Short-Course

Solar PV System Installation and Maintenance

NTQF Level II

Learning Guide -04

Unit of Competence	Apply Principles of Photovoltaic system Operation
Module Title	Apply Principles of Photovoltaic system Operation
LG Code	EIS PIM2 M04 0120 L04-LG04
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LO 4: Distinguish DC and AC appliances

Instruction Sheet	Learning Guide:-13

This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics

- Differences between DC and AC appliances are discussed
- Voltage, current and power ratings of AC and DC appliances is explained.

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to**:-**

- Discuss differences between DC and AC appliances
- Explain voltage, current and power ratings of AC and DC appliances

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information Sheet 1 & Sheet 2 in page 105& 111 respectively.
4. Accomplish the Self-check 1 & Self-check 2 in page 110 & 113 respectively

LO4: Distinguish DC and AC appliances

Information Sheet-1	Discussing differences between DC and AC appliances

1 Basics of AC and DC electricity: definition, difference, application

This chapter is adapted from (giz, 2016)

Since the late 19th century, due to advantages in generation and transmission, grid electricity is provided as alternating current (AC). Hence the vast majority of electrical appliances used in homes, commerce and industry are designed to accommodate AC power. However, AC has a number of disadvantages, particularly since it relies on extensive infrastructure and transformer electronics. Especially for solar-based isolated grids or stand-alone systems, a direct current (DC) system has some advantages.

DC is typically generated directly by a solar PV system and easily stored in a battery bank. Using DC power directly from the PV generator or the battery avoids the transformation to AC via an inverter. This reduces costs as well as electricity losses. Whereas the majority of electrical appliances used, run on AC, especially entertainment and media equipment mostly require direct current (DC) and use an AC adapter when connected to the grid. Furthermore, many DC appliances, while being highly efficient, are available in a robust and simple design, which makes them easier to maintain and repair.

“Off grid areas do not have access to grid electricity and thus they are not familiar with the common AC gadgets. High efficient DC gadgets can be introduced easily in this area, no question of changing AC eco systems.”

In comparing AC and DC systems Lasch and Groh identified some key advantages of DC:

- All modern appliances such as LED lights, televisions, mobile phones, laptops etc. that run on AC are also fully functional on DC in the same voltage range.
- On a DC grid no frequency synchronization is necessary which results in:
  - Easier adding up or scaling up of DC system (energy sources) in parallel.
  - Good grid reliability.
  - Modular growth of DC generators and storage devices is possible, improving the ability to meet a changing demand.
  - Unscheduled outages should not occur.
- Power factor is not a concern in DC systems. A DC system can even operate at very low loads, e.g. a single light, for several hours without significant losses. In AC systems relatively low power consumption is associated with relatively high losses in generators and inverters.

- DC systems are less expensive as no conversion from DC to AC is needed.
- DC system has no inductive or capacitive losses.
- Management of harmonics distortion is much easier in DC than AC.
- DC motors (cooling fans, irrigation pumps etc.) are more efficient than conventional AC motors.
- DC requires a simple two wire distribution network.
- DC floating systems are less prone to shocking hazards (neutral grounding is necessary in AC)

1.1 Concepts of DC & AC appliance

The chapter below is adapted from (Hankins, 2010).

In electricity generation there are two distinct types of electrical current - direct current (DC) and alternating current (AC). Alternating current is the type of current most commonly used in households to power electrical appliances (for example TVs, refrigerators, radios and computers). Grid supplied electricity is alternating current. Direct current is produced by PV modules and stored in batteries. It is possible to convert direct current to alternating current and vice versa using an adapter (e.g. cell phone charger) or an inverter.

Commonly used appliances in PV systems include televisions, DVD players, radios, cell-phone chargers and communication devices, music systems, sewing machines, fans, small tools, refrigerators, office equipment, medical equipment and laptops.

When designing your PV system, it is useful to make a list of all of the appliances that will be used immediately, as well as those that will be purchased in the future. Try to find out the voltage ratings and the power consumption of all of the devices you plan to use. This allows proper sizing of the system and it also allows a decision to be made about system voltage (or whether an inverter is necessary).

Selecting System Voltage: 12V DC or 110/230V AC?

Appliances are available that operate:

- at 12 volt direct current (or 24V DC if the system is wired at 24 volts); or
- through an inverter at 110 or 230 volts alternating current.

When to use DC

Many 12V DC appliances are readily available from solar equipment suppliers. Even super-efficient DC colour televisions are available. If you have a chance, try to select 12V DC appliances for small off-grid PV systems. There are a number of reasons for this:

- DC appliances are often more efficient than AC appliances, especially if they are made for off-grid purposes.

