LIFE CYCLE COSTING OF ACTIVE AND PASSIVE SOLAR RETROFITS

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
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To everybody who said go one more round

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Generally relatively low energy costs have allowed home owners to consume energy without great concern. Given current electricity generation, consuming more electricity means that more CO_2 is emitted in the atmosphere. Educating homeowners, combined with behavioral change and inexpensive upgrades, could reduce annual electrical consumption, and as a result, less CO_2 would be emitted. Reducing electricity consumption would also allow for solar electric generation to become economically feasible, which would further reduce CO_2 from electricity generation.

The reduction of energy would come from a template, beginning with a behavioral change and ending with efficiency upgrades. The template, a didactic tool, breaks down the existing consumption, suggests reduction strategies and then compares existing to a new estimated consumption.

Solar electric without reducing consumption is not economically feasible at this time. The feasibility of a solar system depends on the initial cost, the utility rate per kilowatt hour (kWh), and electrical use. An analysis using life cycle costing (LCC) examined the consumption to determine the optimum size and cost of the solar electric system. Having a production equal to consumption means the home is a net zero energy home (NZEH).

CHAPTER 1
INTRODUCTION

Statement of Purpose

Active and passive solar systems are becoming more common in new construction. However, the majority of existing buildings also are consuming electricity; making it necessary to retrofit these buildings to consume less and produce more. Generally, new buildings, commercial and residential, consume less electricity per square foot (SF), so without retrofitting existing buildings, overall consumption will stay the same. Retrofitting existing construction with solar technologies is a way to reduce consumption as well as potentially preventing demolition for new construction.

Objective of the Study

The objective of this study is to develop a methodology and an LCC model that can be used to examine the feasibility of solar technologies in existing homes. The methodology examines home features and electricity use and uses LCC to estimate feasibility.

CHAPTER 2
LITERATURE REVIEW

New Age of Photo

Solar-generated electricity represents a small fraction of the power consumed in U.S. households. Most homes that use solar-generated electricity are tied to the local utility, usually generating some but not all of the electricity the home consumes

(Gibson 57).

The current dominant photovoltaic (PV) technology is crystalline silicon in various forms that produce an electrical current when exposed to sunlight. PV arrays consist of panels made of silicon wafers, or thin film amorphous silicon. Thin film technology is available in flat panels, roofing slates, and flexible sheets that can be applied to metal roofing (Gibson 56). For the panels to receive the optimum sun-light in the Northern Hemisphere, it is important to face them south or west of south (Gibson 58). It is also important to elevate the panels toward the sun because the panels are then exposed to the maximum amount of light from the sun on the days where it is lowest in the sky. A rule of thumb is that the degrees of elevation equal the location's latitude. They may also be mounted on a tilt or tracking system that follows the sun, which maximizes solar exposure but also adds to the cost and complexity of the installation. A battery backup bank for a grid tied system will also add to the cost of installation. The battery bank typically adds 40% to the initial cost, and is only needed during a utility interruption, or when the home is off the grid (Lane personal communication). In a grid-tied system without a battery back-up, utility supplied electricity stops during a power interruption. With a battery back up system, the home can run normally when the grid is down. The duration of battery life is dependant upon the electrical demand, the size of the back-up system, and the solar conditions.

A silicon cell, or wafer, is a device with no moving parts that generates electricity directly from sunlight. When sun-light strikes silicon cells, electrons break free to create electrical current. Silicon is made into solar cells in several ways. The two most common are crystalline silicon sliced into thin wafers, and the other is an amorphous film. The wafers are set into a glass and polymer sandwich, and the amorphous film (thin film) is applied to a substrate such as wood or metal (Gibson 57). The highest efficiencies come from monocrystalline silicon, which is silicon sliced from a single grown crystal. The efficiency of monocrystalline silicon is 18% or higher depending on the way it is set into the module. The efficiency of most cells is in the mid-teens, and the efficiency of thin-films is lower, generally 10% or less. Researchers and developers say that 40% efficient silicon cells can be produced; however, they are not feasible for mass production (Gibson 58). The greater the efficiency, the less square footage is required for cells to produce electricity.

