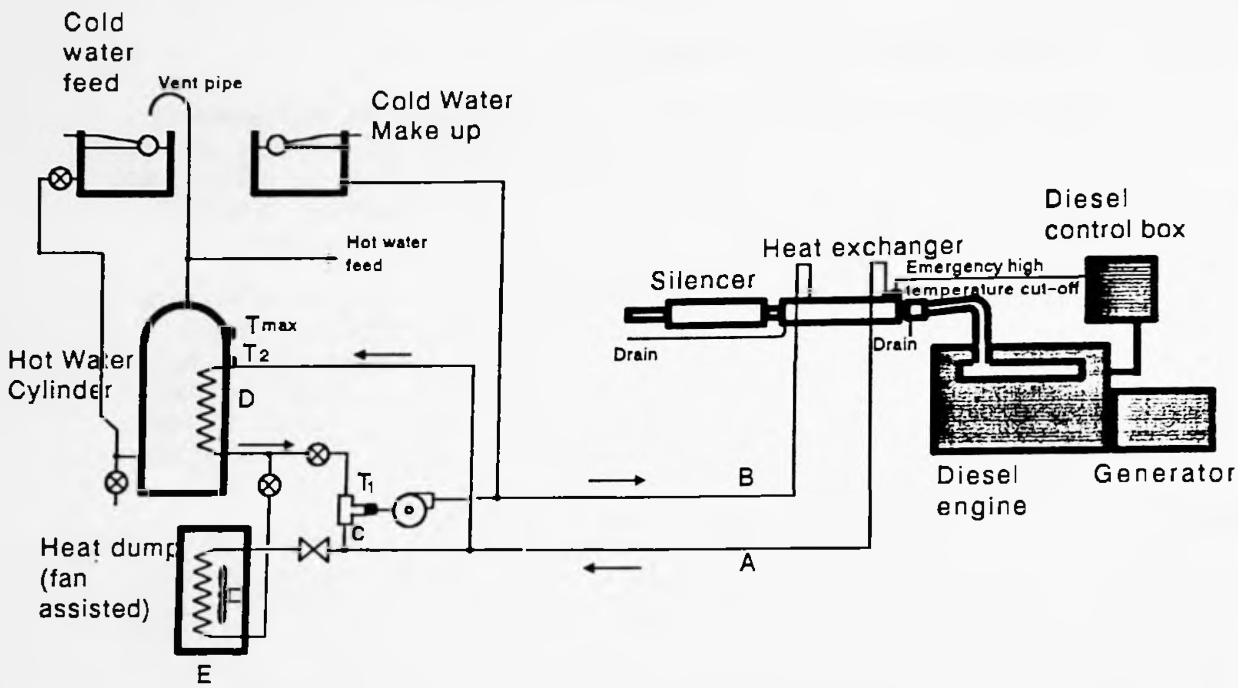
It is becoming common practice with large diesel systems to recover and use as much waste heat as possible, but this practice remains unusual with smaller generating sets even though very useful quantities of heat could be extracted and used for such purposes as space heating and water-heating and could save a certain amount of peat consumption. Households using diesel fuelled ranges for cooking and water heating obviously could save significant quantities of diesel.

The easiest method of using some of the waste heat from a diesel is to fit a special heat exchanger to the exhaust, in which the exhaust gas is used to heat water in a water jacket. Typically 75% of the exhaust heat can be removed for practical purposes. It is also possible to use the engine cooling system (assuming the engine is liquid cooled) but this is more complicated as it can interfere with the engine cooling and not recommended with small engines.

Figure 3.1 shows a typical exhaust heat recovery system integrated with a standard domestic central heating system. The hot water from the engine exhaust feeds the domestic hot water cylinder and there is a thermostatically controlled diverter valve which switches the hot water supply to a "dump radiator" on occasions when the cylinder has reached its required temperature. This is of course a vital component as otherwise the water in the system will boil if there is no way of getting rid of the heat, with potentially dangerous and catastrophic results. The "dump radiator" can be an ordinary, but rather large domestic radiator (a dented or old one will do so long as it does not leak) or if a compact device is wanted, a fan-assisted convector radiator can be used.

Commercial engine exhaust heat exchangers (some examples are given in Section 7) should generally include a safety valve as a precaution in case boiling does take place, and it is also normal also to include a temperature sensor which will trip the engine emergency fuel cut-off and hence the whole heating system too, in the even of over-heating.

Another potentially important precaution recommended by some suppliers is to install the exhaust heat-exchanger below exhaust manifold level so that in the unlikely chance it develops an internal leak, water cannot run into the engine cylinders. This also helps to prevent an airlock in the system that can happen if the heat exchanger was located higher up. In any case the high point of the circuit preferably needs an automatic central heating air bleed valve.



LEGEND

- Circulating pump
- Zone valve
- Hand valve
- Two-way valve
- Temperature sensor

DIESEL ENGINE EXHAUST HEAT RECOVERY: TYPICAL CONTROL LOGIC

If T2>T1 (D warmer than A) then water short-circuited through point C

If T1>T2 (A warmer than D) then water from heat exchanger passes thru' hot water cylinder to heat water, until....

If T1>Tmax when water in cylinder reaches required thermostat temperature, then zone valve redirects water through heat dump

Fig 3.1 diesel engine exhaust heat recovery system

Figure 3.1 shows a typical system of a kind that has been installed experimentally at Sealion Island Lodge. Various features of it are worth detailing as they are likely to be needed on any other systems too. The engine shed is some distance from the Lodge so 15mm Acorn nylon central heating tube threaded through foam insulation was buried in a shallow trench to transmit the water between the engine and the main building. For various reasons this installation had to have the heat exchanger above the engine, (even though it is better located below it if this is possible in other installations both to reduce the chance of air–locks and to remove any chance of water getting into the engine if for any reason the heat exchanger ever develops an internal leak) so in this case it incorporates three safety precautions to prevent any leakage back to the engine. First all pipes slope downwards slightly away from the engine, secondly there are open capillary tube drains both upstream and downstream from the heat-exchanger and lastly a temperature sensor is fitted to the heat exchanger in series with the engine fuel cut-off solenoid so that if the temperature goes over boiling point at the heat exchanger (indicating an airlock or some other problem causing boiling) then the engine will automatically shut down until the problem is rectified.

Because the water circuit is at a high point at the heat exchanger, an automatic central heating air bleed valve is fitted to avoid air locks and localised boiling. Obviously if the flow of water through the heat exchanger is interrupted, localised boiling can start which then prevents the flow from being re-established. With in this case up to 5-6kW of heat going into the heat exchanger it only takes a short interruption in flow to cause overheating. Therefore careful bleeding of the water system is essential to remove virtually all air before running the system.

This system is controlled by a standard central heating controller which can compare the temperatures at the three points indicated (these are standard sensors). At start up when the water in the feedpipes will be cooler than the water at the hot water cylinder, the two way valve short circuits the system through the by-pass "C". When the temperature of water coming from the engine at point T_1 becomes hotter than the lower sensor T_2 on the cylinder, then the controller moves the valve to feed the water from the engine into the hot water cylinder. Once the hot water cylinder entry temperature reaches the tank thermostat setting T_{max}, then the hot water is by-passed through the heat dump (a fan convector central heating radiator) to dissipate the unwanted heat and prevent the heat exchanger getting too hot.

The enthusiastic "do-it-yourselfer" could make a home made mild-steel heat exchanger (and it probably would corrode through after a few years, but if welded up from scrap pipes need not cost a lot to replace). However in such cases it is important to ensure that proper protection against explosion if the water were to boil is provided (a new central heating boiler safety valve could be used) and that proper precautions exist to prevent boiling occurring in normal circumstances or water leaking back into the engine if an internal leak develops.

An interesting challenge is to find a use for dumped heat that needs to be dissipated when the central heating tank thermostat causes the diverter valve to cease delivering hot water to the domestic system. Possible applications might be to put the dump heater in a peat shed where the heat can help to dry the peat (and increase its calorific value as a result) or in a greenhouse or "poly-tunnel".

3.2 Insulation and Draught Proofing

All the heat that is put into a house eventually finds its way out into the atmosphere. The slower that the heat leaks out of the house the better. The rate of heat loss is reduced by insulating roofs, floors, walls and windows, and by eliminating draughts and reducing ventilation rates. Each of these is discussed in this section. Not all the measures for reducing heat loss described here are suitable for all houses.

Figure 3.2 shows the percentage of the total heat which is lost in different ways from a typical poorly insulated house. The easiest and often the most cost effective ways of reducing heat losses are loft insulation and draught proofing.

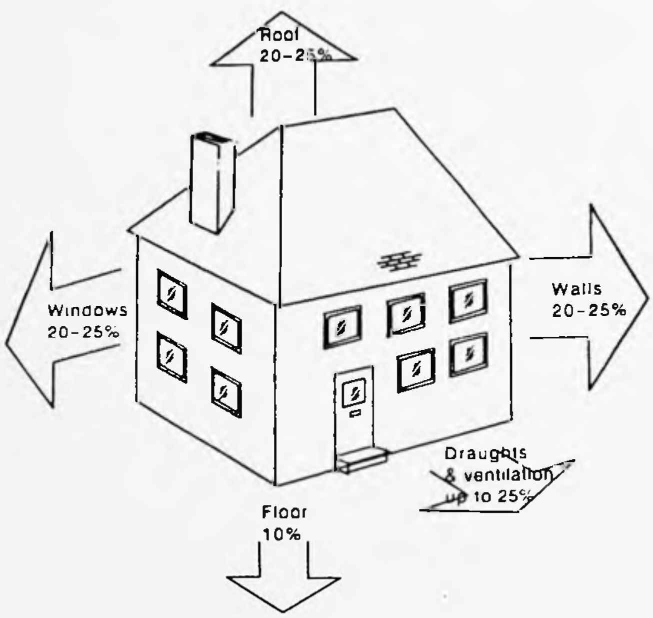
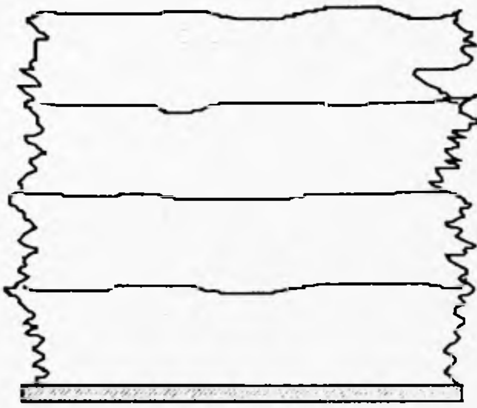


Fig 3.2 the percentage of the total heat which is lost in different ways from a typical house

Loft Insulation

Even if your house already has some loft insulation it may still be worth your while to add more. If your loft has no insulation it is most definitely worth your while to insulate it. Figure 3.3 illustrates the savings in heat and in kilograms and "yards" (yd^3) of peat that a typical householder could make during the coldest quarter of the year (May – July) if he or she added more insulation. Note that a "yard" (i.e. cubic yard) of peat can vary considerably in weight so the figures given are only approximate. It has been assumed that wet peat weighs around 800kg (or 0.8 tonne) per "yard" and dry peat weighs about 200kg per "yard" (i.e. 25% of the wet weight). It has also been assumed that the average temperature difference between the interior and the exterior of the house is 25°C (or 45°F).

The commonest type of loft insulation is mineral wool or glass fibre blanket which is sold in 50mm, 100mm and sometimes 150mm thicknesses. This is laid between the joists in the roof space. An alternative is to lay loose vermiculite chips. Most DIY books give advice about how to lay mineral wool blanket. Also information leaflets and books are available from organizations like the Energy Efficiency Office and the Consumers Association. The addresses of these and other useful sources of information are given in Section 6.



		kWh of energy saved	kg of dry peat	Cu. Yds wet peat
50mm	Saving for this 50mm	70	50	0.25
50mm	Saving for this 50mm	120	90	0.45
50mm	Saving for this 50mm	300	220	1.10
50mm	Saving for this 50mm	1800	1300	6.50
	Ceiling			

BASIS: Winter three month period with heating for 12 hours/day and 25°C temperature difference between the inside and the outside. Loft area = 50 sq m.

Fig 3.3 The savings in heat and in equivalent amounts of peat that a typical householder would make during the period May – July

When laying loft insulation the following general points are worth bearing in mind:

- If there are cold water storage tanks or a central heating header tank in the loft space, these should be insulated too, but no insulation should be placed beneath them (see Figure 3.4). This is to ensure that some heat reaches them and the water does not freeze.
- All pipes in a loft should be insulated to prevent them from freezing.
- Remember to fix some insulation to the top of the loft trap door.
- The roof space must be ventilated so do not cover the eaves with insulation completely.Check that there are air gaps in the eaves.

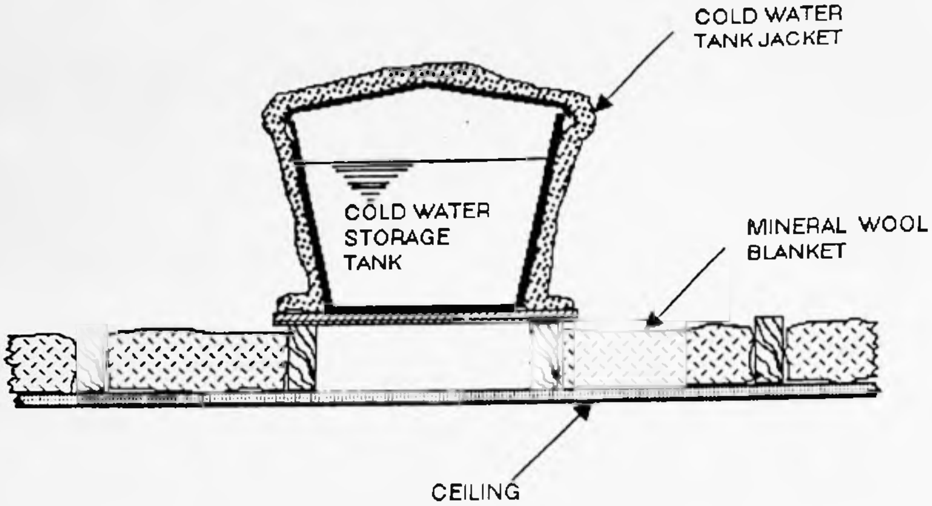


Fig 3.4 Insulate around but not beneath cold water storage tanks to ensure that enough heat reaches them to prevent freezing.

In some old houses it is difficult to gain access to the loft space. In such cases or with flat roofed buildings, it is possible to reduce heat losses by covering the ceiling with insulating board or insulating tiles. (These are different from polystyrene tiles). Insulating board is normally 125mm thick and is available in various decorative finishes or in the form of acoustic tiles which offer the possibility of sound proofing. For a typical house with no loft insulation and a roof area of $50m^2$, with a 25°C average temperature difference between the interior and the exterior, (as described for Fig. 3.3) insulating board fixed to the ceilings would save 1700kWh of heat, which is equivalent to about 1200kg of dry peat (or 6 yards of wet peat) during the winter 3 months.

Draught Proofing

It has been estimated on the basis of much study that a satisfactory ventilation rate for a house is 0.5 – 1.0 air – changes per hour. This ensures a healthy and pleasant atmosphere. Higher ventilation rates are unnecessary and waste fuel. Over 25% of the heat losses from a house may be due to air infiltration and ventilation. In situations of high draughts, ventilation rates can be excessively high, up to several air – changes per hour.

It is relatively easy to decrease air – infiltration through doors and windows by fitting proprietary sealing strips, draught excluders, etc, and to seal off fireplaces when they are not in use. The Energy Efficiency Office and the Consumer Association (see Section 6) have both produced useful publications about different types of draught proofing and how to fix them. The following points are important to note:

- Draught proofing and sealing reduces heat losses and makes rooms feel more comfortable, but it can be overdone. Air is still needed for people to breathe and to allow heating appliances to burn properly. Also if draught proofing is overdone, condensation may become a problem.

- In a typical small house of $50m^2$ floor area under the conditions described earlier, if the ventilation rate were reduced from 1.5 to 1.0 air-changes per hour, the heat demand during the winter 3 months would be reduced by about 400 kWh, which is equivalent to about 280 kg of dry peat or a bit more than 1 yard of wet peat.

Insulating Walls

In a poorly insulated house, about a third of the heat used is lost through the walls. By insulating walls well, this loss can be reduced to less than half of its original value so that the amount of fuel used can be reduced by about one sixth (17%).

Houses with solid walls can only be insulated by cladding the inner or outer surface. This is much more expensive than cavity filling usually practised on brick houses in the UK. External wall insulation is possible but is generally unsuitable for wooden buildings and more often than not is a job for a specialist contractor making it of limited usefulness in the Falklands.

Internal wall insulation, on the other hand, can be done on a DIY basis but it is not a simple job. Special boards consisting of plasterboard backed with insulation, with a vapour check inbetween are available from specialist suppliers. The insulation is commonly expanded polystyrene or polyurethane foam. These boards are fixed securely to the wall with adhesive and/or plaster dabs and screws. Alternatively, ordinary plasterboard or wooden panelling may be fixed to wooden battens. The spaces between the battens are filled with mineral wool or glass fibre blanket. It is essential that a vapour check membrane (polythene sheet) is fixed over the battens to prevent condensation causing rot.

Insulating Floors

It is surprising that a significant amount of heat is lost through the ground floor of a house. It is quite simple to reduce losses through the floor using some or all of the following:

- If the floor is wooden, fix mineral wool blanket underneath it between the joists.

- Lay sheet insulation (a thick layer of special material) on top of the floor.

- Fit thermal underlay and fitted carpet.

- Cover floor with hardboard panels, carpet paper, underlay and carpet.

NOTE: The space under the floor needs to be well ventilated to avoid damp and rot problems. Care is needed to ensure that insulation does not block the ventilation.

Insulating Windows

Windows may be insulated by double (or triple) glazing or more simply by the use of blinds, curtains and shutters.

Compared with measures like draught-proofing, double glazing is expensive and will take much longer to pay for itself in terms of energy savings. However, double glazing does provide a number of additional advantages; it eliminates the cold draughts that are often associated with single glazed windows, and it greatly reduces condensation of windows and hence reduces the frequency with which the frames have to be painted.

The effectiveness of double glazing depends primarily on the distance between the sheets of glass which make up the window. The gap should preferably be at least 5mm, which will reduce the heat loss by about a third. If the gap size is increased to 12mm the heat loss is reduced to about a half. Increasing the gap beyond 12mm has very little further effect in saving heat.

There are two types of double glazing: sealed units which consist of two panes of glass factory-sealed together, and secondary double glazing which is single panes of glass fitted to the inside or outside of existing single glazed windows. Many types of double glazing can be fitted by a competent handyman.

The following points are worth noting:

- The savings from double glazing are greatest in the warmest rooms, so if only a portion of the house is to be double glazed, first consideration should be given to the living rooms.

- Draughts around window frames should be sealed before fixing secondary double glazing since these will reduce the effectiveness of the double glazing.