- It is more efficient to power DC appliances directly from the battery than to use an inverter. Inverters are usually less than 80 per cent efficient and they are even less efficient with loads that use motors (e.g. refrigerators). Running a 200W inverter for a colour TV over the course of a night can consume an extra 150Wh (the entire daily output of a 40Wp module in sunny weather).
- If the inverter breaks down or fails, then so will the AC appliances.
- DC-only PV systems are easier to manage – and well-designed smaller systems are to a large degree self-managing. They are less complex, less can go wrong and they are less likely to be over-discharged because of the charge control low-voltage disconnect.
- Because of inverter losses, it is often better to use DC power to operate small loads that must be left on continuously. Examples of such devices include telephones, doorbells, garage-door openers, motion-sensing devices and alarms.

When to use AC (and an inverter)

Many larger off-grid PV systems (i.e. above 200W) will find that having an inverter is useful. As long as the PV charge is properly sized (and the right inverter type is chosen) it may be a good idea to include an inverter in the system. Choose an inverter when:

- You already have an efficient AC appliance (or appliances). If, for example, you have a music system or a laptop that operates on 230V AC, there is no need to throw it away and look for a 12V DC music system. Use what you have through a properly chosen inverter.
- There is no 12V DC appliance available. In isolated countries or regions, it may not be easy to find 12V DC televisions, laptops or radios. Run what is available through an inverter.
- There is a 110 or 230V AC circuit already wired in the building where the PV system is to be installed (which had been, for example, previously run by a generator). Again, as long as the appliances are carefully selected and energy use is managed, an inverter may be right for this type of system.

1.2 DC & AC appliance

Appliances used in our day to day live are usually AC appliances. Some of our AC appliances, such as radios, TVs and computer anyhow operate on direct current. Those appliances have an integrated inverter to convert the alternating current from the plus into the respective direct current.

This chapter will present typical AC and DC appliances.

1.3 AC Appliances

1.3.1 Air conditioning

Air conditioning (often referred to as **AC**, **A/C**, or **air con**)is the process of removing heat and moisture from the interior of an occupied space to improve the comfort of occupants. Air conditioning can be used in both domestic and commercial environments. This process is most commonly used to achieve a more comfortable interior environment, typically for humans and other animals; however, air conditioning is also used to cool and dehumidify rooms filled with heat-producing electronic devices, such as computer servers, power amplifiers, and to display and store some delicate products, such as artwork.

Air conditioners often use a fan to distribute the conditioned air to an occupied space such as a building or a car to improve thermal comfort and indoor air quality. Electric refrigerant-based AC units range from small units that can cool a small bedroom, which can be carried by a single adult, to massive units installed on the roof of office towers that can cool an entire building. The cooling is typically achieved through a refrigeration cycle, but sometimes evaporation or free cooling is used.

Figure 71:- Air conditioning units outside a building

1.3.2 Electric water boiler

An **electric water boiler**, also called a **thermo pot**, is a consumer electronics small appliance used for boiling water and maintaining it at a constant temperature. It is typically used to provide an immediate source of hot water for making tea, hot chocolate, coffee,instant noodles, or baby formula, or for any other household use where clean hot water is required. They are a common component of Japanese kitchens and the kitchens of many East Asian countries but are found in varying use globally. Some thermo pots are designed with a feature that can purify water.

Figure 72:-Boiler

1.3.3 Tea kettle

A **kettle**, sometimes called a **tea kettle** or **teakettle**, is a type of pot, specialized for boiling water, with a lid, spout, and handle, or a small kitchen appliance of similar shape that functions in a self-contained manner. Kettles can be heated either by placing on a stove, or by their own internal electric heating element in the appliance versions.

Figure 73:- A stainless steel kettle with handle

1.3.4 Refrigerator

A **refrigerator** (colloquially **fridge**) consists of a thermally insulated compartment and a heat pump (mechanical, electronic or chemical) that transfers heat from the inside of the fridge to its external environment so that the inside of the fridge is cooled to a temperature below the ambient temperature of the room. Refrigeration is an essential food storage technique in developed countries.

The lower temperature lowers the reproduction rate of bacteria, so the refrigerator reduces the rate of spoilage. A refrigerator maintains a temperature a few degrees above the freezing point of water. Optimum temperature range for perishable food storage is 3 to 5 °C (37 to 41 °F). A similar device that maintains a temperature below the freezing point of water is called a **freezer**. The refrigerator replaced the icebox, which had been a common household appliance for almost a century and a half.

In most households AC fridges are used, especially when they have a grid connection or a Diesel generator.

1.3.5 Washing machine

A **washing machine** (**laundry machine**, **clothes washer**, or **washer**) is a home appliance used to wash laundry. The term is mostly applied to machines that use water as opposed to dry cleaning (which uses alternative cleaning fluids, and is performed by specialist businesses) or ultrasonic cleaners. The user adds laundry detergent, which is sold in liquid or powder form, to the wash water.