Solar cell output is measured in Watts (W), and panels are rated by their output. Sunlight's energy intensity is 1kW/m^2 or 1,000W/m^2 when it strikes a surface on Earth. A panel rated 18% efficient, means that its output is 180W/m^2 or 18% of 1kW/m^2 or 1000W/m^2. Most panels, or modules, are 1.15 m^2, so an 18% efficient panel of that size would have a rated output of 207W.

It is important to know the consumption of the home in kWh, as this will dictate the size of the solar electric system. For example, if a household uses 600 kWh of electricity for a 30 day month, then the average consumption per day is about 20 kWh. With an average of 5 sun hours per day, that equates to a 4 kW solar electric system: The 20kWh is divided by 5 sun hours = 4kW. So if a 2 kW system were installed it would offset the electric bill by approximately 50%. A solar electric system's size is always described by the kW output (Merry and Masia 16).

In the article, *The New Age of Photo,* it was stated that during the 1970s and ‘80s most of the residential solar electric systems were off-grid, stand alone systems (Gibson 58). From 2002 – 2007, grid-tied systems have been installed at an increasing rate. These systems are connected to the local utility and use net metering. Net metering is a system where the electricity is bought and sold between the homeowner and the utility company at the same rate (Gibson 58).

According to Gibson, reducing the demand for electricity is important because of the high initial cost of a PV system. It is less expensive to spend money on reducing kWh of consumption than it is to spend money on a PV system to produce the amount of electricity needed for the current demand (Gibson 62). There are different alternatives and methods to accomplish this. The first method deals with a change in behavior. Jason Fults from Drops and Watts stated that energy consumption can be reduced 5–10% with a change in behavior. This means spending no money to save money. The change may include turning off all lights and televisions that might be on during the day or night, and unplugging appliances and electronics that have a phantom load. A phantom load occurs when an appliance or piece of electronic is not in the “on” position, but it may have a lighted clock or button that needs a small amount of electricity to run. Washing your clothes with cold water and hang drying them will save electricity. One way to reduce consumption without a change in behavior is to replace incandescent light bulbs in the house with compact fluorescent lamps (CFL’s). According to Energy Star, a typical CFL uses about 78% less Watts to produce the same amount of lumens that an incandescent light bulb does, and they produce about 75% less heat. This is possible because a CFL contains its own ballast. The heat factor can pose a problem in the summer time. Also these lamps last up to 10 times longer than incandescent bulbs (Lighting). For example, a

13W CFL produces the same light as a 60W incandescent bulb. This means that more CFL bulbs can be used and still have less consumption than one incandescent bulb.

Energy Star appliances are also important in reducing consumption without changing behavior. Household appliances that have been rated by the U.S. Department of Energy include: refrigerators, dishwashers, washing machines, hot water heaters, and televisions (Home). There are more household items that have been rated; however, these are the appliances that consume the most electricity. Consumption with respect to some of the appliances depends on behavior, such as how often an appliance is used or if the appliance is used at all.

An Energy Star refrigerator uses roughly 20% less electricity than the minimum standard refrigerator and 40% less than refrigerators from 2001. Their consumption ranges from 300kWh to 750 kWh annually (Refrigerators). Consumption can be reduced by 41% by replacing an older dishwasher with an Energy Star rated dishwasher. Also, less water is used to wash the dishes, so water consumption is reduced (Dishwashers). A major appliance that uses less water is an Energy Star clothes washing machine. Consumption ranges from 113 kWh to 408 kWh annually. These numbers are based on 400 loads of laundry per year (Clothes Washers). Television (TV) consumption depends on the number of televisions in the home and the number of hours they are turned on. Energy Star approved televisions use 30% less electricity in the on position than standard TVs.   Energy Star rated TVs range from 20 Watts in the “on” position to 400 Watts. This range equates to 0.02 kW and 0.4 kW per hour respectively. The phantom consumption for standby mode ranges from 0.000012 kW to 0.001 kW. If the lowest consuming television was plugged in and left in standby mode all year, it would consume 0.105 kWh, and the highest standby would consume 8.76 kWh (Televisions). Also, TVs produce heat, causing a cooling load on the space. This may affect the thermostat depending on how close the thermostat is to the TV. Stoves are not Energy Star rated so behavior is the key to reduction. Ranges and cook tops can be fueled with natural gas.