- For windows which do not open, consideration should be given to fixing the secondary glazing to the outside of the frame. If there are small air leaks around the secondary glazing, these may cause condensation between the panes when the secondary glazing is internal. Condensation will not occur when the secondary glazing is external.

In a typical living room, with a 25°C average temperature difference between interior and exterior, the heat loss through the windows would be reduced by about 80 kWh per year per square metre of window (equiv-alent to about 55 kg of dry peat/year/m^2 of window) by installing double glazing.

For people who do not wish to go to the expense of double glazing, heat losses from windows can be reduced to some extent with curtains, blinds and shutters.

Curtains are most often fitted to ensure privacy and are chosen for their decorative effect, and their use to reduce heat losses is often given little consideration. However, by choosing heavy material or adding a good lining and by ensuring that the curtains are well fitted, they can make appreciable savings to the fuel consumption provided they are closed every night. The heavier the curtain and lining material, the better the insulating effect.

Ideally, the curtains should be a close fit within the window frame but this may be aesthetically unacceptable. However a few simple measures will ensure maximum effect:

- the curtains should either make a snug fit with the window sill or reach close to the floor.
- where a radiator is fitted below the window, the curtains should close behind it or alternatively reach close to a shelf above the radiator.
- a box pelmet above the curtains will reduce down draughts behind the curtains.

Typically, if close fitting, heavy curtains are drawn on every night of the heating season, about 400 kWh of energy, equivalent to about 300 kg of dry peat (1½ yds of wet peat) can be saved in the example described earlier even with single glazed windows.

Window blinds can save an appreciable amount of fuel too. Provided the blinds are a good fit to the windows (they should preferably run in channels at each side of the window frame), they will save approximately 40 kWh per square metre of single glazed window area per year, which is equivalent to about 30 kg of dry peat per square metre, in the example described earlier.

Although double glazing does not pay back very quickly in terms of energy saving if it is *retrofitted*, it certainly pays if a new building is being designed and ready-made window units are to be imported specially, as the marginal extra cost of importing double glazed rather than single glazed windows is small. In fact most modern system houses and prefabs, many of which have been introduced to the islands in recent years, generally automatically are supplied with double glazed sealed window units.

Hot Water Temperature

If your hot water is heated by diesel oil, you should fit a thermostat to the hot water tank and this should be set no higher than 60°C. You could even try and set it at 55°C. This should give a quite adequate temperature and save significant fuel.

If you have a solid fuel boiler or stove, on the other hand, it is important that you do not control the temperature of your hot water because these only respond very slowly. Therefore it is important that excess heat can be dissipated and in such systems the hot water tank is the usual place where excess heat has to be dumped. Most solid fuel stove users in any case soon become expert in damping the system down by limiting the air supply setting when less heat is required.

Therefore the methods of heat conservation so far described will not automatically save fuel with peat burning stoves, but they should allow the stove to be damped down more often and for longer periods which will in turn save fuel. Thermostatically controlled diesel oil burners and electrical heaters will automatically respond to heat conservation measures by shutting down sooner and for longer once their temperature setting is reached.

Considering a new boiler or central heating system

If you are considering installing a new central heating system or intend to replace your existing boiler, it is worth while to take some trouble to obtain the correct size to match the size of system in your house. This will not only save you fuel, but will also in many cases save some money on the initial boiler purchase cost too. Most central heating systems tend to be oversized as often the supplier guesses what is needed and increases the size to be on the safe side. Too large a boiler may be less efficient but will always meet any demand while too small a boiler will not meet the demand during extremely cold conditions.

Before starting to consider what size of system you need, you should look critically at the insulation and draught proofing in your house. By improving the insulation, the heat demand will be reduced so that smaller radiator and boiler sizes can be used.

There are two basic types of central heating system: pumped or gravity. The earliest central heating systems to be installed were gravity systems, where the water flows around the system due to natural convection; in otherwords hotter water is less dense than cool or cold water so the hot water naturally tends to rise from the boiler towards the top of the system passing through radiators on its way. As it cools it falls back through the system due to its increasing density until it re-enters the boiler to be reheated and recirculated. Such systems require larger diameter pipes than most modern systems as the pressure due to convection effects is small so pipe friction needs to be minimised. Most modern central heating systems are pumped; a small electric circulating pump moves the water through the system.

Some old fashioned gravity systems, usually with steel pipes and cast iron radiators, were "direct" in that the hot water supply and heating system are all combined as one. On the other hand, most modern pumped systems with copper pipes and steel radiators are "indirect" in that the water passing through the boiler is retained and constantly recirculated in a closed system and generally contains inhibitor to prevent corrosion and to lubricate the circulating pump much like the cooling system for a car. So the hot water supply is indirectly heated by the hot water from the boiler passing through a coil heat exchanger in the hot water cylinder.

In areas where the water is mineralised or potentially corrosive due to its acidity, it is essential to use an indirect system to prevent excessive firring of the pipes and cylinder in the case of hard water or excessive corrosion often manifested by pin hole leaks due to acid water (the latter being a more common problem in the Falklands). Where water supplies are seriously mineralised, resulting in rapid corrosion of the plumbing consideration should be given to investing in a water treatment system or to using copper cylinders with sacrificial anodes to protect them from pin-hole corrosion.

The use of a pump enables smaller diameter pipes to be used because it can provide the force to overcome the higher friction in small diameter pipes. Table 3.1 summarises the pros and cons of pumped and gravity systems.

Pumped	Gravity
Smaller diameter and therefore cheaper pipe (1/2" and 3/4" usually).	Large diameter, more expensive pipe required (1 3/4" and 2" usually).
Pipes can be inconspicuous.	Pipes are obtrusive and ugly.
Electricity supply to pump must be available	No electricity supply needed
Pumped systems are common and information about them readily available	Plumbers are not experienced in installing gravity systems these days.

Table 3.1: Pros and Cons of Pumped and Gravity Central Heating Systems

If the total costs of pumped and gravity systems are compared it is usually a little cheaper to have a gravity system because the cost of the pump and the power needed to run it is a little more than the extra cost of large diameter pipes over small diameter.

However, if the coast of freighting the equipment to the Falkland Islands is included, the difference in costs becomes marginal and therefore most people would be better off to choose the more common and more modern pumped central heating system. It is also worth noting that gravity systems require much more accurate sizing than pumped systems if they are to distribute the heat evenly.

The pump in the central heating system will need an electrical power supply. If the pump is connected directly to the circuit from the diesel generator the central heating can only be run efficiently when the generator is running. Many central heating systems in the Camp function by convection when the generator is off and in such situations the heating tends to be very uneven. If designing a new system where it is known that the pump will be off for lengthy periods then it may help to tend to oversize pipes (i.e. use 22mm instead of 15mm and use 28mm instead of 22mm).

It would be better if the central heating could be run whenever it is needed, irrespective of whether the generator is running or not. This can only be achieved by using a rechargeable battery to power the pump when the generator is not running. Since the battery will provide DC electricity and the generator provides AC, the situation is not straightforward. The following options exist:

- Use a DC motor pump unit. This would be run directly from the battery all the time. The disadvantage of this is that DC motor pump units suitable for central heating duty are uncommon and fairly expensive.

- Use an AC motor pump unit. This would require an inverter to be used between the battery and the motor. The inverter converts DC electricity from the battery into AC electricity needed for the motor. The motor pump unit could then be run either from the battery and inverter all the time, or it could be switched to run directly from the generator via the battery and inverter at other time. The disadvantage of this option is that inverters are expensive, although the AC motor pump unit is relatively cheap.

Section 4 discusses the use of batteries and inverters in more detail and shows the advantages and disadvantages of DC and AC appliance.

It is worth ensuring that any new central heating system is properly sized. Some central heating supply companies in the UK offer a design service or booklets on the design techniques used (they often advertise in the DIY magazines). Usually they charge for this service but credit the cost of it against purchases of equipment. Even if the equipment is bought elsewhere, as is likely in the Falklands, the cost of the design services offered by the larger and well established companies is usually reasonable and good value if it saves making mistakes as it gives expert advice at a reasonable price.

Before designing and procuring a central heating system it is worth carrying out the following:–

1. Reduce the heat demand of your house as much as possible by insulating and draughtproofing.

2. Calculate the heat demand of each room. For this you will need to know the temperature at which you want the room to be, the temperatures of all adjoining rooms, the dimensions and construction of external and internal walls, ceiling and floors, the number of air changes per hour and the sizes of the windows. If all this information is to hand, the calculations are simple using standard formulae. A typical heat demand of a small, well insulated living room is 1.5kW whilst a typical heat demand for a poorly insulated large living room is 3 or more kW.

3. Estimate the hot water demand in terms of the number of litres required per day.

4. Calculate the boiler size. The boiler must be large enough to meet the heat demands of all the rooms and the hot water, with some reserve capacity (usually 20%) to cope with exceptionally cold spells. Boilers are usually rated in kW or BTU/hr. A typical small house would need a 10 – 15kW (35,000 to 55,000 BTU/hr) boiler whilst a large poorly insulated house could need a boiler as large as 25 – 50kW (90,000 to 180,000 BTU/hr) or more.

5. Decide whether to have a gravity or pumped system, and if the latter, whether to have an AC or DC motor pump.

6. Decide whether to have a one pipe or two pipe system. Figure 3.5 shows the difference between these two arrangements. In a one pipe system the hot water enters a radiator, is cooled as it radiates heat to the room and the cooler water then re – enters the pipe to travel on to the next radiator. In a two pipe system the cooler water leaving the radiators is piped back to the boiler in a separate circuit. In a large house a single pipe system is unlikely to be satisfactory. Generally most modern pumped systems use the twin pipe arrangement as it allows more even heat distribution and control, and single pipe systems are generally only used for the simplest, direct heated, gravity types of system and are not to be recommended for general use.

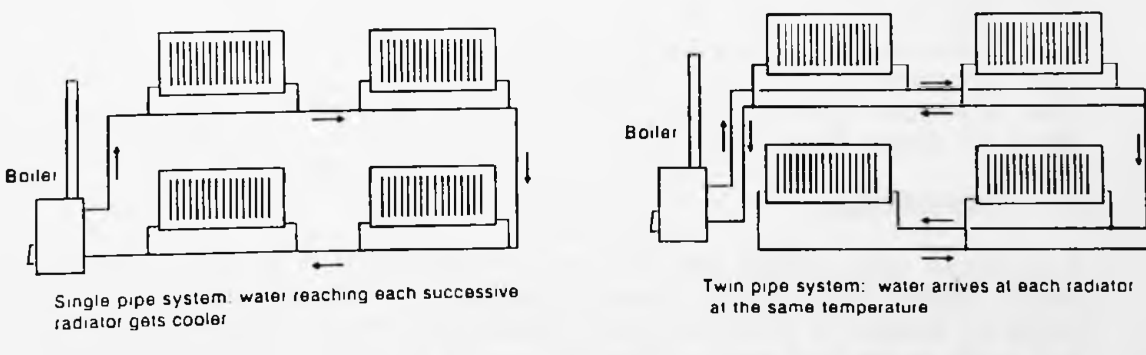


Fig 3.5 One and two pipe central heating systems

7. Decide the routing of the pipes and then calculate the sizes of the radiators required for each room, remembering that exposed pipes contribute to the heat whilst pipes under floor boards or in roof spaces do not, and should therefore be well lagged.

8. Decide the required flow rate of the hot water through the pipes and then calculate the friction losses in the pipes. From this and the position of the pump, header tank and height of expansion tank determine the pumping head needed. When the flow rate and pumping head are known you can choose a suitable pump.

3.4 Fuel Efficient Cooking and Good Housekeeping

Quite big savings in fuel can be made if you are prepared to make small changes to your life style and/or the ways in which you carry out some household activities. The extent to which the recommendations which follow are adopted depends to some extent in most cases on how you rate convenience compared with fuel economy.

a) Showers or Baths

If you have water heated by anything other than a peat fuelled boiler it would be more economical to have showers rather than baths. Typically a shower uses a quarter of the amount of hot water of a bath. However, if you have a peat fuelled boiler in which your hot water tank acts as a heat sink you will probably have ample hot water and the fuel savings will be minimal.

b) Dripping Taps

These should be mended very promptly especially if they are hot water taps. For example, one drip a second for a year would waste about 70 kWh of energy or the equivalent of 50 kg of dry peat (0.25 yards of wet peat).

c) Lights

Switch off any that are not needed, especially if you are running your lights from a battery or if the diesel generator is heavily loaded. In such cases you could also consider substituting more efficient types of light for any frequently used standard incandescent bulb. If the diesel generator is not heavily loaded and you need it to run for other appliances anyway, then switching off lights will have little effect on saving diesel fuel.

d) Fridges/Freezers

You should open fridges and freezers as infrequently as possible. Let freshly cooked food cool to room temperature before putting it into a fridge or freezer. If possible locate fridges and freezers somewhere that tends to be cool and so that the cooling coils at the back are well ventilated.

e) Kettles

If using an electric kettle, fill it with only as much water as you need. The more water you try to heat the more electricity will be needed. The tall narrow plastic jug type of kettles are generally better for boiling small amounts of water. Electric kettles use much more expensive energy than a kettle heated on the hob of a peat range.

f) Saucepans

When cooking in a saucepan, use a lid, as the amount of energy used will be only 25 – 35% of the amount used if you don't use a lid. Pressure cookers also can speed up cooking times and thereby save fuel. Again, this is less important on the commonly used peat – fired ranges than for people using oil fired stoves as the peat stove has to burn continuously anyway in most cases.

g) Microwave Ovens

These are more economical than conventional electric ovens for some foods but not for all. They do however impose a much lower surge load on a small diesel generator than an electric oven but are especially effective for defrosting frozen food in order to shorten cooking time whichever method of cooking is used.

h) Rechargeable (NiCad) Batteries for torches, etc.

Small rechargeable batteries are cheaper in the long term than buying throw – away batteries, (assuming you have a regular need for batteries for small portable devices like torches. You would have to buy a battery charging unit, but if you are using many throw – away batteries this investment will pay for itself in a reasonably short time apart from the added convenience of not having to buy in a stock of dry batteries regularly. See also Section 4.

4.

Increasing Power Availability

4. INCREASING POWER AVAILABILITY

4.1 Use of batteries, inverters and chargers

Battery – backed systems to make the supply better fit the demand

Unless a mains power supply is available, or some sort of continuously available energy resource like hydro – power, most people can only have an intermittent electricity supply. Typically when a diesel generating set is used, it is only economic to run it a few hours daily and perhaps for a few hours in the evening to provide lights and any such luxuries as video/TV, or to run electric kitchen appliances like microwave cookers or deep – fat fryers.

If wind or solar energy is used for electricity generation, using techniques described later in this chapter, then the output will tend to vary with the wind or the sun and some form of electrical energy storage (i.e. batteries) is essential if a supply is to be provided at times when it is needed.

While it is common knowledge that electrical storage, using batteries, is an essential requirement when using wind or solar energy, it is less well known that electrical storage batteries can be used to improve a diesel generation system and even to save considerable running costs by reducing the hours the engine may need to be run in some cases. For example, a diesel sized to take significant daytime loads like numerous freezers, washing machines, hoovers, etc., will frequently be used at night merely to keep the lights going, at which time it may be considerably more powerful than necessary.

Because diesels do not like to be too lightly loaded, and running a diesel at less than 30% to 50% of its rated power results in minor savings of fuel and possible problems with gummed up injectors and rings, many users develop the habit of simply leaving nearly all their lights on to keep a reasonable load even if all those lights are not really needed. Moreover there is little incentive to use high efficiency energy saving lights such as fluorescents, compact folded tube lights, or exterior sodium lighting as the reduced load on the diesel which they offer could be more of an embarrassment than a help at times.

The problem boils down to having to have a diesel sized to meet the peak daytime demand which is frequently then to large for the evening "base load", (see figure 4.1). Ironically this problem makes economising electrical use difficult with many diesel generating sets as switching off things that are not needed has little effect on fuel consumption. *The best way to cut diesel running costs is to run the diesel for fewer hours.*

This sometimes becomes possible if the "key" lights (such as in the living room, the bed rooms and the bathroom) are run from batteries, which can be recharged from the diesel during the daytime. If this arrangement is used, then in many cases the diesel need not be run at night (or may be shut down earlier). Moreover, such an arrangement has the further major "operational advantage" that the key lights will be available at any time of the day or night, "at the flick of a switch" regardless of whether the diesel is running, (providing of course that there is an adequate state of charge in the batteries).

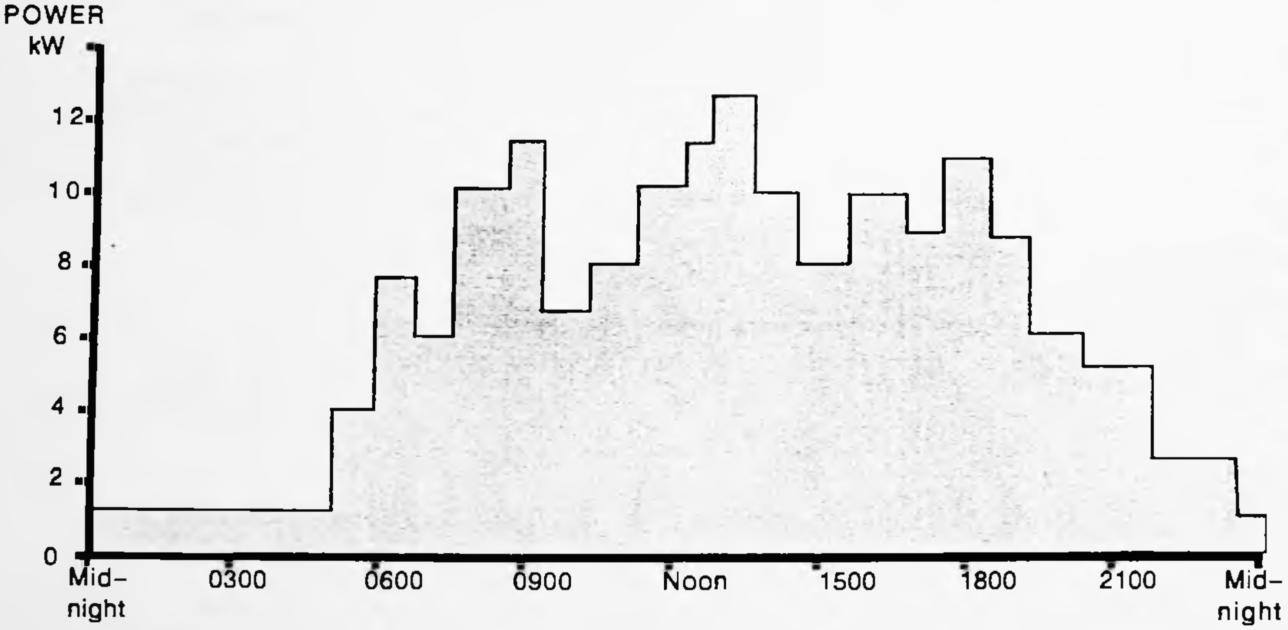


Fig.4.1 Daily electrical demand pattern

Since batteries are expensive items, there is of course a need to minimise the load supplied by them to keep costs down, so once a system of this kind is in use there is every incentive to switch off any lights that are not needed and to use only the most efficient types of lights.