Figure 74:- A typical front-loader washing machine

1.3.6 Dishwasher

A is a machine for cleaning dishware and cutlery automatically. Unlike manual dishwashing, which relies largely on physical scrubbing to remove soiling, the mechanical dishwasher cleans by spraying hot water, typically between 45 and 75 °C (110 and 170 °F), at the dishes, with lower temperatures used for delicate items.

Figure 75:- Dish washer

1.3.7 Microwave oven

(Also commonly referred to as a microwave) is an electric oven that heats and cooks food by exposing it to electromagnetic radiation in the microwave frequency range. This induces polar molecules in the food to rotate and produce thermal energy in a

process known as dielectric heating. Microwave ovens heat foods quickly and efficiently because excitation is fairly uniform in the outer 25–38 mm(1–1.5 inches) of a homogeneous, high water content food item.

A modern microwave oven (2016)

Figure 76:-Oven

1.4 DC Appliances

Nowadays, you can find almost any load you need for rural areas as DC loads, where by the most common loads are lamps and fridges. giz published 2016 a catalogue of DC-Appliances under the title “Photovoltaics for Productive Use Applications”

Table 10: Typical DC Loads from the company SolarWorks

These DC loads are nice in the sense that they can pull power directly from the battery bank without the help of an inverter, which increases the overall efficiency of the system because the loads use the same type of electricity produced by the PV array and stored in the batteries. However, DC loads are found in special locations and must be matched to the voltage available from the batteries and the clients need to have the budget to invest in those loads.

The following sections is based on (Karina Garbesi, 2011) and presents DC appliances for three dominant electricity end-uses—cooling, lighting, and refrigeration, which together consume about 40% of total electricity in residential and commercial

markets (see **Error! Reference source not found.**). For each of these products market information, power characteristics, and a comparison of their energy efficiencies with their AC counterparts are provided. This is followed by a brief summary of DC products for other miscellaneous end-uses.

1.4.1 DC Air Conditioners

Market Analysis:

Based on Internet research, we found four companies that produce DC air conditioners marketed for mobile and stationary applications (see Table 2). DC Airco and DC Breeze produce small, rugged products for mobile applications, with capacities of 5,000 Btu/hr or less. SplitCool and Securus market products suitable for residential or small commercial use that include heat-pump heating, both of which have 1.5 ton (18,000 Btu/hr) cooling capacities and are marketed for PV power integration (using four or more 200W solar panels).

Table 11: DC air-conditioners, manufacturers and DC voltages.

Manufacturer	Applications	Voltage	Source
DC Airco	Mobile (auto/RV)	12V/24V	http://www.outdoorgb.com/p/12v_air_conditioners/
DC Airco	Mobile (telecom and other)	24V/48V	http://www.dcairco.com
DC Breeze	Marine	12V/24V	http://www.dcbreeze.com/specifications.htm
SplitCool	Stationary	12V/48V	http://www.solarpanelsplus.com/dc-air-conditioning
Securus	Stationary	48V	http://www.austinsales.net/products/solcool/index.html

Energy Efficiency Analysis

Figure 77 compares the energy efficiencies of DC air conditioners with their AC counterparts. Although there are far fewer DC products, their efficiencies are consistently higher than their AC counterparts. There are a number of reasons for this. In general, off-grid electricity is expensive, and therefore there is an incentive to produce efficient products. In addition, DC air conditioners offer inherent efficiency advantages.

Modern air conditioners use vapor-compression refrigeration technology, which requires motor-driven pumps to operate. Variable-speed compressors use far less energy than their typical single-speed counterparts (with documented savings of 30% and more) and offer higher performance, because, rather than switching between full-on and full-off to maintain thermal comfort, they match output to need, avoiding energy intensive on-off cycling of the motor and overcooling during on-cycles. Variable- speed compressors are generally powered by variable frequency drives. The typical variable frequency drive first rectifies the AC input (converts it to DC), then uses pulse width modulation to create the desired output frequency. Because the power passes through

a DC phase, it is amenable to operation by direct-DC. The most efficient variable-speed drives use brushless DC permanent magnet motors. We note that the DC solar-powered DC air-conditioning heat pump produced by SplitCool does indeed use a variable-speed brushless DC compressor.

