Solar Energy Usage at Home

EECE 492: Final Report

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ABSTRACT

"The use of solar energy has not been opened up because the oil industry does not own the sun."

~ Ralph Nader

This report investigates the applications of solar energy in buildings and households. Study of various energy sources and their impact on the environment explores the leading reasons for development of solar cells and portrays humans' thirst for more efficient technologies. After extensive literary and quantitative reviews, the values in using solar energy have been revealed.

Solar cells have been around for many years. Once the solar panels are installed on the building, the usage becomes simple. However, usage of solar energy is not limited to solar panels. Solar energy can be used to produce solar electricity, heating, cooling, and lighting. This energy source can be integrated onto the building during construction to ease the usage. This report emphasizes the main applications of solar energy at buildings and highlights the different methods to take advantage of this renewable source of energy.

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LIST OF ILLUSTRATIONS

LIST OF ABBREVIATIONS

AC.....Alternating Current

BOS.....Balance of Systems

DC.....Direct Current

PV.....photovoltaic

1.0 INTRODUCTION

Almost every aspect of people's lives involves usage of energy. As a result, humans have become thirsty for a never-ending source of energy. Upon discovery of fossil fuels, many got excited but soon the negative impacts of these sources were revealed. Oil spillages and Green House Gas emissions were and still are the major issues with this kind of energy. In addition, scientists recognized that these sources will eventually end. A new source of energy needed to be found. In 1839, Alexandre Edmond Becquerel exposed a conductive solution to light and observed the photovoltaic (PV) effect[12]. About 44 years later, Charles Fritts developed the first solar cell using selenium on a thin layer of gold to form a device with efficiency of less than 1%[2]. This invention brought hope to those searching for a never-ending source of energy. Nowadays, the Sun is knows as an ultimate source of renewable energy[13]. Due to this breakthrough, understanding the applications and usages of solar energy are essential.

This report describes the applications of solar cells in buildings. It introduces different types and mechanisms to use solar energy. The two major types of solar energy includes passive and active. Furthermore, the report illustrates the major applications of this type of energy. These applications include solar electricity, solar heating, solar cooling, and solar lighting[13].

2.0 TYPES OF SOLAR ENERGY

Solar energy is the energy of the sun. In the sun, over four million tons of Hydrogen is converted into Helium per second[13]. Given this rate, the sun is recognized to be a renewable energy source because it is predicted to provide energy for another five billion years[13]. Since the energy of the sun will last for many years, it is important to understand how to use this energy. This section describes the two main classes of solar cells, namely, active and passive solar.

2.1 Passive Solar

Passive Solar energy is using the sun's energy without the means of mechanical devices[13]. The windows, walls, and floors are designed to collect, store, and distribute solar energy. This usage includes heat, light, shading, and cooling. Passive solar is heavily based on the orientation of the building. Ideal windows for passive solar energy are those facing south. A noteworthy source of heat loss is at the top of permanently shaded glass windows[14]. Setting the top of glazing and eaves underside 50 per cent of overhang or 30 per cent of window height apart should overcome this flaw. Figure 2.1 shows this design.

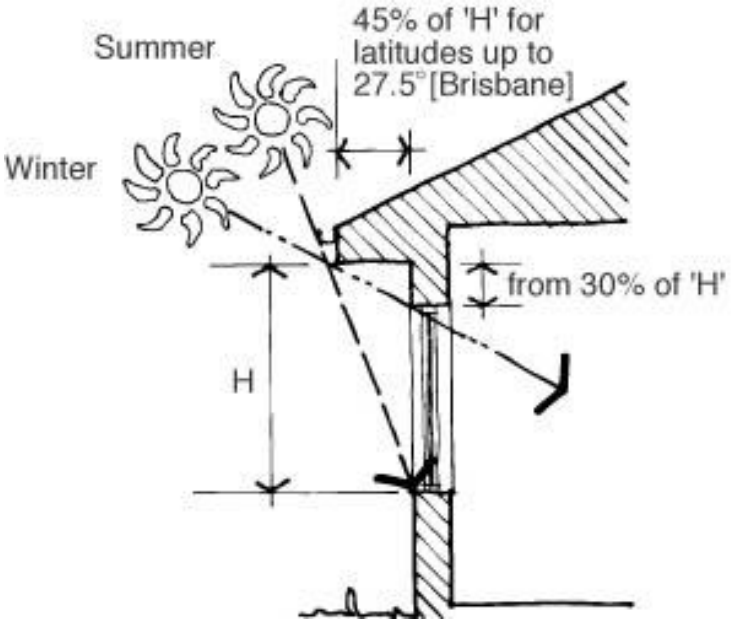

Figure 2.1: Window Orientation of a Passive Solar Home
Source: Your Home Technical Manual, 2010, <www.yourhome.gov.au>