Systems of this kind could be expanded to a sufficient size to power the freezers and TV too. If the freezer is run off a battery backed system it should of course have its thermostat activated and not be run continuously, as so many freezers are when powered directly from a diesel. A freezer is obviously more efficient (and more effective) if powered from a 24 hour unbroken supply and run under thermostatic control. However, as will be explained, the power demand from a freezer is such that a much more substantial battery back system is needed to support it than if merely lights and possibly the TV are to be used.

A possible strategy to consider is to start initially with a small battery backed system to power key lights only and to expand this to take in larger appliances, such as the freezer, later. In fact nearly every Camp resident already has a small battery-backed electrical system, to power their VHF radio-telephone sets. Almost everyone is familiar with how a small battery charger is used to keep the radio's batteries topped up everytime the diesel comes on, so the radio is always available 24 hours per day. What we are talking about here is a larger version of the same arrangement.

Once the battery backed system is in place, then serious consideration can be given to enhancing it further by adding alternative means of charging the batteries to the diesel generator. For example, a small wind-turbine can be added at a later stage to keep the batteries charged so allowing the use of a freezer indefinitely when a resident is away, without recourse to the diesel.

The rest of this chapter will discuss the options available for creating and using battery-backed electrical systems and various supplementary power sources using natural energy resources of the wind, the sun and small streams.

Batteries

There are for all practical purposes just two main types of electrical storage battery (i.e. re-chargeable battery), namely lead-acid or nickel-cadmium. Other types do exist, as do primary cells (i.e. non-rechargeable "throw-away" batteries) but the former are not at present in general use and the latter are only useful for too low power applications such as hand torches (flashlights) or transister radios and "Walkman"s, etc.

Lead-acid batteries

The least expensive option for any significant size of electrical battery storage is the lead-acid battery. The most commonly known version is of course the automotive battery designed for starting cars and other motor vehicles. However car batteries are not to be recommended for any but the smallest of electrical storage tasks as they are designed to be kept at a high state of charge and to put out an occasional short strong current lasting only a few seconds to start an engine. Car batteries do not take kindly to being discharged for any length of time, as normally, every time they are discharged they are immediately re-charged. The cell design in a car battery is optimised to deliver heavy currents and therefore it is ill-suited to supplying smaller currents for many hours before being recharged, as is required for most applications of interest in domestic power supplies.

It is worth understanding that in general, any given type of battery will withstand a certain number of charge-discharge cycles before it fails and needs to be replaced. The greater the average percentage discharge (i.e. the more on average the battery is "flattened"), the fewer cycles it will survive, and vice-versa. Figure 4.2 illustrates this and shows how, in this example, if you discharge the battery

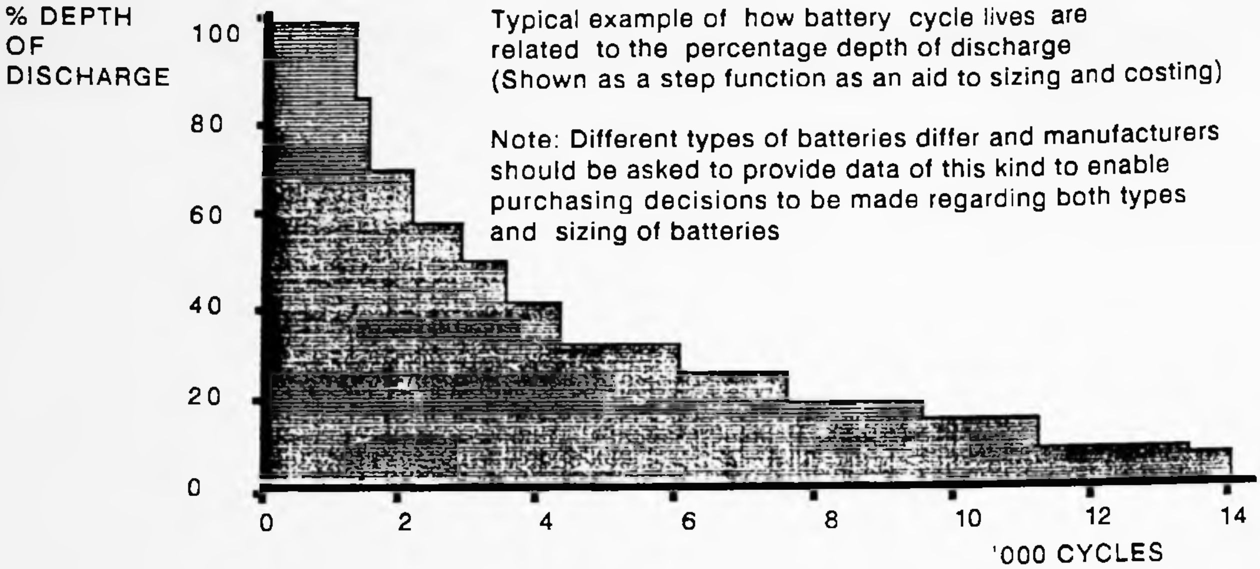


Fig 4.2 Depth of discharge versus number of cycles for a battery

regularly by 80% of its total capacity it may last 2000 cycles but if you only discharge it 20% it may last 8000 cycles. Obviously if you only discharge a battery 20% rather than 80% you will need four times as many batteries to deliver the same energy, but they will last four times as long, which in the Falkland Islands, where shipping costs are high, might seem a better long-term approach to take. Incidentally, totally discharging a lead-acid battery can often be catastrophic and seriously impair its capacity for being recharged.

Therefore sizing a battery installation needs to involve a compromise between making it so large that it is too expensive to be affordable or so small that it gets discharged too much by the average demand for electricity, and hence has a short useful life. Battery suppliers literature normally provides data on the criteria for sizing and in many cases a battery supplier will advise a customer on correct sizing if there are doubts.

The kind of battery needed for serious electrical storage is known as a "deep-discharge" battery. There are also so-called "traction batteries" used for electric vehicles, which also can be usefully applied, although they need more maintenance (topping up) than dedicated stationary storage batteries and they have a higher rate of internal discharge (a battery slowly discharges internally even if it is not connected to an external load).

Deep-discharge storage batteries are available with flat or with tubular plates (the latter tend to be heavier duty and more expensive). They are also available in the old fashioned form with access to each cell (where the electrolyte needs an occasional top up with distilled water) or in sealed form. Sealed batteries sometimes come with jellied electrolyte and such types can be used on their sides or in any position, even upside down in some cases. Sealed batteries are maintenance – free, but significantly more expensive.

Batteries need to be re – charged in a carefully controlled manner. This is usually accomplished by a DC power source. Normally a high rate of charge is acceptable when the state of charge of the battery is low and the charging current needs to be tapered off as the battery approaches its fully charged condition. Many modern battery charging systems contain sensing circuits to adjust the charge rate automati – cally to suit. Sometimes a so – called "equalization charge" is useful in which the battery is left on a low rate of charge, or trickle charge when fully charged as this equalises the state of charge of all the cells and brings up any which may have not quite been fully charged.

Overcharging causes hydrogen bubbles to be generated on the battery plates which can cause damage to the battery internal structure. Most sizeable batteries will take a low trickle charge without producing significant bubbling even if fully charged. It is important to adhere to manufacturers' recommendations on battery charging.

There are two ways to check the state of charge of a lead – acid battery. The most reliable, if the electrolyte can be accessed, is to use an old fashioned hydrometer to suck up a sample of the battery acid and measure its specific gravity. Figure 4.3 illustrates a typical correlation between acid " 'gravity" and cell volts. 1.25 is usually a fully charged battery and around 1.12 is a flat battery.

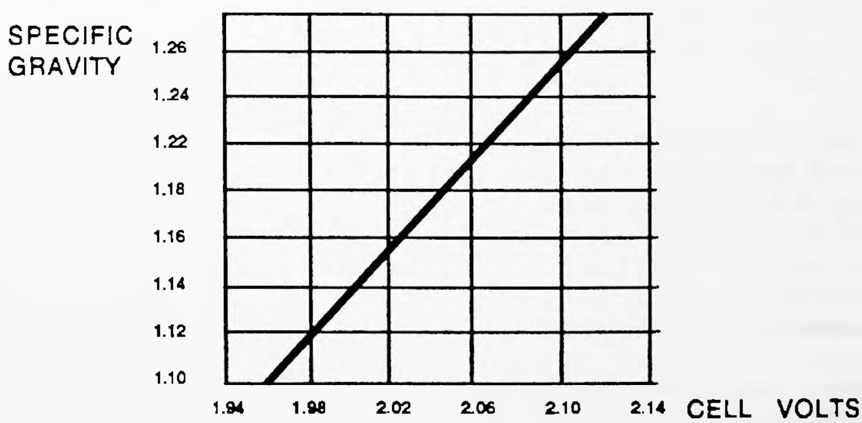


Fig 4.3 Correlation between acid specific gravity and state of charge of a battery

The other method used by most automatic battery charge regulators is to sense the battery voltage. Unfortunately this is not an easy measure of the battery state of charge to interpret accurately as it is sensitive not only to the state of charge, but to the temperature of the battery and to the immediate discharge history. If you draw a heavy current, even briefly, it can depress the battery voltage for some time giving an apparently lower state of charge than really exists. The surest way to check a battery is to measure the "open circuit" voltage (i.e. when no significant current is being drawn) after the battery has been standing idle for some time.

With a standard nominal 12V lead – acid battery, it is usual to charge it at around 14V and it can be considered discharged if the voltage falls below about 11.5V when it has been on open circuit for some time or has not delivered a heavy current in the immediate past. A voltmeter is an almost essential item for any battery backed system to give an instant indication of the situation, although the readings need some interpretation.

Care is obviously needed with lead – acid batteries as the battery acid is extremely corrosive and rapidly attacks almost everything including both a person's skin and clothing.

As unsealed lead – acid batteries produce hydrogen gas, which is highly flammable and potentially explosive, care should also be taken not to expose a battery to naked flames or to sparks, especially if the battery is housed in a confined space. For this reason battery storage areas should preferably be well ventilated. Sealed batteries contain chemicals to absorb the hydrogen that is produced.

nickel – cadmium batteries

The main alternative to the lead – acid is the ni – cad battery. These are generally significantly more expensive for a given rating, but they can withstand a greater depth of discharge than a lead – acid battery, so sometimes a smaller capacity can serve a given duty. Also, nickel – cadmium batteries are less easily damaged by over discharge or over – charging (they are significantly more robust and have a reputation for being more reliable) so simpler and cheaper charge control systems can be used to compensate for their extra unit costs.

Nickel – cadmium batteries can be financially competitive with lead – acid batteries, and particularly with the more expensive sealed lead acid ones. Figure 4.4 indicates battery costs based on data supplied by manufacturers, from which it can be seen that sealed lead – acid batteries are typically twice the median price for the unsealed types and nickel – cadmium batteries may be nearly three times the basic price for lead – acid (for a given capacity).

Ni – cad batteries use an alkaline electrolyte and they are also available fully sealed. In fact small sealed dry – cell replacement Ni – cad batteries are well known and represent a more cost – effective solution than using dry – cells, especially in remote areas like the Falklands where shipping costs make throw – away dry – cells even less attractive than in Europe (as you throw away the shipping costs as well as the battery costs each time!)

The reader is advised to calculate the size of battery that would be appropriate (in the way to be explained below) and then to approach manufacturers of both lead – acid and nickel – cadmium batteries for recommendations on specific sizes and types of batteries and prices. In the end the final decision may be dictated by a combination of price and quality considerations. Its obviously worth paying a premium for sealed batteries or for Ni – cads, but only the customer can decide how big a premium is acceptable.

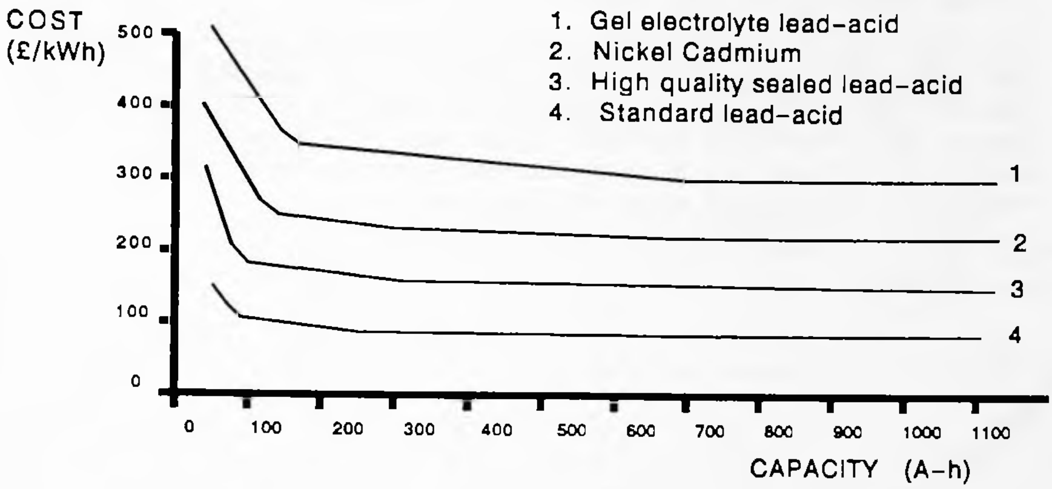


Fig 4.4 comparison of typical battery costs

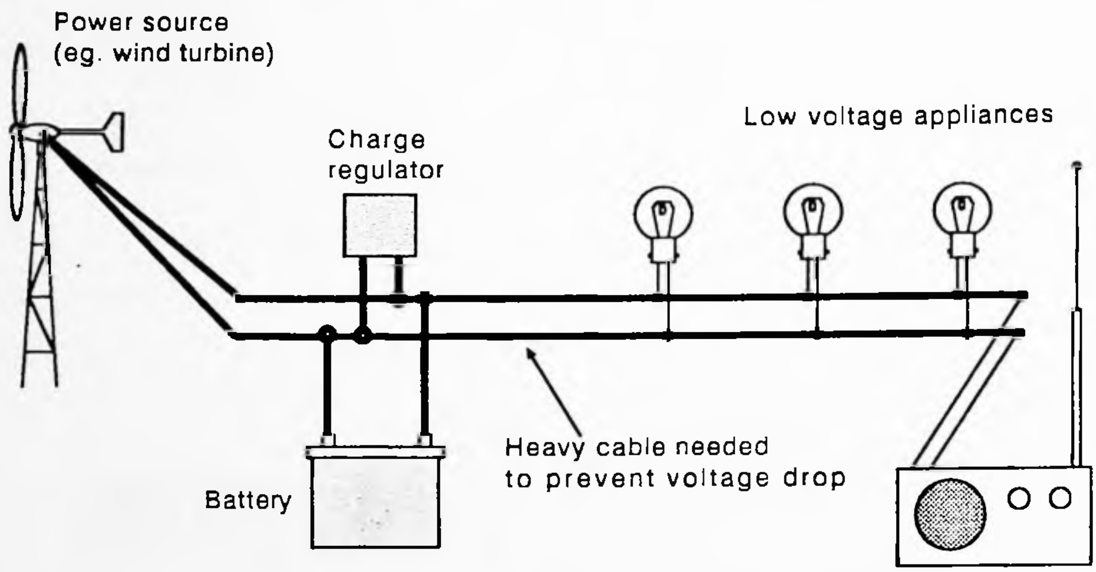
Battery – backed systems

Some typical battery – backed systems are shown schematically in Figure 4.5. In all cases there is a battery bank which needs to be fed with DC electricity at the appropriate voltage to suit the batteries selected.

In most cases multiples of 12V are common, especially 12 or 24V and in a few cases as much as 120VDC. Where lead – acid batteries are used, each cell has a nominal 2V rating so 6 cells are needed to provide 12V (for example most cars and smaller motor vehicles use 12V DC). In the case of Ni – Cad batteries (Nickel – Cadmium), each cell has a nominal rating of 1.2V so 10 cells are needed for 12V and 20 for 24V, etc. 24V is common with commercial vehicles and larger battery systems and the common standard for telecommunications equipment is a nominal 48V. It should be noted that DC voltages greater than 100V are potentially lethal (DC is more dangerous than AC as it causes a person's muscles to grip onto anything live whereas AC tends to throw someone off after the initial shock).

The power supply for recharging batteries can be either a DC source such as solar photovoltaic panels or it can be more commonly a transformed and rectified AC source. AC can readily be changed from one voltage to another through the use of a transformer (with DC it is more difficult to switch voltages in this way). When you transform AC from one voltage to another, the current changes too, so as to keep the power more or less constant. For example if you draw 1A at 240V into a transformer and step it down to 12V, the output will be a nominal 20A because 1A at 240V is 240W so the current to give an output of 240W at 12V is twenty times greater. In practice there is a small loss of power that appears as heat in the transformer, so slightly less than 20A will appear at the output.

This illustrates an important point, namely that the lower the voltage the higher the current for a given electrical power demand. To transmit 20A at 12V needs much heavier cables than 1A at 240V even though the power being delivered is the same. So a low voltage distribution network needs heavy and expensive cables or else the wiring will heat up and energy will be lost.



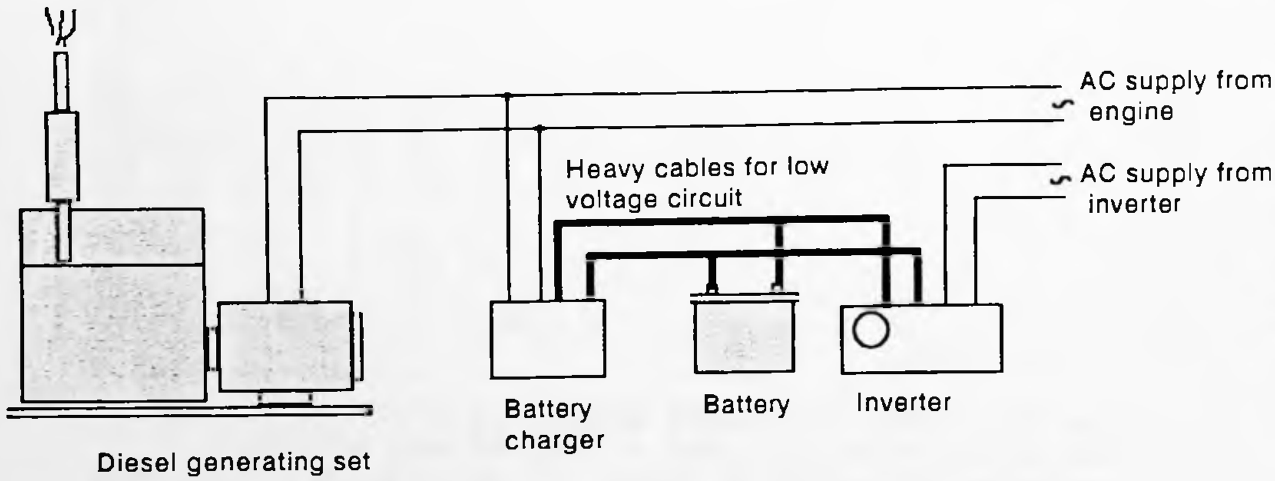


Fig 4.5 Examples of battery backed electrical systems

After adjusting the voltage via a transformer the low voltage AC is commonly transformed to DC using sold state electronic devices known as diodes. Diodes are in effect like non-return valves or one-way valves; they let the current flow one way but block it the other way. To obtain a smooth rectified AC output requires some complexity as a single diode merely lets half the AC wave through and blocks the other half. The interested reader is advised to study a standard electrical text book on this topic as it is not necessary to explain rectification in detail here.