Solar Today

According to Solar Today Magazine, the first efficient solar water heating system was invented in 1891 by Clarence Kemp. The system was built as a network of pipes painted black and placed within an insulated box. The pipes were then covered with a piece of clear glass. A solar hot water system is roughly 20% less expensive to operate than a gas water heater, and it is 40% less expensive to operate than an electric water heater (Young, Merry, Masia 12). Depending on fuel prices, the cost of the solar hot water system becomes either more or less feasible. The price of the solar thermal system depends on two main factors: the size and climate. The size is dependant upon the number of people using water, and how often hot water is needed. A larger system will be needed for a family of 4 that uses hot water for dish and clothes washing, and bathing than a household of 4 that uses hot water for dish washing, but washes all clothes on the cold cycle. The less hot water used, the smaller and more inexpensive the system. There are two types of solar hot water systems: passive and active (Merry and Masia). In warm climates a passive system will suffice, but in colder climates an active system is needed to keep the water drained back during times of the day when temperatures are low. Passive systems are preferred because of their lack of moving parts to maintain, and the lack of a heat transfer fluid. In active systems, the water is drained down into the house, where the temperature is warmer, when the temperature drops below a predetermined minimum; or an environmentally friendly anti-freeze is used to keep the heat transfer fluid from freezing. Cold weather systems require the use of temperature sensors, electric pumps, and automatic control systems. This adds to the cost and complexity of the installation (Young, Merry, Masia 12).

Passive Water Heating Systems

Passive systems are installed in areas where freezing is a little or no issue. The most common types of passive systems are integral collector storage (ICS) and thermosiphon systems. There are no pumps required for this system. Evacuated tubes are also a passive solar water heating system (Young, Merry, Masia 12).

Integral Collector Storage

In an ICS system, water flows up to the roof, using water pressure and into the collector. The collector holds between 30 and 50 gallons of water. If the water is being drawn from the water heater below, the water flows from the collector to the heater and waits for use (Young, Merry, Masia 12). If water is not being drawn from the water heater, then the water stays in the collector on the roof until the water is needed. In a passive system the sun either pre-heats the water or heats the water to a desired temperature taking the load off the water heater. Figure 2-1 shows the cold water supply line routed up to the solar hot water system, where the water temperature increases. Once there is a hot water demand, the water flows down into the hot water tank and from there to the water outlets. ICS systems are similar to thermosiphon solar units in that they can heat water passively without pumps or controller systems. ICS systems offer a low cost system with no maintenance, no moving parts, and zero operational costs (Lane 102).

Thermosiphon System

A thermosiphon system uses the idea that water rises as it is heated. This system uses a flat plate collector. According to *"Solar Water Heating, Take the load off your water heater"*, in this system, water rises as it is heated and flows to the top of the collector, and then to the top of an insulated tank. Colder water at the bottom of this tank is drawn into the lower supply of the solar collector. Water then flows in a continuous loop, continually reheated during the daylight hours (Young, Merry, Masia 12). When a hot water tap is opened in the house, water flows from the top of the storage tank and is replaced with cold water flowing into the bottom of the storage tank. The drawback to a thermosiphon system is that the heavy storage tank is put high on the roof requiring extra structural support. Other solar water heating systems have the storage tank at ground level or in the basement, requiring no additional structural support (Young, Merry, Masia 12).