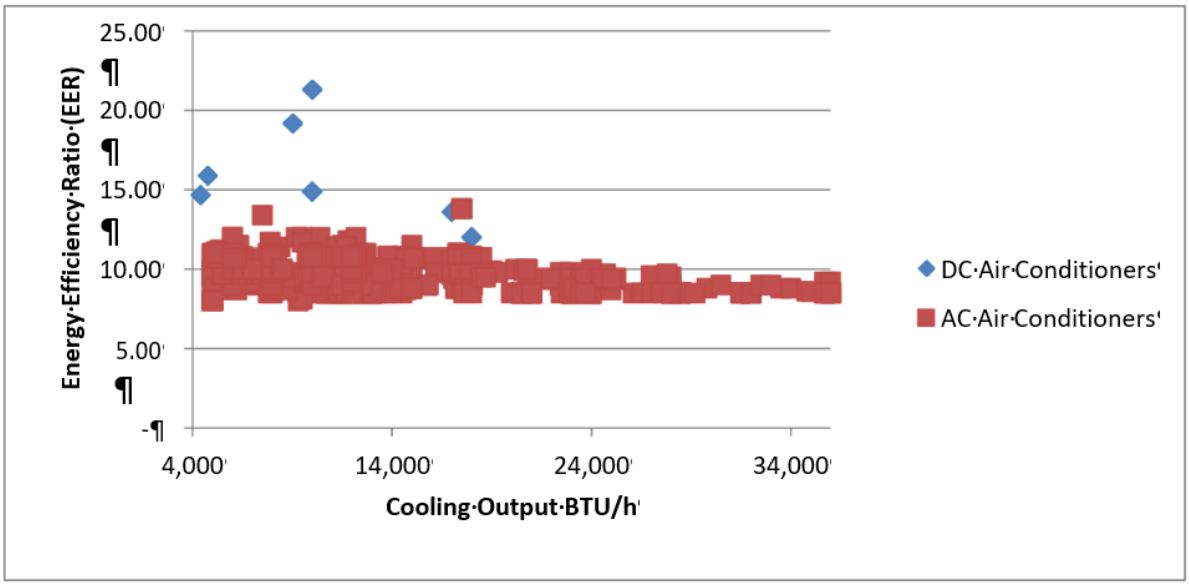

Figure 77: Energy efficiency comparison for DC and AC air conditioners

1.4.2 DC Lighting

Market Analysis

The DC lighting market includes more companies and a larger diversity of products than the DC air- conditioning market, but, like DC air-conditioning, DC lighting represents an insignificant share of the mainstream market, except in such niche markets as outside emergency lighting. This section documents DC lighting products marketed on the Internet. Based on Internet research, there are six companies that produce DC light sources for the DC niche markets: Ablamp, Nextek Power Systems, Phocos, Steca, Thin-Light, and SunWize. Summarized in Table 3, these products include DC lamps (fluorescent, compact fluorescent (CFL), and light-emitting diode (LED) for various fixture types and applications), DC ballasts, fixtures designed for DC lamps (or all kinds), and ballasts for 12V, 24V, and 48V operation.

Energy Savings Analysis

Figure 78, Figure 79 and Figure 80 compare the efficacies of CFL, LED and fluorescent DC lamps with their AC counterparts. For CFLs and LEDs, as with air conditioners, the DC technologies have higher efficiencies on average than their AC counterparts. In the case of CFLs, the DC product efficacy is almost 10% higher than AC counterparts with the same power consumption. For LEDs, the improvement in DC product efficacy is even larger and depends on lamp power. For other fluorescent

lighting (non- compacts) it is difficult to make a reliable comparison because there is very little overlap in the DC and AC technologies in terms of power consumption.

Table 12:DC Lighting Product Manufacturers.

Manufacturer	Applications	Product	Voltage	Source
Ablamp Ltd	Home, street, boat, outdoor	CFL Edison Socket lamps	12V	www.ablamp.com
Ablamp Ltd	Home, office, hotel, shop, landscape, security	LED Edison socket and pin lamps	12V/24V	www.ablamp.com
Ablamp Ltd	Caravan, boat, landscape	LED floodlamp	12V/24V	www.ablamp.com
Ablamp Ltd	Residential, commercial, vehicle	T8-LED fixture, tube, source	12V	www.ablamp.com
Nextek Power Systems	Residential, commercial	Ballasts for T5, T8, and CFL lamps	24V/48V	www.nextekpower.com
Phocos	Home, street	CFL lamps	12V/24V	www.phocos.com
Phocos	Home	LED lamp	12V	www.phocos.com
Steca	Home	CFL floodlight	12V	www.altestore.com
SunWize	Public building, restroom, garage, park, sign, wall washing, driveway, security	Lighting systems: Fluorescent, CFL	12V/24V	www.sunwize.com
SunWize	Bus stop, porch, outbuilding	Lighting systems: LED	12V/24V	www.sunwize.com
Thin-Lite	Home, industrial, commercial sites, area, security	Fluorescent and CFL fixtures and ballasts	12V	www.thinlite.com
Thin-Lite	Indoor, outdoor	Incandescent, halogen fixtures	12V	www.thinlite.com