Normally the transforming and rectification are completed in a single "black box"; this is the battery charger (sometimes known as a "DC Power Supply"). This device commonly also includes some electronic control circuitry to sense the battery condition and hence to control the current to the battery. This is necessary because lead-acid batteries in particular can be damaged if they are charged to heavily for too long or overcharged.

The output from the battery can be used as "raw DC" to power DC appliances. After all most vehicle lights (including high efficiency fluorescents used in buses and caravans) are designed for 12 or 24V DC systems. However, heavy and quite expensive cables will be needed except for the smallest wattage appliances, as can be estimated from the following table:

Conductor c.s.a. (mm^2)	Nominal rating (A @ 240V)	Nominal power (kW @ 240V)	Voltage drop per Amp per metre (mV)	Transmission distance for 10% voltage drop at 10A @24V	@240V	UK Trade Price (£/m)
1.0	11	2.6	40	3	30	0.12
1.5	13	3.1	27	4	40	0.20
2.5	18	4.3	16	8	80	0.30
4.0	24	5.8	10	12	120	0.50
6.0	31	7.4	7	18	180	0.75
10.0	42	10.0	4	30	300	1.50
16.0	56	13.5	3	45	450	2.25

This illustrates clearly how to transmit 10A at 24V (i.e. a mere 240W) requires $16mm^2$ cross-section cable for a transmission distance of only 45 meters if the voltage drop is to be under 10%. The percentage voltage drop gives a direct measure of the cable losses, so a 10% drop represents 90% transmission efficiency (i.e. 10% of the energy transmitted fails to arrive!). In contrast, 240W at 240V requires only 1A so that even $1mm^2$ conductor would allow 300m transmission distance before a 10% loss occurred or, 10A (representing 2400W!) could be transmitted 450m using the same $16mm^2$ cable. Obviously even a 24V system is only feasible if transmission distances and current levels are kept quite small, or very heavy and expensive cables are needed. A 12V system is twice as lossy as a 24V one.

Inverters

A solution to this problem is to convert the battery output back to mains voltage. This is usually done by using a device known as an inverter which accepts low voltage DC and outputs higher voltage AC. A 240V 50Hz inverter permits the use of standard mains wiring and appliances up to whatever its maximum continuous power rating is.

The earliest types of inverter were known as rotary inverters and were essentially a 12 or 24V DC motor driving a 240V AC generator. Devices of this kind are no longer manufactured but can be improvised, but they are relatively inefficient (usually 50% or thereabouts – i.e. for every kWh they deliver they waste a kWh), they are noisy and lack the durability and reliability for continuous operation.

In recent years so called "static inverters" have appeared which convert DC to AC electronically. They are generally quite expensive and the specifications vary widely. The cheapest and crudest inverters produce a square wave AC output and are relatively inefficient even at rated power and often highly inefficient at part load. More sophisticated inverters cost more and produce a "quasi sine wave output"; i.e. approximately the equivalent to normal mains AC power. They tend to be more efficient at rated power (the best are around 90% efficient) and a lot more efficient at part loads. The very best are designed to switch themselves off at no load. A danger with inverters that don't do that is that they can drain the batteries they are connected to even when no power is needed.

Inverters had a tendency to be unreliable, but a few brands have been made in some quantities now and it is certainly worth trying to find an inverter that has a "track record" and is widely used as well as having good efficiency right across its power spectrum from no load to maximum rated power. Another important feature with inverters is their overload capacity. The better models can handle from 4 to 6 times their rated power for brief periods. Since many electrical appliances draw a surge of current greater than their normal power requirement when first switched on, some overload capacity is generally an important requirement.

Another problem with inverters is a tendency to create radio frequency interference. This can often be suppressed with special added on electronic components (the manufacturer ought ot be able to advise), but again it is worth questioning a supplier on this issue and perhaps obtaining guarantees that the inverter will be free of radio frequency interference or that appropriate suppressors are provided.

The most sophisticated inverters come as combined inverters and battery chargers. They effectively act as a UPS (Uninteruptable Power Supply) when connected to a battery bank. Basically when power is received by the inverter (whether from an unreliable mains supply or from a diesel generating set) if the battery voltage is below a pre-set value the unit will charge the batteries and connect the mains/diesel supply to the load. Once the battery voltage reaches the level indicating they are fully charged the inverter-charger ceases to charge. If the mains/diesel stops and there is a demand for power from the 240V 50Hz output of the inverter, it immediately switches in the battery as an energy source and acts as an inverter. If the mains or the generator comes back on, the unit links it straight back to the load and starts to recharge the battery again at the same time.

Some units even have a sensor to cut off the system if the battery state of charge falls below some minimum level, to prevent over-discharging the batteries. Then of course no power will be available until the diesel or the mains come back on, but at least the batteries will be safeguarded. It is possible even to get the signal that shuts off the batteries due to over-discharge to auto-start a diesel generating set to avoid any significant break in the power supply. Usually there will be from one to several seconds break in the supply while the switchover takes place, but this is a small inconvenience to have a 24hour lighting system.

Sizing a battery

The capacity of a battery is generally given in A-h (Ampere-hours); i.e. a 20 A-h cell will deliver up to 20A for 1 hour or 10A for 2 hours or 40A for 30 minutes. If the battery in question consisted of 6 such cells in series (i.e. a 12V battery) then the energy capacity would be simply the voltage times the capacity:

$$\text{(volts)} \times \text{(amps)} \times \text{(hours)} = \text{Wh}$$
$$12 \times 20 = 240\text{Wh}$$

This battery would also be called a 12V 20Ah battery rather than a 240Wh battery. The reason is that the *actual* usable stored energy may differ from the value we have just calculated for a number of reasons.

In practice the total capacity of a battery depends on the temperature, the *rate* at which it is discharged and the number of cycles it has previously experienced. If you take 100hours to discharge and recharge a battery at a very low current you can get as much as 100% more capacity than if you subject the same battery to a 10hour charge-discharge cycle with ten times the current. Manufacturers of batteries publish graphs or tables in their sales literature giving their batteries capacities at different rates of discharge.

Furthermore, if you want a good life from a lead-acid battery it is probably prudent to size it so that you discharge it to no greater than 50% of its nominal capacity under normal circumstances before it is recharged (a Ni-cad battery can reasonably be discharged perhaps to 70% or more without risk). So a rule of thumb to size a small system not requiring short heavy currents, is to take the manufacturers nominal A-h rating, multiply it by the voltage and halve the answer to obtain the maximum battery energy available between recharging. For example if you wish to run 100W of lights for 6h per night plus a 100W TV for 3h per night, the daily electrical energy requirement will be 600Wh + 300Wh = 900Wh.

Since an inverter will be required to convert battery power to mains power standards, we must assume some losses from the inverter and cabling. 70% might be a reasonable guess for a reasonably modern system, so the gross output from the battery will need to be:

900/(70/100) = 1285Wh every 24h

If we do not wish to discharge the battery below 50% of its nominal capacity, we will need a battery capable of delivering a nominal output at 100% discharge of:

1285/(50/100) = 2570Wh every 24h

Let us assume we go for a nominal 24V battery system (as being slightly more efficient than a 12V one), then the A-h rating for this battery needs to be:

2570 / 24 = 107 A-h

This gives an idea of the kind of battery sizes you need to be looking at. In the end it is advisable to write to battery suppliers with a specification giving the following information:

a) rate of discharge (how many amps for how many hours)
b) end voltage (inverter input voltage)
c) temperature (what kind of temperature will the battery be exposed to – outside or indoors?)
d) cycle length (typical charge-discharge cycle period)

This should enable a manufacturer to recommend the most cost-effective options to meet your duty requirement.

Although manufacturers' warranties are of limited usefullness in the Falklands (the cost of returning a dud battery for exchange is probably prohibitive and few warranties will cover such details as shipping costs) they are worth reviewing if only as an indication of the confidence a manufacturer places in their product.

A generously sized, *good quality* (i.e. not cheap) heavy-duty, deep-discharge battery ought to last 3000 cycles at 50% discharge (which is over 8 years on a 24hour cycle) and 5000 cycles at 30% discharge which is 13 years. So quite respectable life expectations are possible from batteries providing they are properly sized and reasonably maintained (when of the kind that needs maintenance). Figure 4.2 indicates a typical curve for cycle life as a function of depth of discharge. Obviously these curves vary for different batteries.

4.2 Use of Wind Energy

The Falkland Islands have a wind energy resource that is second to none. For example, the mean windspeed at Stanley is 7.7m/s (15.5kt) over the year, and the monthly mean for June, the least windy month, is not a lot less at 7.1m/s (14.4kt). These represent exceptionally high means with unusually low variability over the year compared with most other parts of the world. The energy content of such a wind régime is approximately 2 to 3 MWh/m^2 per year (or in the order of 5 to 7kWh/m^2 per 24 hours). Of this, about 20% should readily be accessible using modern wind–electricity generating systems – i.e. at least 1 kWh of electricity per day, on average, for each square meter of wind turbine rotor.

Despite this seemingly excellent wind resource, little useful experience has yet been gained at using wind turbines in the Islands. The one exception where windmills have been used in the Falklands for many years are a number of UK manufactured (now obsolete) Climax farm–windpumps which were used for livestock water supplies (although these are mechanical rather than electrical devices). The fact that a number of these machines have been in regular and reliable use for over thirty years (eg. at Darwin, near Port Howard and at Fox Bay West), indicates that, given appropriately selected, reliable and robust equipment, wind power can be usefully exploited in the Falklands. Unfortunately the UK manufacturer of the Climax Windpump has long since ceased production and spares are no longer available, so these machines have tended to go out of use as and when any key component fails.

Wind electricity generation has so far only been practised on a very small scale in a handful of places in the islands. There is a 10kW installation which charges a battery–inverter system at Pebble Island. Other than the Pebble Island machine a number of very small machines, mostly 50W Rutland wind–chargers, with rotors around 90cm in diameter have been used generally quite successfully for small applications, such as electric livestock fences (eg. Port Howard, Salvador and Pebble Island) and for the Educational Service VHF (2m band) repeater stations on Pebble Island and to the north of Port Howard.

A very important point that applies to all wind–turbines or windmills, is that it is vital to install them where the wind is clean and unobstructed. Any nearby obstructions will have a turbulent area in their lee which can be extremely damaging to any wind turbine located in the turbulent zone. Therefore windturbines need to be installed at least 3–4m above the wake from any solid obstruction on their windward side, more to avoid damage from turbulence than because of the obvious loss of energy that also results.

An important point in connection with all types of wind–turbines is to understand that in almost all cases their main purpose is to save fuel that would otherwise be used to perform the same function. Even the stand–alone systems such as those powering mountain–top VHF repeaters indirectly save fuel be reducing the need to visit the sites regularly with a Land–Rover in order to change the batteries and any wind–electricity generators connected to a domestic supply (such as at Pebble Island), serve the purpose of reducing diesel running hours and the load on the diesel.

Therefore, when evluating whether a wind turbine is worth purchasing it is necessary to balance its cost against the anticipated fuel savings (and also to take account of any operational advantages and labour that might be saved).

Types of wind – powered system

Windpumps

Windpumps are windmills dedicated to pumping water, (see Figure 4.6). They are generally driven by a multi – bladed fan – like rotor which most people are familiar with from Westerns (as the windpump was originally developed in the US mid – West for watering livestock on the prairies).

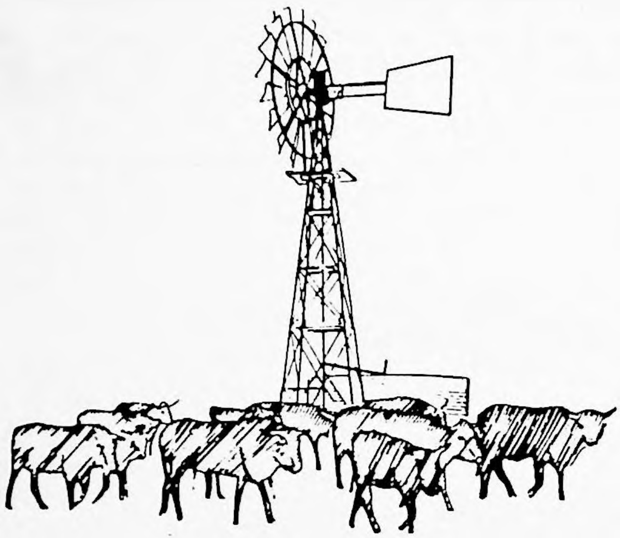


Fig 4.6 Typical farm windpump

Today a number of windpumps can still be purchased. The main sources of supply are Australia, New Zealand, the USA and if trade links are re – established it so happens that Argentina produces large numbers of relatively low cost farm windpumps. Examples are of course given in the Buyers Guide section of this manual.

Mechanical windpumps are generally a more reliable and cost – effective solution than using a wind – electricity generating "wind turbine" to drive an electric pump.

The manufacturers' literature will give tables showing the output of water for a given pumping head and windspeed. The basic information needed when ordering a windpump is:

- the depth from which the water must be lifted (i.e. the distance from ground level down to the rest level of the water in the well or water source)
- the delivery head (i.e. the height above ground level of the water level in the storage tank to which the water will be pumped)
- the horizontal distance from water source to storage tank and the pipe diameter for the pipeline (to assess the extra pressure needed to overcome pipe friction)

- the mean windspeed (if in doubt use the figures given previously for Stanley which in any case significantly exceed the highest windspeeds most manufacturers include in their pumping tables)

- the average daily output of water that will be required

To give an approximate idea of the output that might be expected from a windpump, the following table shows the daily water delivery assuming a mean windspeed of 6m/s (to be conservative by Falklands standards) for a range of different total pumping heads (i.e. static head plus pipe friction head) for *every square meter* of windpump rotor. If for example, three times as much water is required per day, then a $3m^2$ rotor (which is 1.95m or slightly more than 6ft in diameter) will be needed. To remind those whose maths is a bit rusty, the relationship between the *area* of a circle like a windpump rotor, and its *radius (i.e. half the diameter)* is:

$$\text{Area} = 3.14 \times (\text{Radius})^2 \quad \text{(where 3.14 is the constant } \pi\text{)}$$

AVERAGE OUTPUT IN LITRES/DAY FROM A WINDPUMP WITH A $1m^2$ ROTOR AREA IN A MEAN WINDSPEED OF 6m/sec

Total pumping head in metres	Average daily water output (litres)	(Imp.gallons)
5	38,000	8,400
10	19,000	4,200
20	9,500	2,100
40	4,750	1,050
60	3,200	710

Any windpump system generally needs a storage tank as obviously there will be calm days when little or even no water is pumped. It has been found from experience that in a windy place like most potential sites in the Islands, a tank with 3 days capacity (i.e. three times the average daily water requirement) will make it virtually 100% certain that water will always be available. A smaller tank may cause shortfalls in the supply during very calm periods, but providing there is at least 1.5 day's capacity such shortfalls will be rare.

One point to consider when purchasing windpumps (or any other types of water pump) is freezing. Providing the pump is well submerged in the water source and that the riser pipe is well lagged in exposed, windy places, freezing will not be a problem, but some windpump manufacturers provide a facility to avoid damage occuring in the even that the pump temporarily freezes.

Another consideration is whether or not to use a suction pump (where the pump is above the supply water level and therefore has to suck the water) or a submerged lift pump which avoids suction. It is always better to avoid suction pumps as they require priming to get them started and if they lose their prime they can run dry and suffer serious damage as a result. In some situations a suction pump is unavoidable, in which case it is best to make the delivery line run "up-hill" from the pump so it always is full of water near the pump and to provide a non-return valve in the suction line *in addition* to the foot-valve to help keep any water in the suction line from running back to the water source. It is also worth having the suction line rise to a slightly higher level than the pump so that the pump is at a low-spot in the pipe line which will tend to stay full of water.

Wind electricity generators (WEGs)

There are four main types of wind-electricity generating system that are possible (see Figure 4.7) but only two main options for most

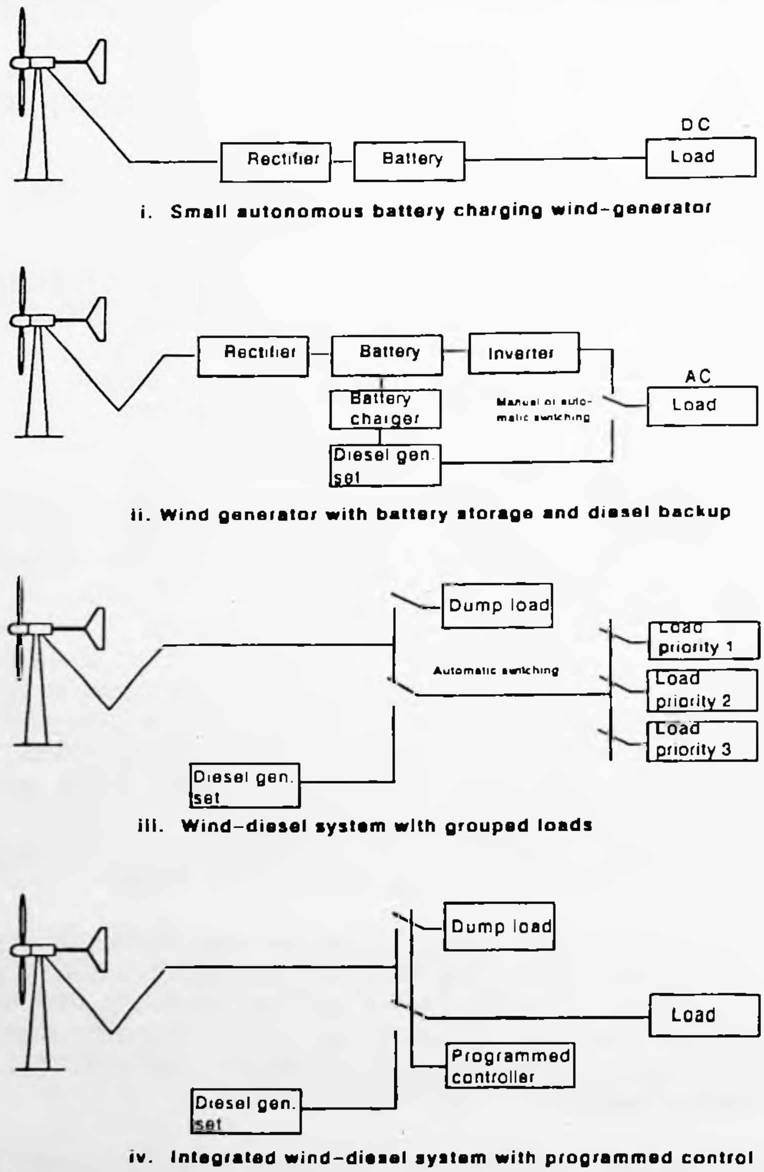


Fig 4.7 Four main types of wind-electricity generating system

potential users with no more than a small-scale applications. The two larger options are more of relevance for community supplies which are beyond the scope of this manual.

i. battery charger

Here quite a small wind turbine, probably in the power range 50 to 250W (maybe 1000W at the most) (for example see Figure 4.8) is used to charge a bank of batteries. At its simplest this can be a 50W windturbine a car battery (unsuitable though those are, as explained in the previous section) and a very small electrical load such as an energiser for an electric fence or one or two lights (preferably fluorescent with integral inverters).