Using south-facing windows to provide natural lighting and heat for your home are examples of passive solar energy. The number of windows is also a significant subject and depends on house location and family preferences. One should remember too many windows may make the house uncomfortably warm or too few may lead to a not warm enough temperature.

Another way of taking advantage of passive solar is designing an appropriate floor plan upon construction of the house. The living area and kitchen are the places that the families mostly hang out at; therefore, these areas are the main ones to be located along the north frontage[14]. Since bedrooms do not need as much heating, they can be placed along the south or east facade[14]. Garage, laundry room, and bathrooms require the least amount of heating. These places are best to be situated on the west or the

east facing the short side of the house and act as a buffer to hot noon sun or the cold western winds[14]. Figure 2.2 shows a picture of a passive solar home.

Figure 2.2: A Passive Solar Home
Source: Sun Plans, 2010, <sunplans.com>

The advantage of using this kind of solar energy is that costs nothing when the house is being built from scratch or going through renovations. Using passive solar energy helps a great deal with utility bills and the saved money can go towards upgrading the heat insulation system.

2.2 Active Solar

Active Solar energy is using the sun's energy with the means of mechanical devices[13]. The devices are designed to collect, store, and distribute solar energy. Solar energy can be collected using a flat-plate collector made out of an insulated glass covered box[13]. Inside the box, black absorber plates

are implemented to convert the energy from the sun into heat[13]. The solar energy can be collected once the heat is transferred to a liquid or air. This energy can be stored in tanks for liquid based systems or in rock bins for the air based systems[13]. The energy can then be distributed using pumps, radiant slabs, central forced air, or hot-water baseboards[13]. The air systems use fans to rotate the heat around. More details on both liquid and air distribution systems are provided in section 4.2. These methods of distributions are valuable to heating living spaces, providing hot water supply, and heating the pool if one is available at the house. Figure 2.3 shows a picture of the Solar House in North Carolina State University. This house integrates both passive and active solar systems[2].

Figure 2.3: Solar House in North Carolina State University
Source: Islandman: NCSU Solar House, 2011, <islandman-bruce.blogspot.ca>

The main advantage of active solar system is that it can be installed on any home despite its orientation and floor plan[13]. The heat can be distributed all around the house and reduces monthly utility payments. However, for the liquid based system, homeowners should take into account the cost of fluids and their storage in addition to material costs of the mechanical systems for implementing the active solar system.

3.0 SOLAR HOME APPARATUSES

There are many solar accessories that homeowners can obtain in order to use the sun energy. Each of these components serves a different function. This section describes several apparatuses such as solar panels, shingles, and inverters.

3.1 Solar Panels

Solar cells convert the sunlight received by them to electricity using PV effect[5]. Each cell computes just under 2W of power[13]. To facilitate a greater amount of power, multiple solar cells are required to connect to one another and form a solar panel[8]. The more solar panels installed, the more power is outputted. Merging several panels together is known as a solar array[13]. There are three major types of solar panels: Monocrystalline modules, Polycrystalline modules, and Thin-film modules[13]. Monocrystallines are built by cutting a single crystal rod of silicon into thin and fine layers to make solar cells[13]. Polycrystallines are made of several silicon crystals. This type of panels are made by melting silicon, pouring it to a mold in shape of a bar, and then slicing the cooled bar to thin layers[13]. Thin-films are made of amorphous-silicon alloys and are more flexible than the other two forms[13]. Solar inverters are described in Section 3.3 in more depth. The load is anything that uses electricity such as household lighting, fridge, dishwasher, etc.