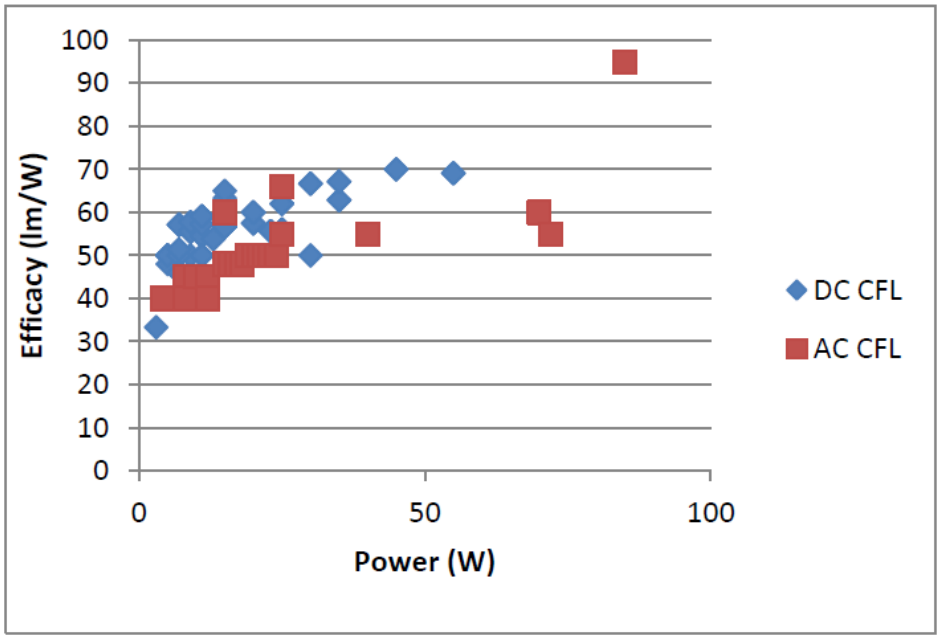

Figure 78: Efficacy comparison for DC and AC CFLs.

Figure 79 compares the efficacy of DC and AC LEDs, based on data compiled by the California Energy Commission. DC LEDs in general have significantly higher efficacy than AC LEDs, particularly for lower luminosity bulbs

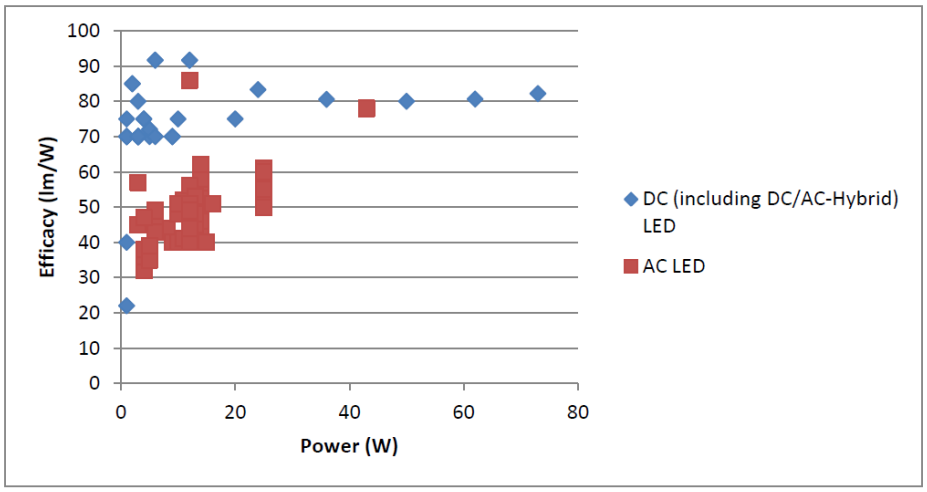

Figure 79: Efficacy comparison for DC and AC LEDs

As for fluorescent lighting, the collected data concentrate mostly on low power for DC fluorescent, but on high power for AC fluorescent, and thus cannot be compared directly. However, the efficacy shows a consistent trend for both DC and AC fluorescent lighting products.

Finally, incandescent lighting sources should have essentially the same efficiencies for AC or DC operation, because the technology is indifferent to current form. What is notable is that incandescent light sources have considerably lower efficacies in general than fluorescent and LED sources, and so should generally be avoided in DC power systems unless absolutely necessary. It is worth noting however, that reflector

and halogen lamps, which are incandescent, have considerably higher efficacies (25% - 35% higher) than standard vacuum-bulb incandescent, which are slated to be phased out under the lighting provisions of the 2007 Energy Independence and Security Act.