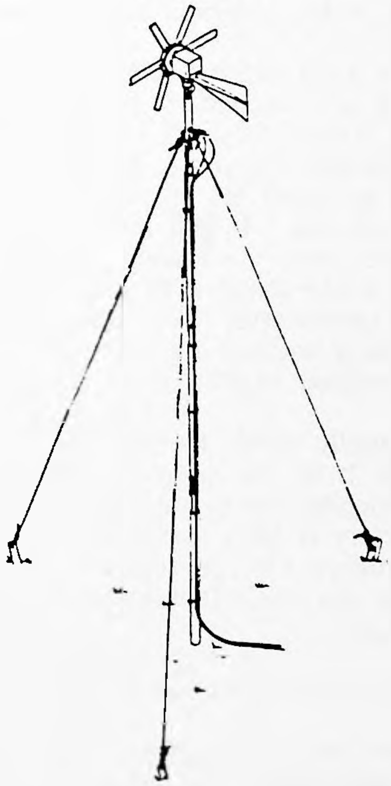


Fig 4.8 Typical small battery charging wind generator (50W Marlec "Rutland" Windcharger)

With very small systems you can afford to provide a significantly larger battery capacity than is strictly necessary as the load is so small, which allows you to get away with a car battery as the depth of discharge will be quite low and car batteries are more easily obtained than specialised batteries.

The output from the battery will have to be delivered over quite a short distance unless very heavy and expensive cables are used or unacceptable losses are incurred, so such wind turbines need to be located with 10 or 20m of the application they serve.
Small wind turbines in the 50W range typically cost around £200 to

£300, can be obtained by mail–order and are easy to erect using a length of water pipe as a mast.

If guy wires are used follow the suppliers instructions. Generally it is prudent to use at least four and preferably five guy wires or if the minimum of three is used only one has to become uprooted to cause catastrophic failure. Fencing wire is generally not good enough as it stretches and goes slack.

A small braced tower (welded up from scrap steel bits and pieces) is generally more robust than relying on guy wires and also it is sometimes difficult to anchor guy wires on rocky ground or very soft peaty ground that is common in the islands.

ii. wind battery charging with occasional use of diesel generator

The next most ambitious wind turbine would be in the 250–2000W range, and might be introduced as a secondary power source for an existing diesel–battery–inverter system as described earlier in this chapter. A windturbine like this might frequently keep the battery bank sufficiently well charged to avoid the need for starting the diesel at all or to greatly reduce its use. It will also allow an isolated family to leave their house empty knowing the windturbine will keep the batteries sufficiently well–charged to keep their freezer going while they are away. In otherwords it will keep vital small electrical appliances going indefinitely without the need for frequent human intervention such as is needed to start or stop a diesel in most cases.

One extra component usually needs to be purchased with the windturbine and is generally available from the supplier, and this is a charge regulator which shunts surplus power into a ballast resistor to dissipate it once the battery is fully charged (otherwise there is a risk of damaging the battery). Charge regulators are usually relatively inexpensive but they are important and pay for themselves in preventing battery damage.

iii. Wind–diesel system with grouped priority loads

Much larger windturbines can be considered for community use (in the 50–100kW range) and they have been successfully installed for example in the UK on Lundy, Fairisle and on Foula in Shetland (for example see Figure 4.9). Here the windturbine is usually oversized to the extent that it meets essential community electrical needs such as lighting even in the lightest of winds.

The loads are divided into separate prioritised electrical circuits so that top priority (lighting, TV, etc) is always served except when there is a windless period (when the diesel obviously has to be started), the next priority is important loads where the timing of the power supply is unimportant so long as enough power is delivered on average, such as freezers, 'fridges, etc. Finally the lowest priority load is storage heating for both domestic heat and for hot water. There is then a "ballast load" for dumping power as waste heat in situations where the windturbine produces more power than can be absorbed usefully by the normal load circuits, as can frequently happen in summer when little heat is needed and less lighting too.

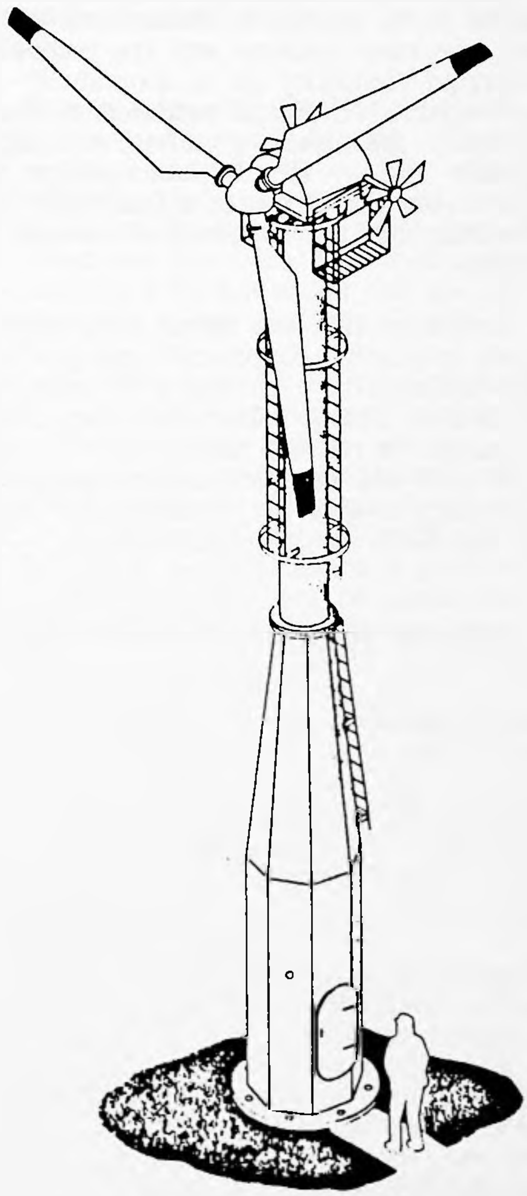


Fig 4.9 Typical community wind turbine (Wind Harvester UK)

A microprocessor controls the switching by sensing the demand for electricity and the availability of power from the windturbine and when necessary the controller can also start the diesel. Systems of this kind have been found to work reliably in the various UK islands where they have been tried and generally the need for using the diesel is relatively rare.

iv. Integrated wind – diesel systems

Finally it is possible to integrate a windturbine with a small diesel power system where several diesels are generally used to meet the peak load. Here the windturbine can frequently reduce the number of diesel generating sets that need to be operated. Much work is in hand world-wide on "wind-diesel" integrated systems and the technology for introducing wind-generated electricity up to around 20-30% of the total load is now well-established. Major settlements like Port Stanley could readily reduce the diesel-generator running hours through such an approach. Wind-diesel systems where the windturbine is of a similar capacity to the diesel are at a less well-developed stage at the time of writing, but are expected to become commercially viable in the near future.

In general, it can be concluded that the power range from 2kW to around 30kW is difficult to satisfy economically using wind turbines at present even though the systems exist and it is technically feasible, (the 10kW system at Pebble Island being an example) because such systems are big enough to require substantial electrical storage capacity if batteries are used and complex control equipment and inverters but not big enough to give the economies of scale obtained from wind turbines in the 50kW or larger size range.

How much electrical energy can you get from the wind and is it cost-effective?

It has already been explained that, typically, a wind turbine should deliver in the region of 1kWh (or slightly more) per day for each square meter of rotor area. For example, a machine rated at 50W will deliver approximately 500Wh/day and a 250W rated machine should produce around 2.5kWh/day. The former will cost in the region of £350 installed and the latter, nearer £1000 (not including batteries, inverters or other equipment).

Assessing cost-effectiveness is not straightforward as a small amount of energy for an important purpose (eg. for a radio or a single key light) is often worth much more to the user than a larger amount of energy for something less important. But an indication of what the output from a small windturbine costs can be had if say we write the machine off over 5 years (they ought to last longer than that, but let's be cautious). Five years is 1825 days, so in that time a 50w machine will deliver about 900kWh (so the average investment cost per kWH would be around 38p/kWh) while the larger 250W windturbine will deliver around 4600kWh (giving a similar crude cost of 21p/kWh). These are competitive with the cost of electricity from small diesel generating sets and clearly have the potential advantage of requiring much less human involvement once the system is up and running.

This slightly simplistic analysis ignores battery costs and considers the windmill purely as an "add-on" to an existing diesel-battery system, which seems perhaps the best way of introducing windpower anyway.

4.3 Use of solar energy

There are two primary options for using solar energy in the Falkland Islands; solar photovoltaics (solar cells) which is a technology that produces low voltage DC electricity directly from sunlight (see Figure 4.10) and solar water heaters (which use solar energy to heat water – as in Figure 4.11).

A few farmers have recently imported solar photovoltaic (photo–cell) powered units for livestock electric fencing. There is insufficient experience yet to report conclusively on how effective this technology can be in the Falklands, since the solar energy availability in mid–winter at the latitude of the islands is quite limited. Most of the units so far imported are from the New Zealand–based supplier Gallagher, who expressed doubts about the use of their equipment during short winter days in the Falkland Islands.

Analysis of the solar régime by IT Power Ltd., using computer software that can estimate solar insolation for any location in the world, indicates that solar photovoltaic systems can only be cost–effectively applied for very small scale power applications where the high cost of solar panels necessary to access adequate levels of solar energy during short June/July days will remain within acceptable limits and where a static (non–mechanical) device is preferable to a wind–charger (eg. where a lot of turbulence might be experienced) or where the power demand is even too small for the smallest wind chargers. The most likely general application for solar photovoltaics in the Falklands is for electric fences although Cable & Wireless PLC have used larger solar photovoltaic arrays to power the telephone repeaters recently installed in the Camp.

An analysis by IT Power produced the following indications of mean daily solar insolation on a horizontal surface in kWh/m^2 for each month (these were theoretically derived, actually measured figures may differ slightly from these):

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	annual mean
5.3	4.2	3.3	1.9	1.0	.65	.79	1.5	2.8	4.3	5.3	5.6	3.05

Clearly the average irradiation available in June is very limited, but the situation can be improved by installing a solar photovoltaic panel at an optimum angle of about 60° to the horizontal to maximise the solar energy intercepted; setting a panel at this angle would result in an average of 1.22kWh/m^2 per day being accessed in June at the inclined surface, although if the panel were left at that angle all the year around, less than the optimum would be received in summer (although there is so much more solar energy available at that time that for most purposes this would not normally matter).

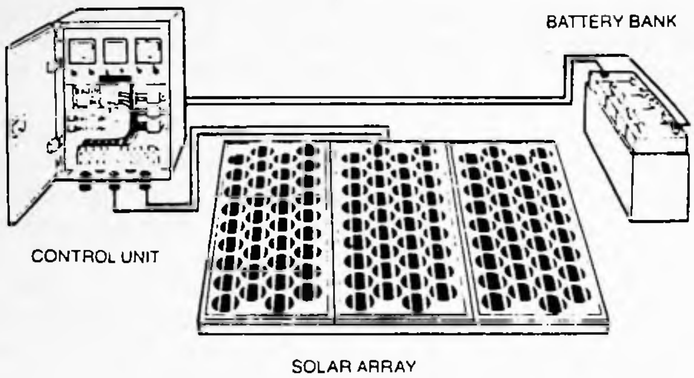


Fig 4.10 Typical photovoltaic array (Courtesy BP Solar – UK)

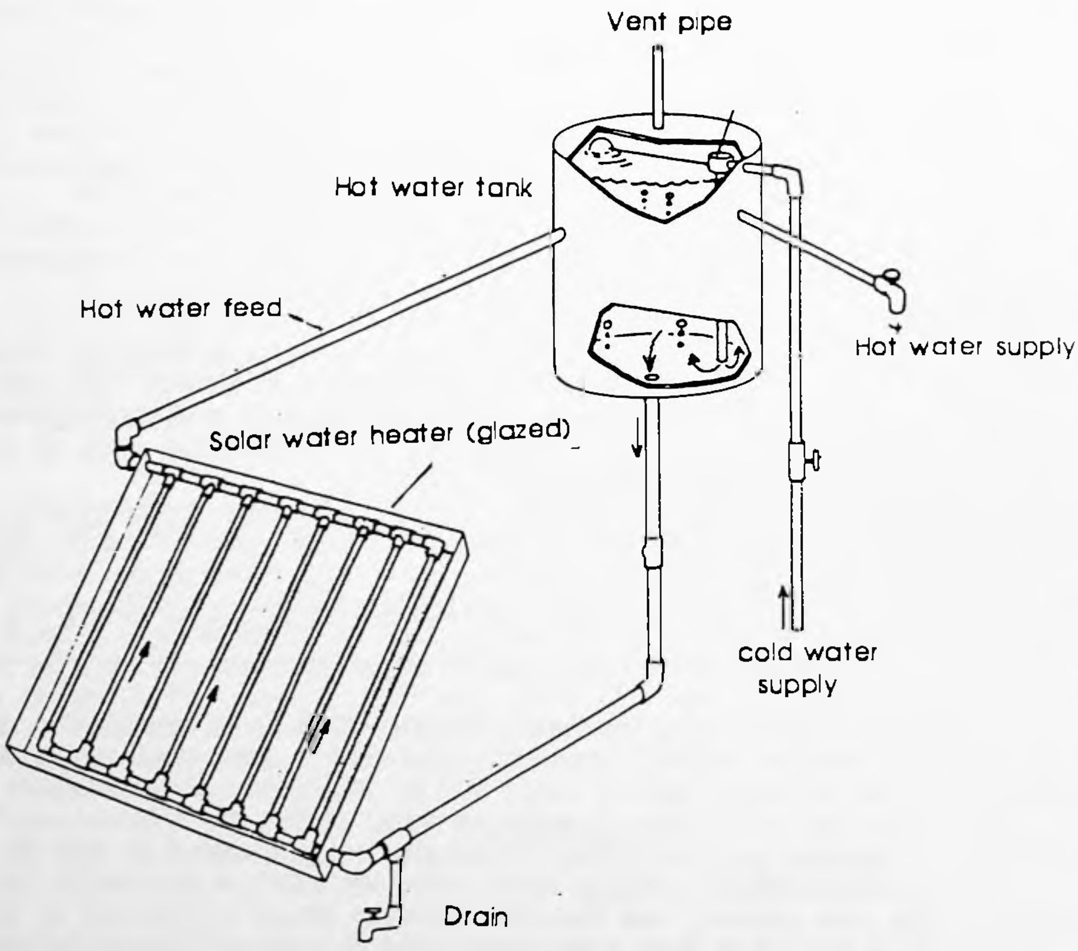


Fig 4.11 Schematic of a solar water heater system

Solar energy could also be used for heating water (via flat plate solar water heaters) but it is doubtful that this would be very useful in the winter due to the limited availability of solar energy. It does make sense to use solar water heaters in places where the summer requirement for hot water is larger than in winter, for example the Tourist Lodges and other such establishments. Sea Lion Lodge, for example, uses solar water heaters as peat cutting presents problems on Sea Lion Island due to the small population and the demand for hot water peaks conveniently for the Lodge during the summer tourist season.

As with solar photovoltaic panels there are benefits in setting the angle of a solar water heater higher than the latitude in order to extend the season during which useful inputs of solar heat might be collected. At Sea Lion the solar water heaters are set at 45°.

4.4 Use of hydropower

Micro-hydro-electric power is a relatively mature and widely used technology which can be highly cost-competitive compared with all other options (notably diesel-generation), given adequate river resources close to a place of use. It also has the advantage of generally requiring much less maintenance than diesel plant and of lasting much longer.

The basic requirement is a small stream and terrain such that it is possible to arrange to divert some (or all) the water from the stream through a pipe to allow it to fall sufficient distance to generate useful amounts of power if it is then passed through a small turbine (see Figure 4.12).

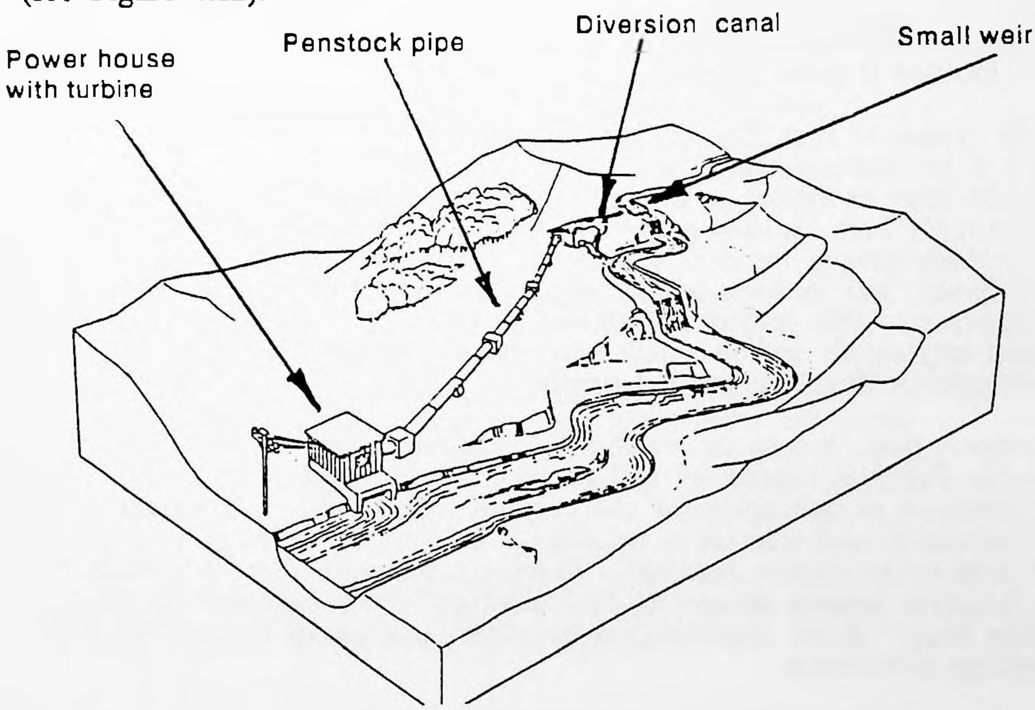


Fig 4.12 Schematic of a micro-hydro system

To estimate the potential power in a stream you need to know just two facts, the volume of water available "Q" and the head through which the water can be engineered to fall through an enclosed pipe to a turbine "H". Q of course varies from day to day and what is most important is the minimum flow that can regularly be counted on even in dry periods. H can be measured with some accuracy or estimated using large scale contoured maps in cases where quite high heads are to be considered.