3.2 Solar Shingles

Solar shingles act like regular shingles in terms of roof protection but add a greater value to the home. Solar shingles are more flexible than solar panels and look much more pleasing in comparison to solar panels which look like big boxes[13]. These shingles are most efficient when they are installed on the side of the building facing south[13]. However, if this is not convenient one can install them facing slightly west or east and sacrifice some efficiency[13]. The bonus to these shingles is they blend in with the conventional shingles, creating a roof that looks nice while being useful[13]. Figure 3.1 shows a picture of solar shingles. These shingles come in different shapes and colors to meet the needs of wide variety of customers.

Figure 3.1: Solar Shingles
Source: The Latest Word on Solar Roofing Tiles, 2011, <roof-contractor.org>

3.3 Solar Inverters

North American homes use 120 VAC for their electric devices. In some parts of the world such the Middle East and parts of Europe and Asia, 240 VAC is used to power devices. For solar power users, this voltage requirement needs to be met depending on their region. The function of solar inverters is to convert the direct current (DC) generated in solar panels to alternating current (AC) [13]. Furthermore, the inverters adjust the voltage to the voltage desired by the homeowner.

There are several types of inverters: Grid-Tied, Off Grid, and On/Off Grid Inverter[13]. The grid-tied inverter is directly implemented to the building electricity grid. The DC from solar panels is converted to AC and directly available at the household's breaker panel[13]. This system is simple but will fail during power outages. The off grid inverter collected the DC from the panels and stores it to batteries[13]. The inverter then converts the DC to AC from the batteries to be used at home. The benefit of this type of system is that the house is always supplied with electricity, even during utility breakouts. However, the constant storage requires high quality batteries that are often very expensive. The on/off grid is almost the merging point of the other two categories of inverters. This inverter is works in a grid-tied system with backup batteries[13]. Therefore, when electricity is available from utility companies, the system connects to the household breaker. Once the utility power fails, the backup batteries come into play and provide electricity for the household.

4.0 APPLICATIONS

Now that different types and components of solar energy usage are covered, it is worthwhile to look into the applications of this energy source in more depth. Numerous applications and design implementations have been assigned to solar energy and PV cells. This section covers four major applications of this sort of energy: electricity, heating, cooling, and lighting.

4.1 Solar Electricity

One of the main usages of solar energy is electricity. Solar power is the result of converting sunlight to electricity using PV devices. Figure 4.1 shows a diagram of how PV devices are used with balance of systems (BOS) electricity. The PV device is the solar panels. The balance of systems (BOS) includes devices between solar panels and the electric device to be powered. An example of BOS is an inverter. Solar inverters were described in Section 3.3 in more detail. The load is anything that uses electricity such as household lighting, fridge, dishwasher, etc.

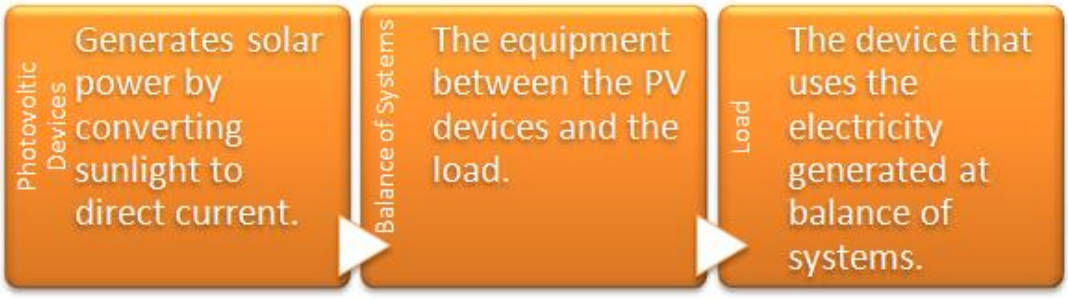

Figure 4.1: Solar Panel Functionality Diagram

Source: What is Solar Energy, 2008, <www.solar-energy-at-home.com>

4.2 Solar Heating

Solar heating can be done using both passive and active methods. These techniques both contribute to heating living spaces or household water. This section emphasizes on methods of accomplishing these means.