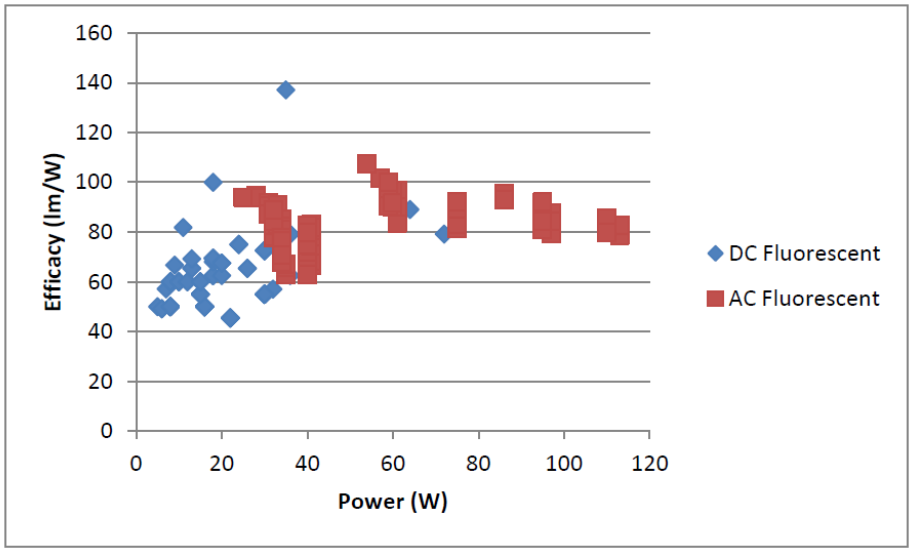

Figure 80: Efficacy of DC and AC fluorescent lighting products.

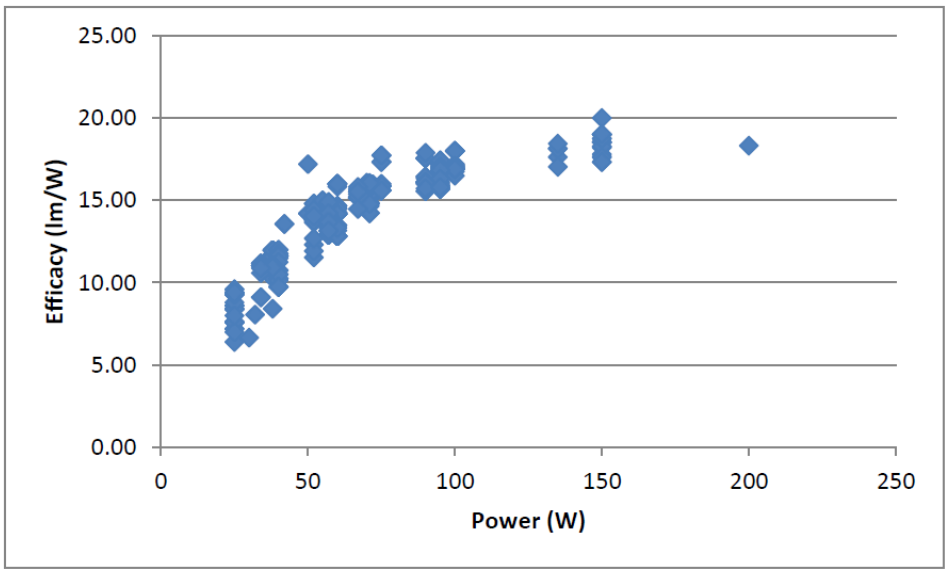

Figure 81: Efficacy of AC incandescent lamps.

1.4.3 DC Refrigeration

Market Analysis

The table below lists the main manufacturers of DC refrigeration products and their targeted markets including marine, RV, and off-grid homes. There are five main manufacturers offering a relatively limited selection of 12V and 24V models. In RV applications propane-powered refrigerators are often preferred because of limited

battery capacity and the high current requirements of the 12 V_{DC} and 24 V_{DC} refrigerators .

Table 13: DC refrigerator product manufacturers.

Manufacturer	Applications	Voltage	Source
Phocos	Solar-powered applications	12V/24V	http://www.phocos.com
Norcold	Marine, RV, trucking, camping/hunting/ fishing, vans	12V/24V	http://www.thetford.com
Sun Frost	Home	12V/24V	http://www.sunfrost.com
SunDanzer	Home, remote location	12V/24V	http://www.eco-distributing.com
Dometic	Hotel, RV, truck, marine	12V/24V	http://www.dometic.com/enus/Americas/USA/Start

Energy Efficiency Analysis

Refrigerator efficiency is dominated by two factors: compressor efficiency and insulation. As with air conditioners, costly off-grid power provides an incentive for energy efficiency, especially with large power users like air conditioning and refrigeration. Again, variable-speed compressors offer large energy savings, with brushless DC motors being the logical choice of driver. While limited information is available about the underlying technologies used in these products, the Sun Frost models use the Danfoss model BD35 and BD50 variable-speed compressor, depending on capacity. The combination refrigerator/freezer models use two compressors (one for the refrigeration compartment and one for the freezer), allowing each to operate at optimal efficiency.