The power available from a hydro-plant, P is, numerically:

$$P = gQH$$

and if metric units are used where g (the acceleration due to gravity) is $9.81m/s^2$, Q is in litre/second and H is measured in metres, then:

$$P = 9.81 \times (Q \text{ litre/sec}) \times (H \text{ metre}) \quad \text{Watts}$$

In practice a small hydro system is unlikely to convert more than 50% of the available power into useful electricity, so the electrical output to be expected, bearing in mind that 9.81 is approximately 10, is:

$$P(e) = 5 \times (Q \text{ litre/sec}) \times (H \text{ metre}) \quad \text{Watts}$$

which, of course, can be divided by 1000 to give a figure in kilowatts.

Unfortunately there are few rivers or streams which flow all the year in the Falklands, and even fewer settlements in convenient proximity to potentially usable micro-hydro-power sites as most settlements are on the coast. The only existing micro-hydro installation in the Islands has been recently completed at Port Howard. Other rivers of a size that might allow future hydro development are mainly at some distance from settlements, so electrical transmission costs could only be justified if quite large levels of power could be tapped.

The system at Port Howard has a maximum output at present of 13kW(e), but it has some potential to be extended later to a higher head which would raise its output to around 20kW. Interest in a micro-hydro system for Port Howard goes back to the mid 1950s, when river flow was accurately gauged for over a year and correspondence on the supply of equipment was initiated with a major UK supplier of micro-hydro equipment. This project is intended to offer a limited 24 hour/day electricity supply and to supplement the already stretched and intermittent diesel-generated supply.

Longer-term, it may be worth identifying other potential hydro sites in the Falkland Islands, even if at present they are remote from settlements or habitation, on the grounds that any new settlement or habitation if and when it is required could possibly be sited near to a good micro-hydro resource. There are believed to be a number of northwards flowing streams in both East and West Falkland that might offer micro-hydro opportunities but most such places are remote from existing settlements.

Since the potential for micro-hydro in the Falklands is severely limited this hand book will not deal with this topic in detail, although certain relevant products are included in the buyers guide, in particular hydraulic ram pumps.

The hydraulic ram-pump is worth mentioning as it is a little-known, extremely simple device with no moving parts other than valves, which works by the effect known as water hammer where if you suddenly stop a flow of water it causes a violent and sudden pressure rise (the bang in the pipes that can occur if you close a tap too suddenly is an example), see figure 4.13. The hydraulic ram is fed by a drive pipe from a small weir and has a valve which gets slammed closed by the water flow the moment it reaches a pre-set velocity. The resulting sudden pressure rise reaches a pressure greater than the delivery head so that a small proportion of the flow discharges through another non-return valve into the delivery pipe, causing some water to emerge at a much higher level. The valve that was slammed shut by the flow falls open, usually due to gravity, as soon as the pressure level falls again, water discharges below the pump until the flow through it again reaches the velocity at which the valve slams shut, causing a repeat of the cycle.

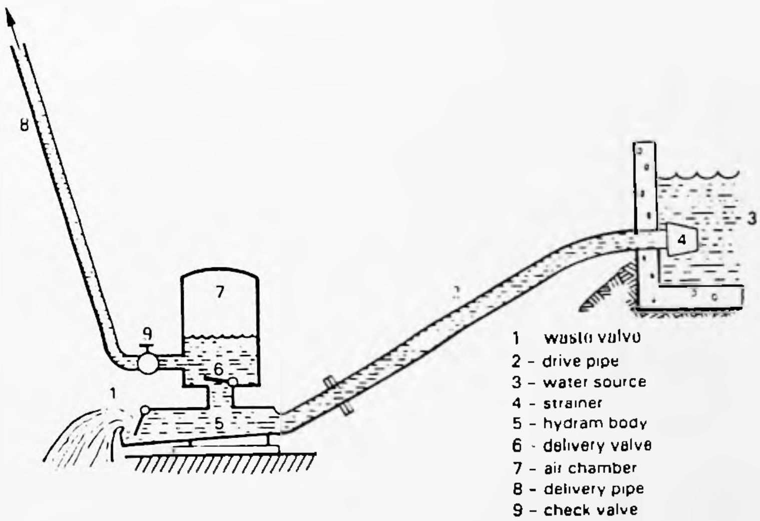


Fig 4.13 Hydraulic ram pump

Hydraulic ram pumps were originally invented at the end of the 18th Century by the Montgolfier brothers in France (who are better remembered as the first successful developers of hot air balloons). They are extremely reliable and long-lasting (if solidly manufactured) and a few manufacturers still produce them. they are seriously worthy of consideration if stream flow is needed to pump a smaller quantity of water to a higher level, especially in remote areas where a small water supply is needed (eg. shepherd's shelters or if drinking troughs are needed where cattle or horses are grazed).

4.5 Other unconventional energy generation possibilities

There are possibilities for using peat to generate electricity. However, this is not practical at the present time due to a general lack of reliable and cost – effective equipment for its implementation, even though in some cases such equipment existed and was widely used in the past. Nevertheless there are many developments taking place and it can be anticipated that suitable equipment will become available within the next decade or so, especially if there is another significant increase in oil prices. The primary options for generating electricity from peat are: –

i) gasifying plants (or "producer gas units") (see Figure 4.14) which can fuel conventional spark ignition internal combustion engines similar to a petrol engine or which can supplement the fuel supply for a diesel engine. Unfortunately the gas quality from present equipment is usually so poor that most modern engines suffer greatly reduced performance and rapid deterioration due to carry over of tar and acid pollutants in the gas unless very expensive gas cleaning equipment is introduced.

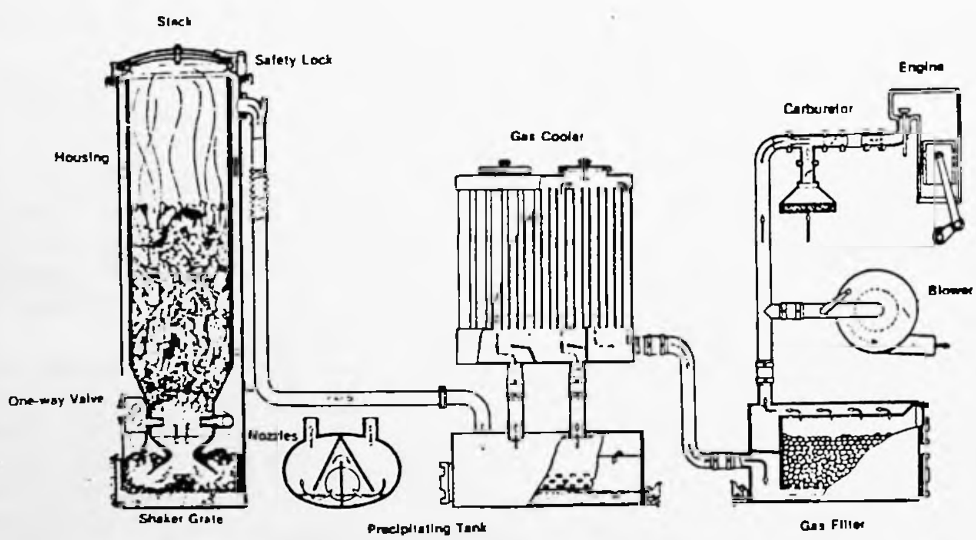


Fig 4.14 Gasifier for running a small engine

ii) small steam engines; the problem here is a combination of non – availability in the small sizes of interest and high capital cost of mechanised and adequately safe modern furnace/boiler systems (traditional steam systems would be too labour intensive to be any use even if still available). The forestry industry in Brazil has yielded several types of robust steam engine powered generating sets in the 30 to 100kW range (see Figure 4.15). These are available "off-the-shelf" in wood-waste burning form but specialised furnaces and peat handling equipment would be needed to run such equipment on peat. Although the use of peat fired steam plant for electricity generation would certainly be technically feasible, it probably would only become seriously worth considering if significant increases in the world market price for diesel fuel take place.

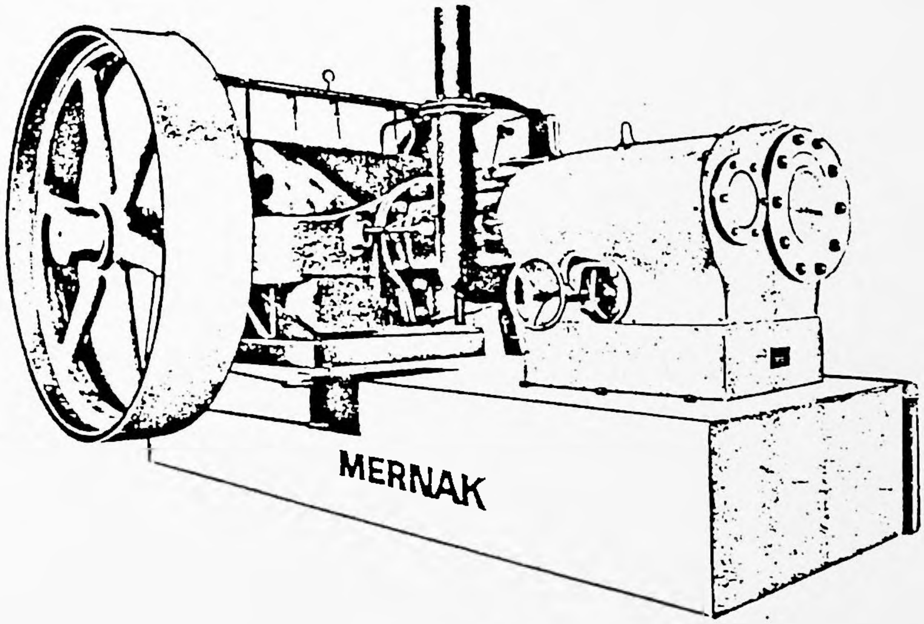


Fig 4.15: 25kW Brasilian reciprocating steam engine

iii) small Stirling engines (or hot air engines) are under development. These could burn peat although only one significant system (10 to 40kW from Stirling Power Systems AB, Sweden which needs propane as a fuel) is currently commercially available, and this machine is unattractively expensive and moreover it is doubtful if a suitable burner for fuel such as peat is available for it. Also Stirling Engines remain immature (despite a 150 year history), and are only produced in limited quantities, and therefore not cost competitive with diesel at present. A lot of development is taking place in this promising field, including by I T Power who produced this book, and may result in appropriate commercially available systems for domestic power generation appearing during the 1990s.

5.

Cost – Effectiveness

5. HOW TO DETERMINE COST – EFFECTIVENESS

Sometimes you have to spend money to save money, but sometimes spending money is just spending money. We all need to use energy to survive and, so far, we have shown that there are ways to increase the amount of energy available and there are ways to conserve energy and make what you already have go further. The question in the end is whether any supposed improvements are worth paying for, in other words, are they cost – effective?

One of the first difficulties you run into when comparing technologies is the fact that there are two main costs associated with everything and these are difficult to compare. These two quite different categories of expenditure are:

- the first cost or purchasing cost (often known as the "Capital Cost") and
- the running costs sometimes known as "O & M costs" or "Operation and Maintenance costs".

Some technologies are low in first cost but have high running costs and conversely, most which have low running costs have high first costs. If anyone invents an energy device with *both* low first costs and low running costs it would no doubt replace everything else we use at present, but at this time nothing so attractive exists. For example, a diesel generating set has relatively low first costs (the pounds per kilowatt of capacity you need to pay for a diesel are quite low compared with other power sources – perhaps £200 – 500/kW) but over the life – time of a diesel generating set there is a continuous need to purchase fuel, consumable spares, lubricants and the labour to undertake maintenance and repairs. In contrast, a solar photovoltaic power array is extremely expensive, around £5000/kW, but it needs no fuel at all and virtually no maintenance so that the running costs are extremely low and moreover it tends to last longer than most small diesel engines.

Similarly, it costs money to save energy. Better insulation, waste heat recovery equipment from a diesel, battery backed electricity supplies to reduce diesel running hours, all involve extra investment. Here the question is whether the extra money invested creates a sufficient reduction in running costs to make it a good investment.

It should be added that the financial aspects of energy generation and conservation are definitely not the only factor to consider. There are often many other good reasons than financial ones for investing in something; convenience being a common one. A battery backed lighting system may save diesel running hours, but often the convenience of having lights available at any time is a more important factor than whether or not it pays back in saved diesel fuel. Similarly, good draught proofing might save peat for the fire, but the improved domestic comfort of getting rid of draughts is another good reason to spend some money on this measure.

But even if a measure is for non-financial reasons it is worth assessing whether it is also financially worthwhile (or if not, what are you actually having to pay in reality to achieve it?).

To do this kind of financial calculation requires the ability to compare the value of a capital investment (or a sum of money spent today) with a future cash-flow (i.e. a projected series of payments that will have to be made over a certain number of years).

The simplest comparison of this kind is known as "Simple Payback" or "Crude Payback". For example if you invest £1,000 in some equipment and you assume it will have a useful life of 10 years before it needs replacing, then in "Simple Payback" terms the cost is £1,000/10 or £100 per year. If this investment saves diesel fuel or peat or labour (or whatever) which is worth over £100 per year than the investment can be considered worthwhile, and if it fails to save as much as £100/yr it is not financially worthwhile.

Simple payback is not a strictly accurate method of evaluating an investment since it takes no account of the value of your capital. This is because a sum of money can be invested at a bank or similar institution to increase in value in accordance with the applied interest rate. If a sum is invested instead in equipment such as to generate power or even to reduce energy losses, then its potential for interest accumulation is lost. If the capital is not available, then the capital has to be borrowed and will incur the need for regular repayments of both the original capital sum and the predicted interest accumulation. Therefore in business, it is normal to compare a capital investment with the regular repayments that would be necessary to borrow it, whether or not the money needs to be borrowed.

For example, if you borrow £1,000 from a bank for a period of 10 years at an interest rate of 10%, you are likely to have to pay £170/year for ten years (assuming the bank allows equal annual payments at a fixed rate like this). In otherwords you pay back £1,700, of which £1,000 is the principal (the original sum borrowed) and £700 is the interest. So you can assume if you purchased a piece of equipment for £1,000 that the annualised value of the capital, assuming a ten year life and a 10% discount rate (or interest rate) is £170/year and not £100/yr as with the simple payback method. Even if you do not really have to borrow the money, this still is true, since, if instead of buying the equipment you had put your £1,000 in a deposit account yielding 10% per annum for 10 years, you would have had £1,700 at the end of that period in the account, so by *not* investing the money you will have deprived yourself of £700 in interest accumulation over that period which ought to be accounted for.

In reality of course, discount rates vary between banks, building societies and other possible places you can lend or borrow money to or from and the rates vary all the time too. However taking a fixed "typical" discount rate, like say 10%, does give a reasonable method for assessing the value, or the return to be expected from an investment. Moreover, even if it may not truly allow a prediction of what will really happen (as you obviously can't predict what the Bank Rate will be in the future, although some specialists try to make a living by doing so!) it does offer a sound and realistic way of comparing different options, since the cheapest option at a reasonably realistic fixed discount rate will generally be the cheapest option even when the rate changes (providing it does not change radically from the assumed value).

This method for prediction of the value in the future of a sum of money spent now is known as discounting. If the discounted annual repayment is "A", the original capital sum is "C", the loan period is "n" years, and the interest rate is "i" (for instance, at a 10% interest rate "i" has the value 0.1) then it can be shown mathematically that:

$$A = C\frac{i(1 + i)^n}{(1 + i)^n - 1}$$

The annual repayment A is also referred to as the "discounted annualised capital cost". To save you working out these values, Table 5.1 includes factors for a common range of discount rates for periods up to 25 years. If you multiply the capital sum "C" by the appropriate factor you obtain the annualised equivalent repayment "A".

It is noticable that low discount rates (such as apply to "soft loans" make capital seem cheaper so that systems involving high first costs and low running costs (i.e. renewable energy systems) seem more cost-effective when discount rates are low and options with relatively low first costs and high running costs seem more financially competitive when discount rates are high.

To make reasonably rigorous financial comparisons between different methods of power generation (or energy conservation) it is necessary to follow the following procedure:

1. annualise the capital cost using an appropriate lifetime and discount rate

2. estimate the annual recurrent or operating costs (i.e. fuel, maintenance, spares, repairs)

3. add the annualised capital cost to the total recurrent or operating cost to obtain the total annual cost

4. estimate the useful energy production per year (or in the case of a conservation technique, the useful energy saved). The word "useful" should be noted, since in practice a 10kW diesel set, for example, may on average deliver only 5kW of useful power for 3,000 hours per year, which is 15,000kWh – it would obviously be

a mistake to multiply the rated power of 10kW by the hours per year.

5. divide the total annual cost by the estimated useful output (or saving) to get an average cost per kWh

6. repeat this procedue for each option to be considered and compare the results

If this procedure is carried out for each option you wish to choose between it will at least give a financial criterion for selecting the most cost-effective option. In the end you may choose for other reasons an option that is not the seemingly most cost-effective, but at least you will know exactly the extra spending needed to obtain the preferred method of energy generation or energy conservation.

There are other finanical/economic evaluation techniques, but they are generally more complicated and will add little to the value of what can be achieved either by a "simple payback" calculation or where more sophistication is wanted, by simply using this basic Discounted Cash Flow approach.

Year	Discount Rate				
	0.02	0.05	0.10	0.15	0.20
1	1.00	1.00	1.00	1.00	1.00
2	1.02	1.05	1.10	1.15	1.20
3	0.52	0.54	0.58	0.62	0.65
4	0.35	0.37	0.40	0.44	0.47
5	0.26	0.28	0.32	0.35	0.39
6	0.21	0.23	0.26	0.30	0.33
7	0.18	0.20	0.23	0.26	0.30
8	0.15	0.17	0.21	0.24	0.28
9	0.14	0.15	0.19	0.22	0.26
10	0.12	0.14	0.17	0.21	0.25
11	0.11	0.13	0.16	0.20	0.24
12	0.10	0.12	0.15	0.19	0.23
13	0.09	0.11	0.15	0.18	0.23
14	0.09	0.11	0.14	0.18	0.22
15	0.08	0.10	0.14	0.17	0.22
16	0.08	0.10	0.13	0.17	0.21
17	0.07	0.09	0.13	0.17	0.21
18	0.07	0.09	0.12	0.17	0.21
19	0.07	0.09	0.12	0.16	0.21
20	0.06	0.08	0.12	0.16	0.21
21	0.06	0.08	0.12	0.16	0.21
22	0.06	0.08	0.12	0.16	0.20
23	0.06	0.08	0.11	0.16	0.20
24	0.05	0.07	0.11	0.16	0.20
25	0.05	0.07	0.11	0.16	0.20

Table 5.1: Annualised Capital Cost Factors for various discount rates

6.