The thermosiphon and ICS systems can be used in cooler climates if they're converted to a drain-down configuration. When temperatures drop to near freezing, valves open to drain the collector, often into a weather-protected indoor storage tank. When temperatures rise again, the collector system is refilled, either from water pressure or by using an electric pump to push water back up from the indoor storage tank. Because of the automatic control systems, drain-downs are considered active rather than passive (Young, Merry, Masia 14).

Evacuated Tubes

An evacuated tube system is more expensive than other passive systems, but it is also much more efficient, so it takes less space on the roof (Young, Merry, Masia 14). Heat from the sun is collected in double-walled glass tubes that are arranged with one end higher than the other. Each tube is built like a thermos bottle with a vacuum between the walls. In the center of the tube is a copper pipe containing propylene glycol, which is a nonpoisonous anti-freeze. The outside of the glass remains cool to the touch, but inside the copper pipe turns hot and the glycol boils. Steam then rises to the top of the pipe, where it heats water in a manifold. The water circulates back to a heat exchanger in a hot water storage tank in the home. Once the steam condenses it flows to the bottom of the tube completing the loop. These systems work in both warm and cold climates (Young, Merry, Masia 14).

Active Solar Water-Heating Systems

Active systems use electric pumps to circulate water through the collectors. In warm climates, a direct or open-loop system is practical (Young, Merry, Masia 14). The two differences between a passive system and a direct system are how the water enters the storage tank and the pump. Water goes into an insulated storage tank, and a pump draws water out of the storage tank to pass through the solar collector and then the water returns to the storage tank. Hot water for household use is drawn from the top of the storage tank. An automatic control system starts the pump whatever the collector is warmer than the storage tank (Young, Merry, Masia 14).

In colder climates, the most common system is the closed-loop anti-freeze heat-exchanger system or active indirect system. When the collector is warm, a propylene glycol antifreeze solution is pumped through the collector at one end and through a heat exchanger in the hot water storage tank at the other. The heat exchanger heats potable water for domestic use. The heat exchanger is usually located at the bottom of an insulated storage tank. Sometimes the storage tank is also the home water heater, with an electric or natural gas heating mechanism for use when the collector is cold. The anti-freeze solution is food safe because if there is ever a leak in the heat exchanger, antifreeze would contaminate the drinking water (Young, Merry, Masia 14).

Efficiency Upgrades

The cheapest and easiest way to see dramatic energy savings is through efficiency upgrades. Summer and winter, the typical home wastes energy in several ways, including: inefficient bulbs; inefficient water-heating systems; inefficient heating and air-conditioning systems; air infiltration through the envelope including: ceilings and roof, windows, outside walls, doors, floors and foundation, soffits, flashing, and other joints (Masia 24).

Lighting

An effective way to reduce an electric bill is by replacing incandescent light bulbs that are used for lighting. Incandescent bulbs waste about 95% of their energy as heat. A 100 W bulb generates as much heat as an electrically heated dipstick designed to keep a V-8 engine warm in cold climates (Masia 24). Incandescent bulbs are so wasteful that federal law will ban their sale after 2013. Assume that a home burns (6) 75W bulbs for 6 hours each night. The yearly consumption of the bulbs would be 985.5kWh. With an electric rate of $0.125/kWh, the cost would be $123.19. If these bulbs were replaced with (6) 23W CFLs with the same lumen output for the same six hours each night, the consumption would be reduced to 302.22 kWh. Assuming the same rate of $0.125/kWh, the new cost would be $37.77. Converting to CFLs would also eliminate 360 W of heat from the house per night (Masia 24). This helps in the summer time in the south when cooling the house is a priority.

Appliances

One way to determine the consumption of the appliances is to use a meter that shows the consumption of whatever appliance it is plugged into. KILL A WATT is a power meter that displays the consumption of appliances that can be plugged into 110V outlets. With the information displayed, the homeowner can determine the appliances consumption, and then determine if methods of use and/or the appliances themselves need to be changed (New 30).