To compare the efficiencies of AC- versus DC-powered refrigerators, data were collected from manufacturers, the U.S. Environmental Protection Agency's (EPA's) Energy Star program [17], and the California Energy Commission (CEC) [12]. For DC products the manufacturers' energy efficiency data were used. For one manufacturer (Sun Frost), data from the EPA Energy Star program were used to corroborate manufacturer claims. In general, currently marketed DC refrigerators are smaller than standard AC residential refrigerators; Figure 82 compares the efficiency of DC models only with AC models in the same capacity range, using the typical refrigerator efficiency metric of kilowatt-hours per year of operation. Only combination refrigerator/freezers, powered by either AC or DC, were selected for comparison. Based on the available data, the DC products use considerably less energy—on average less than half of the energy of their AC counterparts.

While DC refrigerators are more efficient, they are also far more costly than AC Energy Star products with similar capacities, as shown in Table 5. This is probably only in part due to the advanced technologies used to reduce their energy use. It is well known that appliances prices tend to fall with cumulative production. Given the far larger market in AC refrigerators, and hence far larger cumulative production, it is not fair to compare niche market prices with mainstream market prices. In the United States, the inflation-adjusted wholesale price of standard AC refrigerators fell by almost a factor of three in the last three decades.

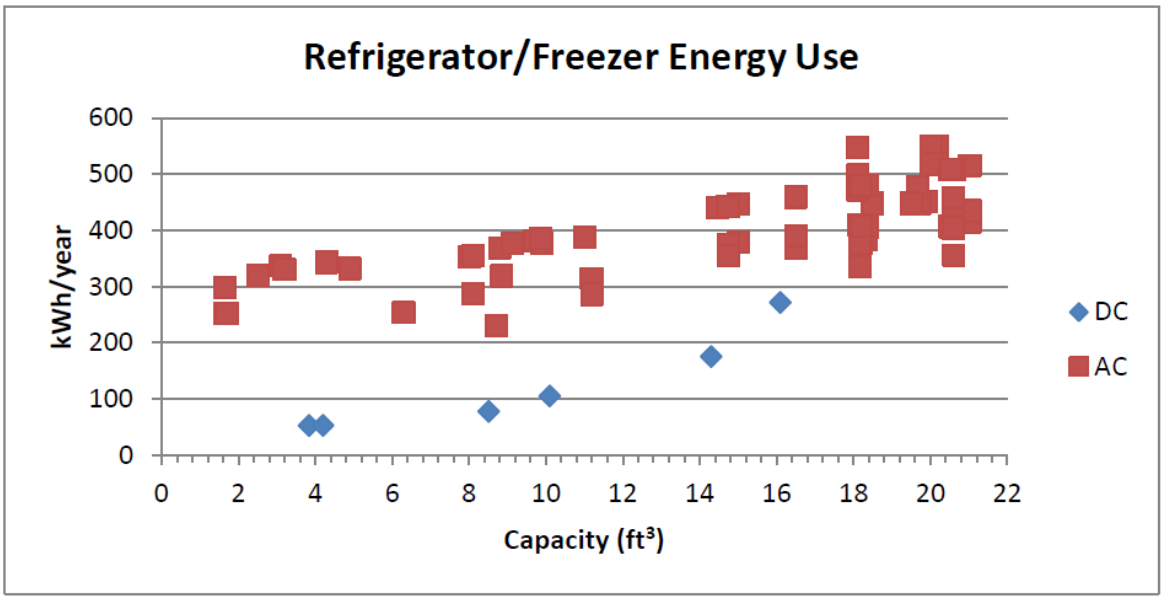

Figure 82: Energy use for DC and AC Refrigerator/Freezers

Figure 83:- DC cooling box

1.4.4 Miscellaneous DC Appliances

An assortment of other DC appliances are offered for sale on the Internet. These are dominated by 12V fans, griddles, and microwaves advertised to the automobile and RV markets. Other miscellaneous appliances include 12V blenders, heaters, and hair dryers. Most are designed to operate on car batteries.

More and more DC appliances for the off grid market are available nowadays. from (giz, 2016) prepared a very comprehensive catalogue will all DC appliances with a special focus on use DC appliance for productive use of energy.