Further Information

6 SOURCES OF FURTHER INFORMATION

6.1 Addresses of organizations able to offer specialised advice (Note all addresses are in the UK except where other countries are indicated)

Building Research Establishment
Advisory Service
Bucknalls Lane
Garston
Watford WD1 7JR
Specialised questions on building design and materials

Combined Heat & Power Association
Bedford House
Stafford Road
Caterham
Surrey CR3 6JA
Trade association for manufacturers of CHP equipment

Draughtproofing Advisory Association
P O Box 12
Haslemere
Surrey GU27 3AN

Energy Efficiency Office
Department of Energy
Thames House South
Millbank
London SW1P 4QJ
Publishes a number of useful booklets on energy conservation and also on UK manufacturers of Energy Generation or Conservation equipment

Solid Fuel Advisory Service
Hobart House
Grosvenor Place
London SW1X 7AE
primarily deals with coal

External Wall Insulation Association
P O Box 12
Haslemere
Surrey GU27 3AN

The Consumers Association
14 Buckingham Street
London WC2N 6DS
Publishers of Which? magazine

Central Heating Efficiency Confederation
P O Box 17
Northampton NM4 0PG

British Standards Institution
Linford Wood
Milton Keynes MK14 6LE

Energy Efficiency Centre
The Building Centre
26 Store Street
London WC1 7BT

Heat Pump Manufacturers Association
2nd floor
Nicholson House
High Street
Maidenhead
Berks SL6 1LF

Glass and Glazing Federation
6 Mount Row
London W1Y 6DY

Solar Trade Association
Brackenhurst
Greenham Common South
Newbury
Berks RG15 8HH
Mainly represents companies concerned with solar heaters (rather than solar photovoltaics)

Trade Association for Biomass Industries Ltd
PO Box 7
Southend
Reading RG7 6AZ
Represents British companies involved with energy production from biomass, such as burning, fermentation (alcohols, etc) or digestion processes (biogas, etc).

British Wind Energy Assocation (BWEA)
5 Hamilton Place
London W1V 0QB
Learned society open to individuals and companies or other organizations concerned with the production of power from wind energy. Publishes magazine called "Wind Directions".

National Association of Water Power Users
c/o Arnold, Greenway & Sons
P O Box 27
Exchange Chambers
10b Highgate
Kendal
Cumbria LA9 4SX
Association for manufacturers and users of water power in the UK. Publishes regular newsletter and will suggest contacts to answer specific technical questions to do with water power

UK Section of the International Solar Energy Society (UK–ISES)
Kings College
Atkins Building South (128)
Campden Hill Road
London W8 7EH
Learned society open to individuals and companies or other organizations concerned with the production of power from solar energy. Produces various publications.

Enquiries Bureau
Energy Technology Support Unit
Building 156
AERE Harwell
Oxon OX11 9NP
Publishes leaflets and other booklets on energy efficiency projects carried out in the UK (advises UK Department of Energy on energy conservation and renewable energy technologies)

Centre for Alternative Technology
Machynlleth
Powys
Wales SY20 9AZ
Demonstration centre showing environmentally benign methods of generating power or growing crops with bookshop and numerous relevant publications available

6.2 Books and pamphlets

"The Draughtproofing Handbook"
London Energy & Employment Network
99 Midland Road
London NW1 2AH price £5
good source of detailed information on the choice and application of draught proofing

"Energy Savings with Home Improvements"
from Which? Book Offer,
Dept of Energy Library, Room 1020, Thames House South,
Millbank, London SW1P 4QJ price £5.95

"Cutting Home Energy Costs"
from
Energy Efficiency Office, Department of Energy,
Thames House South, Millbank, London SW1P 4QJ,
This is a step-by-step guide to cutting energy costs

"The Which? Book of Do-it-Yourself"
"The Which? Book of Plumbing and Central Heating"
"The Which? Book of Home Improvements and Extensions"
The Consumers Association
14 Buckingham Street
London WC2N 6DS

"Wind Power Equipment" by D F Warne, (1983) published by E & F N Spon Ltd., Freepost, Northway, Andover, Hants SP10 5BR

"Heating Water by the Sun" by M G Hutchins and W G Gillett, available from UK-ISES (qv) cost £3.00

"Keeping Warm for Half the Cost"
by J Colesby and P Townsend (1981) cost £2.95
basic handbook on insulating a house in the UK
"Windpumping Handbook" by Sarah Lancashire, Jeff Kenna and Peter Fraenkel (1987) cost £6.95 A4 paperback
basic introduction to windpump types. siting, maintenance and economics
"Ferrocement Water Tanks and their Construction" by S B Watt, cost £4.95 paperback
describes in practical detail how to build cylindrical water storage tanks up to 150m^3 capacity from wire reinforced cement mortar
"Field Engineering: A Guide to Construction and Development Work in Rural Areas" compiled and Edited by P Stern from original by F Longland. £12.50 hardback or £5.95 paperback
covers many aspects of engineering projects in remote areas, including energy and other topics like building, sanitation, water supplies, roads, river crossings, small dams, bridges, etc.
"Solar Photovoltaic Products: A Guide for Development Workers", by Anthony Derrick, Catherine Francis and Varis Bokalders
covers available photovoltaic systems £12.50
The above group (and numerous other publications) available from:
I T Publications
103-105 Southampton Row
London WC1B 4HH

"All About Inverters" by David Copperfield
"The 12Volt/Low volt Shop" by David Copperfield
"How to install Solar Electric Panels" by David Copperfield
"Windpower for the Homeowner" by Donald Marier
Examples of books available from
ASE (Alternative Sources of Energy), 107 South Central Avenue, Milaca, Minnesota 56353, USA

"Guide to Small Wind Energy Conversion systems" Twidell, 1987, price £15
Excellent general review of windpower options and how to apply them, from 50W battery chargers to 100kW machines.
"Design with Energy", Littler, (1984) 366p price £19.50
Book for architects and those with serious technical interest in low energy and passive solar building design
"Home Insulation, DIY" Thomas (1985) 63pp 99pence
Sensible advice on insulation
plus dozens of other related publications from:
Centre for Alternative Technology
Machynlleth
Powys
Wales SY20 9AZ

"Alternative Energy Sourcebook"
Real Goods Trading Co., 3041 Guidiville Road,
Ukiah, California 95482, USA,
telephone 707 468 9214
Probably the most comprehensive catalogue of renewable energy power supplies, energy storage equipment, inverters, and domestic equipment specially selected for use in remote areas. Includes useful articles on the items in the catalogue and detailed descriptions and specifications. 176 page large format paperback book which cost US $5.00 for the 1988 edition. The publishers can supply the equipment they describe in their catalogue. Most appliances for domestic use tend to be to US standards rather than to UK standards (i.e. mains voltages of 115V and 60Hz) but a lot is for low voltage battery operation.

6.3 Periodical publications and journals

"Industrial Exchange and Mart"
Contact the Marketing Dept. (IEM), Link House,
25 West Street, Poole, Dorset BH15 1LL
Weekly Journal of industrial advertising includes new and second-hand generating sets construction materials, pumps, etc.

"Real Goods News"
Real Goods, 3041 Guidiville Road,
Ukiah, CA 95482, USA
tel 707 468 9214
Quarterly magazine and equipment catalogue of the Real Goods Company includes useful articles and detailed descriptions and prices for a wide variety of useful products for use in remote areas, such as renewable energy equipment, energy conservation equipment, including many unusual and hard–to–find products such as 12V DC microwave ovens, composting toilets, 12V telephone answering machines and televisions, water purifiers, small generators, etc.

"Monergy News"
Occasional publication by the Energy Efficiency Office, Department of Energy, Thames House South, Millbank, London SW1P 4QJ
Glossy officially produced free magazine with articles on methods for domestic energy conservation and advertisements and details of other sources of information relating to this topic.

7.

Product Information

7. PRODUCT INFORMATION

NOTES:

1. All firms are in the UK except when some other country is indicated

2. While we believe the firms listed manufacture products of good quality and value, the authors obviously do not have first hand experience of each and every manufacturer listed and therefore cannot take responsibility for the reliability and quality of either the companies listed or of their products.

3. We would welcome any feedback from readers on their experiences in dealing with firms listed, or of any other firms or products found to be good for use in the Falklands but not so far listed. Any such feedback may be channelled through the Falkland Islands Development Corporation's office in Stanley.

4. The omission of any firm or product should not necessarily reflect badly on them.

5. When calling UK telephone numbers from outside the UK, it is necessary to leave out the initial zero in the area code when dialing. With US numbers the entire number as given is dialed after the overseas call code and the US country code (which is 1).

HEAT RECOVERY FROM DIESEL GENERATING SETS

E J Bowman (Birmingham) Ltd
Chester Street
Birmingham B6 4AP tel 021 359 5401

exhaust gas heat exchangers for small and medium sized diesels

Windhoff – Perfex UK Ltd
Scotia Close
Brackmills
Northampton NN4 0HR tel 0604 68404

exhaust gas heat exchangers for small and medium sized diesels

Modine Manufacturing Co
Standard Industrial Products
1500 De Koven Avenue
Racine
Wisconsin 53401
USA

Applied Energy Systems
One Whippendale Road
Watford
Herts WD1 7LZ

complete small combined heat and power systems

BATTERY-BACKED ELECTRICAL SYSTEMS AND COMPONENTS

Brinsea Products
Station Road
Sandford
Avon BS19 5RA tel 0934 823039

Small inexpensively priced portable square wave inverters rated at 60 or 150 watts

Northern Electro Engineering
Whittle Street Works
Tottlington Road
Bury
Lancs tel 061 764 7658

Small inexpensively priced portable square wave inverters rated at 25, 150. 300 and 500 Watts

Trace Engineering Co
5917 195th NE
Arlington
WA 98223
USA tel 206 435 8826

Series of high quality, high efficiency, quasi sine wave inverters and inverter-battery chargers in sizes from 600W to 6kW

Dytek Laboratories Inc
165 Keyland Court
Bohemia
New York 11716
USA Tel 516 589 9030

Manufactures equipment to marine specifications including both square wave and quasi-sine wave inverters rated from 300 to 2500W (115 volt - a transformer will be needed to run 240 volt appliances) and marine automatic battery chargers with 12, 24 and 32V outputs

12 Volt Products Inc
756 Morning Glory Avenue
P O Box 664
Holland
PA 18966
USA tel 215 355 0525
Wide variety of products for battery backed systems ranging from batteries, inverters and battery chargers, photovoltaic panels, small wind–generators, etc., from various reputable manufacturers to a profusion of 12 and 24V appliances and accessories. They offer a comprehensive illustrated catalogue which will be of considerable interest to anyone with a low voltage electrical system

R D Power Ltd
Short Drove
Downham Market
Norfolk PE38 9PT tel 0366 382459
Automatic battery chargers in a variety of sizes

Matchpower Systems Ltd
Holmes court
Boston Road Industrial Estate
Horncastle
Lincs LN9 6JW tel 06582 6390
Range of inverters from 60W to 4kW, uninteruptible power supplies, battery chargers, etc

Heart Interface Corp
811 1st Avenue S
Kent
WA 98032
USA tel 206 859 0640
Range of high efficiency quasi–sine wave inverters from 600W to 2.5 kW.

Savawatt Ltd
Falstaff House
12 Victoria Road
Bidford on Avon
Warcs B50 4AS tel 0789 778005
Range of electronic soft–start controllers that reduce the power surge on start up and also save electricity with electric motors such as on freezers and refrigerators. Savawatt make domestic units specially intended for use with domestic freezers and claim payback times of 12 to 18 months using electricity in the UK priced at about 5p/kWh; obviously paybacks will be very much quicker in the Falklands where electricity generally costs upwards of 13p/kWh. The basic domestic Savawatt unit is priced at around £48 in the UK and carries a 2 year warranty.

Fairford Electronics Ltd
Coombe Works
Derby Road
Kingsbridge
Devon TQ7 1JL tel 0548 7494
Single and three – phase soft – start devices, with similar capabilities to those of Savawatt described immediately above

GEC Industrial Controls Ltd
West Avenue
Kidsgrove
Stoke – on – Trent
Staffs ST7 1TW tel 07816 3511
produces range of industrial soft – start motor controllers to reduce power surge on start up (useful with heavily loaded diesel generators which could otherwise be stalled) and also saves power when running.

MTE Ltd
Leigh on Sea
Essex SS9 5LS tel 0702 527111
Range of three – phase soft – start motor controllers with adjustable start ramp times (i.e. start speed up rate can be varied). Claimed the savings can pay for the device even at UK electricity prices in a matter of months.

GP Electronics
Bovey Tracey
Devon TQ13 9DS tel 0626 832670
Manufacture specialised power electronic devices including load controllers for micro – hydro – electric or diesel generating sets (to maintain full load or some desired load level by switching power automatically to and from a heating load when the main demand requirement fluctuates – ensures balanced phases with three – phase systems too). Also produces synchronising devices for synchronising smaller generators to larger ones or into a grid system.

Sturdy Electric Co Ltd
Hamsterley Colliery
Newcastle – upon – Tyne
NE17 7PY tel 0207 560271/2
Manufacturers of specialised transformers: for example for three – phase to single – phase conversion.

Lab – Craft Ltd
Bilton Road
Waterhouse Lane
Chelmsford
Essex CM1 2UP tel 0245 359888
Portapower battery packs for caravans and boats, various inverters and low voltage lighting systems, plus solar photovoltaic panels

SAB NIFE

tel UK 0325 312666
High efficiency, stand alone inverters for use with SAB NIFE nickel – cadmium batteries and solar photovoltaic powered systems. Available in wide range of power ratings.

GNB Absolyte Batteries
Solar Energy Centre
Thorney Weir House
Thorney
Iver Bucks SLO 9AQ tel 08954 42357
Markets range of sealed, maintenance – free deep – discharge storage batter – ies specially intended for solar photovoltaic or other such battery backed electrical systems. Claims specially long – life and high quality for batteries.

Chloride Industrial Batteries Ltd
P O Box 5
Clifton Junction
Swinton
Manchester M27 2LR tel 061 794 4611
One of the largest battery manufacturers in the world, has a very wide range of lead acid stand – by, industrial and other deep – discharge batteries of all kinds as well as automotive batteries.

Crompton Batteries Ltd
Unit 4
Roydonbury Industrial Estate
Horsecroft Road
The Pinnacles
Harlow Essex tel 0279 413032
Specialise in high quality heavy duty lead – acid deep discharge batteries

Chloride Alcad Ltd
Union Street
Redditch
Worcs B98 7BW tel 0527 62351
Chloride's Nickel – Cadmium battery company

Sonnenschein Batteries
F W O Bauch Ltd
49 Theobald Street
Boreham Wood
Herts tel 081 953 0091
Small completely sealed and maintenance-free gelled electrolyte lead-acid batteries and appropriate recharging devices

ELECTRIC POWER GENERATION / PRIMARY POWER SOURCES

DIESEL GENERATORS

R A Lister & Co Ltd
Dursley
Glos GL11 4HS tel 0453 4141
Manufacturer of Lister diesels ranging from 2kW up to 225kW liquid and air cooled

Petbow Ltd
Sandwich
Kent CT13 9NE tel 0304 613311
Wide variety of diesel gen-sets from 3.6kW up to 6000kVA. Smaller sets tend to use Lister or Petter diesels

William G Musgrave Ltd
Magna Road Industrial Estate
South Wigston
Leicester tel 0533 786398
Lister diesel based generating sets from 4.25 to 25 kVA

Dorman Diesels Ltd
Incall Road
Stafford ST16 3UB tel 0785 223141
Industrial generating sets from approximately 25kVA up to 1250kVA

John Robson (Shipley) Ltd
Shipley
Yorkshire tel 0274 582041
Heavy duty open flywheel horizontal cylinder medium speed (1100rpm) diesel engines of 16-19, 22-28 and 26-32 bhp

Hawker-Siddeley Power Plant
Thrupp
Stroud
Glos GL5 2BW tel 0453 884800
Packaged Lister and Petter diesel generating sets to a wide variety of specifications in the entire Lister/Petter size range.

Hatz Great Britain Ltd
One Sketchley Meadows
Hinckley
Leics LE10 3EN tel 0455 611546
Suppliers of German-made Hatz range of diesels in ratings from 1.5 to 80bhp (approx 1 to 50kW). Includes sound-proofed units.

Heron Power Ltd
46-62 Gatwick Road
Crawley
West Sussex RH10 2XF tel 0293 518000
Suppliers of Suzuki portable spark ignition (petrol) generators in power range 150W (electrical at 12V) to 3300W (at 240V AC)

WIND-ELECTRICITY GENERATORS

Marlec Engineering Co Ltd
Unit K
Cavendish Courtyard
Sallow Road
Corby
Northamptonshire NN17 1DZ tel 0536 201588
A range of 50, 250 and 1000W wind generators for battery charging. Over 15,000 of the 50W machines have been sold and a number have been used already in the Falklands.

L V Motors
Works Road
Letchworth
Herts SG6 1NB tel 0462 684202
A range of small wind battery chargers of nominal ratings around 15, 25 and 50 Watts at either 12 or 24V. Also sell various low voltage DC appliances including small pumps.

Whirlwind Power Co
207½ East Superior Street
Duluth
MN 55802
USA tel 218 722 1492
range of 2kW, 4kW and 10kW wind-generators with synchronous inverters, batteries, battery chargers, low voltage appliances and other related components

LMW Windenergy
Lijnbaanstraat 1a
9711 RT Groningen
The Netherlands tel 050 145229 (drop leading zero from overseas)
Comprehensive range of small wind-generators 150W, 250W, 600W, 1000W, 2500W, 3600W, supplied as complete systems with batteries, inverters and even end use devices like refrigerators or pumps.

Bergey Windpower
2001 Priestley Avenue
Norman
OK 73069
USA tel 405 364 4212
Range of 1kW, 2kW and 10kW wind electricity generators using a direct driven permanent magnet alternator with the fewest possible number of moving parts. Supplied with batteries, inverters and control systems.