4.2.1 Space Heating

Passive heating is possible by correct orientation and design of the house. This type of solar energy can be stored using thermal mass[13]. Thermal mass absorbs the heat and saves it[13]. As the sun sets, this material slowly releases its saved heat energy, providing a warm house for its owners. Examples of thermal mass include concrete slabs, brick walls, and tile floors[13]. Active heating is achieved using pumps and fans. As mentioned in section 2.2, there are two methods for active heating: liquid and air.

In the liquid system, the heated fluid (usually water), is circulated by a circulating pump. Radiant Slab systems use radiant tubing embedded within a concrete slab[13]. When the system is on, the concrete radiates the heat to warm up the house[13]. The slab acts as a thermal mass so once the system is off, the concrete slowly releases the stored heat and maintains a warm temperature[13]. Another method for liquid system circulation is the Hot-Water Baseboard[13]. Such system uses but radiation and convection[13]. The hot water goes through a fin pipes and covers a larger surface area and higher efficiency[13].

The air systems can be either closed-loop or open-loop. The closed-loop system uses the air from the house, heats it, and returns it to the desired area[13]. The open-loop system uses the outdoor air and performs the same process.

4.2.2 Water Heating

The three basic steps to water heating using solar thermal energy are gathering heat in a collector, transferring the heat to water, saving the heated water until use[13].

The two types of passive solar water heating systems are thermosiphon systems and batch heaters[13]. The thermosiphon system consists of a storage tank above the collectors[13]. This system uses natural convection. Natural convection states that due to density difference, cold water sinks and warm water rises and creates a flow of water[13]. Since the tank is located above the solar collectors, when cold water sinks, it comes back to the collectors where the heat can be transferred to it. As this water warms up, it rises and creates room for the other portion of cool water and creates a loop for warm water as shown in Figure 4.2.

Figure 4.2: A Thermosiphon
Source: What is Solar Energy, 2008, <www.solar-energy-at-home.com>

The batch heater has a very simple design. It consists of a black water tank placed inside of an insulated collector box[13]. The box is covered with a glazed glass to let the sunlight hit the tank[13]. The flow of water is forced by the pressures in the household's plumbing controls[13]. Figure 4.3 shows a picture of a batch heater.

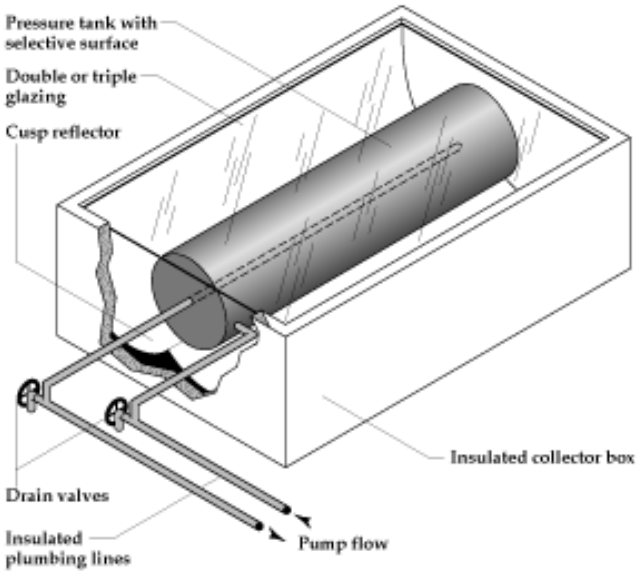

Figure 4.3: A Batch Heater

Source: What is Solar Energy, 2008, <www.solar-energy-at-home.com>

The two types of active solar energy water heating systems include closed-loop and open-loop systems. The closed-loop system, also known as the indirect system, uses a heat transfer fluid such as antifreeze[13]. The antifreeze is warmed up in the collector and pumped to a storage tank to transfer its heat to household water[13]. Figure 4.4 shows a closed-loop water heater example.