The catalogue can be downloaded from giz:

- https://energypedia.info/images/9/98/GIZ_%282016%29_Catalogue_PV_Appliances_for_Micro_Enterprises.pdf

The catalogue contains appliances for

- Livestock breeding
  - Poultry farming
  - Milking
  - Solar Fences
- Food Production – Water Pumping
  - Surface Pumps
  - Submersible Pumps
  - Direct Drive / Pump Inverter
- Food Processing – Milling
  - Grain Mills
  - Huller, Sheller, Husker, Grater, Polisher
  - Oil-Press
- Food Storage – Cooling
  - Freezers
  - Refrigerators 1
  - Walk-in cold rooms
- Food for Sale
- Tailoring
- Workshop Tools
- Media and Entertainment
  - Secretarial Services
  - Cinema, Television and Radio
- Energy services – Charging, Metering and Measuring
- Haircutting & Other Services

Self-Check -1	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Matching from column B to column A

A	**B**
1. Refrigerator	A) home appliance used to wash laundries
2. Tea kettle	B) a device which is used to transfers heat from the inside to its external environment
3. Electric water boiler	C) a small kitchen appliance
4. Air conditioning	D) thermo pot
5. Washing machine	E) used to cool the air and to remove a moisture

Note: **Satisfactory rating - 5 points** **Unsatisfactory - below 5 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = _____

Rating: _____

Name: _____ Date: _____

Short answer question

Information Sheet-2	Differences between DC and AC appliances

2 Differences between DC and AC appliances

Current (DC), the electric charge (current) only flows in one direction. Electric charge in alternating current (AC), on the other hand, changes direction periodically. The voltage in AC circuits also periodically reverses because the current changes direction.

Table 14:-Comparisme of AC &DC

Different between AC and DC Generator	
AC	**DC**
In our Home we use AC current to provide power to all the appliance such TV,Fridge, Light etc. 	DC current is often used in charging the batteries and in all electronics system as the source of power supply 

Self-Check -2	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. What is the difference between DC and AC current, considering the flow direction of the electricity)

Answer;

Note: **Satisfactory rating - 1 points**

Unsatisfactory – below 1 points

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = _____

Rating: _____

Name: _____ Date: _____

Short answer question

Information Sheet-3	Identifying voltage, current and power ratings of AC and DC appliances

3 Identifying voltage, current and power ratings of AC and DC appliances

3.1 Energy savings

Estimated percept energy savings from switching from the standard appliance to the most efficient DC compatible appliance run on AC, and from avoided AC-DC conversion losses in the DC-appliance.

Table 15:-Energy savings AC & DC

Appliance	(A) Energy savings from switching to DC-compatible run on AC	(B) Energy Savings from avoided AC-DC power conversion losses
Lighting-Incandescent	73%	18%
Lighting-Reflector	71%	18%
Lighting-Torchiere	69%	18%
Refrigerators	53%	13%
Freezers	53%	13%
Dishwashers	51%	12%
Electric Water Heaters	50%	12%
Electric Space Heaters other than Heat Pumps	50%	12%
Spas	50%	12%
Central Air Conditioners	47%	11%
Electric Clothes Dryers	45%	11%
Room Air Conditioners	34%	11%
Furnace Fans and Boiler Circulation Pumps	30%	13%
Clothes Washers	30%	13%
Ceiling Fans	30%	13%
Electric Cooking Equipments	12%	12%
Lighting-Fluorescent	1%	18%
Home Audio	0%	21%
Personal Computers and Related	0%	20%
Rechargeable Electronics	0%	20%
DVDs/VCRs	0%	31%
Security Systems	0%	17%
Color TVs and Set-Top Boxes	0%	15%
Coffee Makers	0%	13%
Electric Other	0%	13%

3.2 Comparison Voltage between AC & DC appliance

Table 16:-Voltage Comparison AC & DC

No	Item description	AC appliance	DC appliances
1	Air conditioning	220-240v	12V, 24V,48v,
2	Electric water boiler	220-240v	12V, 24V,48v,
3	Tea kettle	220-240v	12V, 24V
4	Refrigerator	220-240v	12V, 24V
5	Washing machine	220-240v	12V, 24V,48v,
6	Dishwasher	220-240v	12V, 24V,48v,
7	Microwave oven	220-240v	24V,48v,
8	Light	220-240v	6,12V, 24V,48v,

Self-Check -3	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Matching from column B to column

Appliance		**Energy saving from switching DC compatible run on AC**
NO	**A**	**B**
1.	Freezers	A. 50%
2.	Washing machine	B. 34%
3.	Florescent lamp	C. 1%
4.	Room air conditioner	D. 30%
5.	Electric water heater	E. 53%

Note: **Satisfactory rating - 5 points**

Unsatisfactory - below 5 points

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = _____

Rating: _____

Name: _____ Date: _____

Short answer questions

List of Reference Materials

1. KhamphoneNanthavong, Promotion of the Efficient Use of Renewable Energies in Developing Countries: Photovoltaic, DGS REEPRO, 2008.
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