SMALL HYDRO-ELECTRIC SYSTEMS

Biwater Hydro Power Ltd
Millers Road
Warwick
CV34 5AN tel 0926 411740
Small (and medium) scale hydro-electric systems

Evans Engineering & Power Co.,
Trecarrell Mill,
Trebullett,
Launceston,
Cornwall PL15 9QE, tel 0566 82285
Small (and medium) scale hydro-electric systems using electronic load control

Irem SpA
Via Vaie 42
10050 S Antonino
Torino
Italy 011 9649133/4/5
Small (and medium) scale hydro-electric systems

Gilbert, Gilkes & Gordon Ltd.,
Kendal,
Cumbria LA9 7BZ
Small (and medium) scale hydro-electric systems

Water Power Engineering,
Coaley Mill,
Coaley,
Dursley,
Glos GL11 5DS
Small scale hydro – electric systems

SOLAR PHOTOVOLTAIC SYSTEMS

Solapak Ltd
Factory Three
Cock Lane
High Wycombe
Bucks HP13 7DE tel 0494 452941
Variety of complete solar photovoltaic battery charging systems

Chloride Solar
The Lansbury Estate
Lower Guildford Road
Knaphill
Woking
Surrey GU21 2EW tel 0483 797773
Solar powered battery charging systems and lighting systems

BP Solar Systems Ltd
Windmill Road
Haddenham
Aylesbury
Bucks HP17 8JB tel 0844 292288
UK's largest PV manufacturer (part of the BP oil group) and supplier of variety of PV systems including solar/diesel integrated power systems

STEAM ENGINES

Mernak SA
Industria Brasliera de Maquinas
Rua Otto Mernak 276
Caixa Postal 23
96500 Cachoeira Do Sul
RS Brasil tel 051 722 2144

Reciprocating packaged steam engine generating sets of robust traditional design widely used in the Brasil forestry industry in power ratings of approximately 25, 50, 60, 100, 150, and 180kW. Furnace normally optimised for wood combustion but could possibly be converted to burn peat.

SUPPLIERS OF INTEGRATED ENERGY SYSTEMS INVOLVING COMBINATIONS OF DIFFERENT POWER SOURCES

Manxwind Energy Services
14 Church Road
Port Erin
Isle of Man tel 0624 832021
Design and supply hybrid systems involving diesel, wind and solar photovoltaic power

Winsund Energy Systems Ltd
5 Harbour Court
Dunbar
East Lothian
Scotland tel 0368 63907
Design and supply hybrid systems involving diesel, petrol engine, wind and solar photovoltaic power and appropriate control systems Also supply small generating sets, photovoltaic panels and small wind generators

Integrated Power Corporation
7524 Standish Place
Rockville
MD 20855
USA tel 301 294 9133
Offer high quality integrated Remote Area Power Supplies using engines, photovoltaics and wind turbines, with storage batteries, mainly for professional applications such as telecommunications, remote navigation aids, military applications, etc.

BP Solar Australia
1/98 Old Pittwater Road
P O Box 519
Brookvale
NSW 2100
Australia tel 02 938 5111
Integrated Remote Area Power Supplies based on diesel engines, solar photovoltaics and batteries complete with inverters and control systems

LIGHTING

REC Specialities
530 Constitution Avenue
Camarillo
CA 93010
USA tel 805 987 5021
Low–voltage (12 and 24VDC) fluorescent lighting

Lab – Craft Ltd
Bilton Road
Waterhouse Lane
Chelmsford
Essex CM1 2UP tel 0245 359888

Low voltage (12 and 24V DC) fluorescent lighting
Small inverters
Emergency lighting systems
Mawdsley's Ltd
Standby Power Systems Divn
Dursley
Glos GL11 5AE tel 0453 4131
Emergency battery backed lighting systems

Sunnyside Solar
RD4 Box 808
Green River Road
West Brattleboro
VT 05301
USA tel 802 257 1482
Low voltage and high efficiency lighting systems
Solar photovoltaic lighting systems

Thorn Lighting Ltd
P O Box 18
3 King George Close
Eastern Avenue West
Romford
Essex RM7 7PP tel 0708 66033
"2D" range of folded tube 240V fluorescent lights
Low voltage tungsten halogen high intensity lighting

Phosco Ltd
Great Amwell
Ware
Herts SG12 9TA tel 0920 2272
Industrial and municipal floodlights and sodium light units

Osram – GEC Ltd
PO Box 17
East Lane
Wembley
Middx HA9 7PG tel 081 904 4321
Opus series of compact high – efficiency folded tube fluorescent lamps to fit directly into standard lighting sockets

Philips Lighting
City House
420 – 430 London Road
Croydon CR9 3QR tel 081 689 2166
SL Series of compact high efficiency folded tube substitute bulbs

GTE Sylvania Ltd
Otley Road
Charlestown
Shipley
West Yorks BD17 7SN tel 0274 595921
Sylvania Lynx Diamant compact fluorescent lamp with adapter for use in regular bayonet or edison screw sockets. Also Tru – Aim dichroic 12V quartz halogen spot lamps

WATER PUMPING

Stuart Turner Ltd
Henley on Thames
Oxon RG9 2AD tel 0491 572655
low voltage (12 and 24V) DC electric pumps

Walter Jones/Airscrew Howden
111 Windmill Road
Sunbury on Thames
Middx TW16 7EF tel 0932 765822
low voltage (12 and 24V) DC electric pumps, electric motors, fans, DC – AC controllers

Marshall Speake & Co Ltd
76 Mountgrove Road
London N5 2LT tel 081 346 5652
Water purification and distillation equipment

PMS Weir Bank
Bray on Thames
Berks SL6 2ED tel 0628 770011
Water purification by filtration and reverse osmosis

W D Moore & Co
3 Keegen Street
O'Connor 6163
Western Australia tel 09 337 4756
Farm windmill pumps

Southern Cross Machinery
277 Ruthven Street
Toowoomba
Queensland 4350
Australia tel (38) 1255
Farm windmill pumps

Ernest Hayes (NZ) Ltd
PO Box 8390
Riccarton
New Zealand tel (03) 382 033
Farm windmill pumps (and other equipment specifically for the sheep farmer and the wool industry)

Dempster Industries Inc
PO Box 848
Beatrice
Nebraska 68310
U S A tel 402 223 4026
Farm windmill pumps

John Blake Ltd
P O Box 43
Royal Works
Accrington
Lancs BB5 5LP tel 0254 35441
Hydraulic ram pumps (use stream power to pump water)

Green & Carter Ltd.,
Vulcan Works,
Ashbrittle,
Nr Wellington,
Somerset TA21 0LQ
Hydraulic ram pumps (use stream power to pump water)

Evans Engineering & Power Co.,
Trecarrell Mill,
Trebullett,
Launceston,
Cornwall PL15 9QE tel 0566 82285
Hydraulic ram pumps (use stream power to pump water)

GENERAL / MISCELLANEOUS SUPPLIERS

Real Goods Trading Co
3041 Guidiville Road
Ukiah
California 95482
USA tel 707 468 9214
Produce an excellent 176 page American Quarto comprehensive catalogue called the Alternative Energy Sourcebook (cost $5.00 in 1988) and supply all goods in it.

British Central Electrical
Shakeshaft Electrical Wholesale
Export Dept
Briticent International
Crow Arch Lane
Ringwood
Hants BH24 1NZ tel 0425 474617
Electrical wholesalers stocking wide range of switchgear, cables, lights, heaters, etc. Catalogue available on request.

12 Volt Products Inc
756 Morning Glory Avenue
PO Box 664
Holland
PA 18966
USA tel 215 355 0525
Specialists in 12V/24V appliances and power generation / storage. Many unusual and hard to find products of relevance to conditions in the Camp. Comprehensive catalogue available.

Columbus Ltd
83/85 Heath Road
Twickenham
Middx TW1 4AW tel 081 892 9117
Stockist of wide variety of small generating sets, motors, workshop equipment, pumps, air compressors, etc. Illustrated catalogue available on request.

A.

Annexes

1. Units and Conversion Factors

2. Electrical Consumption for Typical Appliances

Notes on Units and Tables of Conversion Factors

Unfortunately a wide variety of different measuring systems are in current usage internationally (and the UK is almost like the world in microcosm in this respect, since we are in the midst of a slow conversion process from our own traditional system which is still generally used in modified form in the USA, to the SI (Systême Internationale) metric system). As a result the information supplied by manufacturers can be in all kinds of units.

We have generally sought to show SI units (or sometimes other non-SI metric units), in conjunction with British units where possible. However it proves very difficult to abandon some non-SI units such as the ubiquitous horsepower, which usually means more to people in terms of mechanical shaft power than kW. Although SI prefers either mm or m, we have given engine capacities in cc, which should of course be written as cc^3! Again, we would plead that this is what people are generally familiar with and it is certainly the most common engine capacity unit used by manufacturers.

The following tables of units and conversion factors may help in sorting out any confusion which may arise from the selection of different units quoted in this Guide.

A. Methods used for indicating multiples of ten and their standard prefixes

name	*numeric*	*exponent*	*prefix*	*standard symbol*
millionth	$\frac{1}{1,000,000}$	10^{-6}	micro-	μ
thousandth	$\frac{1}{1,000}$	10^{-3}	milli-	m
hundredth	$\frac{1}{100}$	10^{-2}	centi-	c
times thousand	x 1,000	10^3	kilo-	k
times million	x 1,000,000	10^6	mega-	M
times billion	x 1,000,000,000	10^9	giga-	G

B. Principal units in common usage; names and symbols (alternatives in brackets)

	Metric		*British/US*	
length	•millimetre	mm	inch	in (")
	centimetre	cm	foot	ft (')
	•metre	m	yard	yd
	kilometre	km	mile	m.
area	square metres	m^2	sq.ft.	ft^2
	hectare	ha	acre	acre
volume	cubic cm	cm^3 (cc)	cubic inch	in^3 (cu in)
	litre	l	gallon	gal
	cubic metre	m^3	cubic feet	ft^3 (cu ft)
mass	gramme	g	ounce	oz
	•kilogramme	kg	pound	lb
	tonne	t	ton	ton
velocity	•metres/second	ms^{-1} (m/s)	feet/second	ft/s
	kilometres/hour	kmh^{-1} (km/h)	miles/hour	mph (m/h)
			knots	kt
rotation/frequency	•herz	Hz	cycles/second	c/s
	revolution/min.	rev/min (rpm)	revolution/min.	rev/min (rpm)
	radoam/sec.	Ω	radian/sec	Ω
flow rate	litre/minute	l/min	gallon/minute	gal/min (gpm)
	cu.metre/second	m^3s^{-1} (m^3/s)	cu.ft/second	ft^3/s (cusec)
			cu.ft/minute	ft^3/min (cfm)
force	•newton	N	pound force	lbf
	•kilonewton	kN	ton	ton
	kilogrammeforce	kgf		
	tonne	t		
torque	newton-metre	Nm	pound feet	lbf ft
	kilonewtonmetre	kNm		

	Metric			*British/US*	
work/heat/energy	calorie	cal		British Thermal Unit	BTU (B.Th.U.)
	kilocalorie	kcal		Therm	therm
	*joule	J		footpoundforce	ft lbf
	*megajoule	MJ		horsepower-hour	hp h
	gigajoule	GJ			
	watthour	Wh			
	*kilowatthour	kWh			

power	*watt	W		foot-pound/second	ft lbf/s
	*kilowatt	kW		horsepower	hp
	*megawatt	MW		brakehorsepower	bhp
	metric horsepower	CV (PS)			

electrical	*amps	A	(current)	volt-amps	VA
	milliampère	mA		kilovolt-amps	kVA
	ampères/hour	Ah			
	*volts	V	(potential difference)		
	ohms	Ω	(resistance)		

pressure	*pascal	Pa		pounds/square inch	
	megapascal	MPa		gauge	psig
	*bar	bar		pounds/square inch	
	kilogram per	kgcm^2		atmospheric	psia
	square centimetre	(kg/cm^2)		atmosphere	atm
				foot water	ftH_2O

*Preferred units are indicated by an asterisk.

C. Conversion factor tables

length	*mm*	*m*	*km*	*in*	*ft*	*mile*
	1	.001	10^{-6}	.0394	.0033	5.4×10^{-7}
	1000	1	.001	39.4	3.28	5.4×10^{-4}
	10^6	1000	1	39360	3280	.539
	25.4	.025	2.5×10^{-5}	1	.083	1.4×10^{-5}
	305	.305	3.0×10^{-4}	12	1	1.9×10^{-4}
	1.6×10^6	1609	1.609	63360	5280	1

area	*m*^{2}	*ha*	*km*^{2}	*ft*^{2}	*acre*	*sq. mile*
	1	10^{-4}	10^{-6}	10.76	2.5×10^{-4}	3.9×10^{-7}
	10000	1	.01	1.1×10^5	2.471	3.9×10^{-3}
	10^6	100	1	1.1×10^7	247.1	0.386
	.0929	9.3×10^{-6}	9.3×10^{-8}	1	2.3×10^{-5}	3.6×10^{-8}
	4047	.4047	4×10^{-3}	43560	1	1.6×10^{-3}
	2.6×10^6	259	2.590	2.8×10^7	640	1

volume	*l*	*m*^{3}	*in*^{3}	*gal (US)*	*gal (Imp)*	*ft*^{3}
	1	10^{-3}	61.02	.264	.220	.0353
	1000	1	6102	264	220	35.31
	.0164	1.6×10^{-5}	1	4.3×10^{-3}	3.6×10^{-3}	5.8×10^{-4}
	3.785	3.8×10^{-3}	231.1	1	.833	.134
	4.546	4.5×10^{-3}	277.4	1.201	1	.160
	28.32	.0283	1728	7.47	6.23	1

mass	*g*	*kg*	*t*	*lb*	*ton*
	1	.001	10^{-6}	2.2×10^{-3}	9.8×10^{-7}
	1000	1	.001	2.205	9.8×10^{-4}
	10^6	1000	1	2205	.984
	453.6	.4536	4.5×10^{-4}	1	4.5×10^{-4}
	10^6	1016	1.016	2240	1

velocity	*m/s*	*km/h*	*ft/s*	*mph*	*kt*
	1	3.60	3.28	2.237	1.768
	.278	1	.912	.621	.539
	.305	1.097	1	.682	.592
	.447	1.609	1.467	1	.868
	.566	1.853	1.689	1.152	1

rotation	Hz (or c/s)	rpm	rad/s
	1	60	6.283
	.0167	1	.1047
	.159	9.549	1

flow rate	l/min	m^3/s	(Imp) gal/min	ft^3/s
	1	1.7×10^{-5}	.220	5.9×10^{-4}
	60000	1	13206	35.315
	4.546	7.6×10^{-5}	1	2.7×10^{-3}
	1699	.0283	373.7	1

force	N	kN	kgf	t	lbf	ton
	1	.001	.102	1×10^{-4}	.225	1×10^{-4}
	1000	1	102	.102	225	.100
	9.807	.010	1	.001	2.205	9.8×10^{-4}
	9807	9.807	1000	1	2205	.984
	4.448	.004	.5436	4.5×10^{-4}	1	4.5×10^{-4}
	9964	9.964	1016	1.016	2240	1

torque	Nm	kNm	lbf.ft
	1	.001	.738
	1000	1	738
	1.356	1.4×10^{-3}	1

work/heat/energy (smaller units)	cal	J	Wh	BTU	ft.lbf	hp.h
	1	4.184	1.2×10^{-3}	3.9×10^{-3}	3.088	1.6×10^{-6}
	.239	1	2.8×10^{-4}	9.4×10^{-4}	.7376	3.7×10^{-7}
	860.4	3600	1	3.414	2655	1.3×10^{-3}
	252	1055	.293	1	778	3.9×10^{-4}
	.324	1.356	3.8×10^{-4}	1.3×10^{-3}	1	5.0×10^{-7}
	6.4×10^5	2.6×10^6	745.7	2546	2.0×10^6	1

(larger units)	kcal	MJ	kWh	BTU	hp.h
	1	4.2×10^{-3}	1.2×10^{-3}	3.968	1.6×10^{-3}
	239	1	.2778	947.8	.3725
	860.4	3.600	1	3414	1.341
	.252	1.1×10^{-3}	2.9×10^{-4}	1	3.9×10^{-4}
	641.6	2.685	.7457	2546	1

power	W (or J/s)	kW	CV	ft.lbf/s	hp	BTU/min
	1	.001	1.4×10^{-3}	.7376	1.3×10^{-3}	.0569
	1000	1	1.360	737.6	1.341	56.9
	735	.735	1	558	1.014	41.8
	1.356	1.4×10^{-3}	1.8×10^{-3}	1	1.8×10^{-3}	.077
	746	.746	.9860	550	1	42.44
	17.57	.0176	.0230	12.96	.0236	1

power flux	W/m^2	kW/m^2	hp/ft^2
	1	.001	1.2×10^{-4}
	1000	1	.1246
	8023	8.023	1

calorific values	cal/gm	MJ/kg	BTU/lb
	1	4.2×10^{-3}	1.80
	239	1	430
	.556	2.3×10^{-3}	1

POWER AND ENERGY REQUIREMENTS OF TYPICAL ELECTRICAL APPLIANCES

Item	Power (W)	Usage (hrs/month)	Energy (kWh/month)	Cost @ 13p (£/month)
Blanket, electric	190	80	15	£1.95
Charger, (car batteries)	200	10hr/chg	2/chg	26p/chg
Clock, electric	1	720	0.7	9p
Clothes drier	2000	20	40	£5.20
Clothes washer[1]	300 to 3000	15	5 to 45	65p to £5.85
Coffee pot, electric	900	10	9	£1.17
Coffee percolator	300 to 600	10	3 to 6	40p to 80p
Computer, micro	100	30	3	39p
Dishwasher[1]	300 to 3000	15	5 to 45	65p to £5.855
Disposal unit, waste	400	0.3	0.1	1p
Drill, electric	250	1 (?)	0.25	3p
Food blender	250	2	0.5	7p
Freezer (small) 12 cu ft	250	200[2]	50	£6.50
Freezer (large) 30 cu ft	600	200[2]	120	£15.60
Fryer, deep fat	1500	6	9	£1.17
Furnace, oil burner	100	240[3]	24	£3.12
Grill	1000 to 2000	5	5 to 10	65p to £1.30
Hair drier	200 to 1000	5	1 to 5	13p to 65p
Heater, portable	500 to 3000	per hour	.5 to 3	6p to 39p/hr
Hi-Fi/Stereo	40 to 100	per hour	.04 to .1	1p to 2p/hr
Iron	1100	12	13	£1.69
Lights (average) winter[4]	600	100	60	£7.80
Lights (efficient)[5]	150	100	15	£1.95
Pump, water (typical)	400	30	12	£1.56
Recorder, tape (casette)	25	10	.25	3p
Refrigerator	250	200	50	£6.50
Saw, circular 8"	250	per hour	0.5/hr	6p/hr
Sewing machine	75	10	.75	9p
Shaver	12	.5	.1	1p
TV, Black and White	100	120	12	£1.56
TV, Colour	150	120	18	£2.34
Toaster	1500	4	6	84p
Vacuum cleaner	600	10	6	84p
Water heater (immersion)[2]	3000	90	270	£35.10
Water heater (shower)	8000	15	120	£15.60

[1] If hot water is supplied then the lower level applies, but if the water is heated from cold electrically then the higher level may apply

[2] These are "guesstimated" running hours; can vary a lot with conditions

[3] Varies considerably with the season; winter month assumed here

[4] Assumes average 6 room house in winter

[5] Same house as above but using 15W folded tube fluorescent lights instead of 60W tungsten bulbs

Power Ltd
The Warren, Bramshill Road
Eversley, Hants. RG27 0PR, UK
Telephone (0734) 730073
Telex 846852 POWER G
Fax (0734) 730820