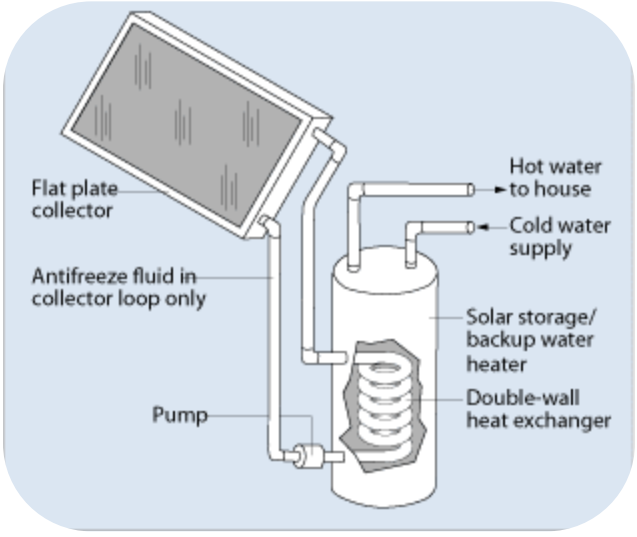

Figure 4.4: Closed-Loop Solar Water Heater

Source: What is Solar Energy, 2008, <www.solar-energy-at-home.com>

The open-loop system, also known as the direct system, heats the household water in the collector and stores it in a storage tank[13]. The warm water is piped to the house for usage[13].

4.3 Solar Cooling

Passive Solar Cooling is done by designing the house in a way that the amount of sunlight received is minimized during hot summers[13]. It can also be achieved by proper shading elements and natural ventilation[13]. Figure 4.5 shows an example of such orientation.

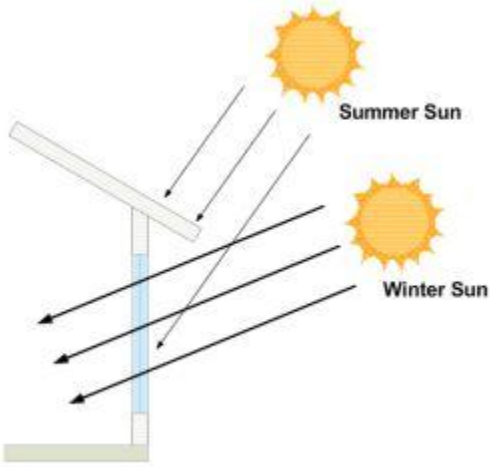

Figure 4.5: Passive Solar Cooling Demonstration
Source: What is Solar Energy, 2008, <www.solar-energy-at-home.com>

Two major type of active solar cooling includes Solar Absorption Cooling and Solar Desiccant Cooling. The Solar Absorption Cooling uses heated water to run an air conditioner[13]. Solar heat is used to separate absorbents and refrigerants from one another in the air conditioner[13]. Next, the refrigerant is compacted and evaporated to create a cooling effect[13]. Solar Desiccant disposes of moisture in the air by passing air through the desiccant

material. The desiccant will absorb the moisture until it is soaked and loses its ability to absorb any more moisture[13]. Then, the solar heat evaporates that wetness into outside air and the cycle continues. The continuation is because the level of moisture goes up again and the desiccant will get soaked.

4.4 Solar Lighting

Solar lighting can be used for outdoor purposes or day lighting. The outdoor solar lighting uses PV power to convert solar to electricity. These lights store energy during the day and use it at night. They can provide lighting for gardens, pathways, driveways, and patios as well as Christmas lighting and mission solar lighting[13]. Figure 4.6 shows several examples of these lightings. The day lighting is a passive type of lighting and can be achieved by correct window arrangements.

Figure 4.6: Solar Lighting Examples

Source: Solar Garden Lights Illuminate Your Garden or Deck, 2012, <ecologicearth.net>

Source: Solar Light|Solar Light with Motion Sensor|Solar Security Light, 2010, <diyshop.com>

Source: Make Your Deck the Safe Place for Neighborhood Fun, 2012, <mylifeonthedeck.com>

5.0 CONCLUSION

After extensive research, it can be concluded that solar energy is a useful source of renewable energy. With many components and applications available, there is no excuse to avoid using this ultimate energy source. Energy can take on different forms. PV devices make it easy to transform the solar energy to electricity. Moreover, solar energy is also available to provide heating, cooling, and lighting.

This report discussed the two types of solar energy, passive and active. Each of these types contributes differently to electricity, heating, cooling, and lighting. Passive solar energy is based mainly on house orientation plan whereas the active solar energy relies on the components installed to and within it. All these applications were developed to make our planet a better place. These applications are growing and each day innovators are working on expanding these functions. Solar power is becoming very popular and may one day completely replace other sources of energy and make our planet a greener and healthier one.

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