Large appliances can also consume a lot of energy, especially if they run frequently. A refrigerator is an example of an appliance that runs frequently. Older refrigerators should be replaced. Computers and televisions can draw 5 to 10 Watts continually even when shutdown, unless the plug is pulled or there is a switch to cut off the power supply (Masia 24). A possible solution is a switchable power strip or a switch controlled outlet. A television along with a cable box can consume on average 310 W while in the on position. This equates to 0.31kW/hour. An electric water heater can draw 2,500 Watts. This means that a water heater recycling hot water can consume 2.5kW/hour. One method that can be practiced, besides reducing hot water use is turning down the thermostat on the hot water heater to 122°F (50°C). Also, insulated pipes help the hot water heater run more efficiently, along with using low flow water fixtures including but not limited to: water faucets, toilets, showerheads (Masia 24). Alternative measures to these methods are to shut off the hot water heater when not in use using a timer or a switch.

HVAC (Heating Ventilation and Air Conditioning)

As with making sure the hot water heater is running as efficient as possible, it is important the HVAC run as efficient as possible to ensure low consumption and costs. Methods such as changing the air filter quarterly, cleaning and sealing the air ducts, and making sure ducts are properly insulated will improve system efficiency. The system should be designed to heat or cool re-circulated air from inside the house. If the air ducts are in the attic, it is important to make sure the attic is sealed and insulated, or ventilated to keep the space cool during the summer months and warm during the winter months (Masia 24). Also replacing the heating and cooling compressor and fan coil with a more energy efficient unit is another action that can be taken, but it is more expensive. Replacing the unit may be considered early on in the process of making the home more energy efficient, if it is more than five years old.

Blower Door Test

According to Energy Efficiency and Renewable Energy (EERE) a blower door test uses a powerful fan that mounts into the frame of an exterior door. The fan pulls air out of the house, lowering the air pressure inside. The higher outside air pressure then flows in through all unsealed cracks and openings. The auditors may use a smoke pencil to detect air leaks. These tests determine the air infiltration rate of a building. Blower doors consist of a frame and flexible panel that fit in a doorway, a variable-speed fan, a pressure gauge to measure the pressure differences inside and outside the home, and an airflow manometer and hoses for measuring airflow. There are two types of blower doors: calibrated and un-calibrated. It is important that auditors use a calibrated door. This type of blower door has several gauges that measure the amount of air pulled out of the house by the fan. Un-calibrated blower doors can only locate leaks in homes. They provide no method for determining the overall tightness of a building. The calibrated blower door's data allow the auditor to quantify the amount of air leakage and, after air sealing, test its effectiveness. There are four steps to prepare for a blower door test. These steps include: close windows and open interior doors; turn down the thermostats on heaters and water heaters; cover ashes in wood stoves and fireplaces with damp newspapers; shut fireplace dampers, fireplace doors, and wood stove air intakes (Blower).

By performing a home energy audit and/or a blower door test; it may be determined that replacing older windows and doors, and insulating the attic and floors, for more than one story, are important. These upgrades can be costly but in the long run they are considered a good investment over the lifecycle of those upgrades.

Working with a Solar Installer

There are some important points to consider when deciding on a solar contractor. The first point to consider is the experience and certification of the installer (Hall 26). An examination of the track record of successful installations and satisfied customers is an area to look at along with knowing if the installer is certified by the North American Board of Certified Energy Practitioners (NAB-CEP) or by the state board. Some other things to consider are the ability to finance, file paperwork for permits and incentives and measure system performance, follow building codes with regards to installation and roof integrity, and safety procedures as specified by OSHA (Hall 26). One more thing to consider is the contractor's follow-up service record. This information can be found by checking references, this means calling past customers, and finding out whether the schedules were met and problems were solved (Hall 26). When a contractor comes for a consultation they will evaluate the home's power needs. Historical data will be looked at to determine the size of the solar electric system needed as well as the size of the roof or land where the system can be mounted. In the instance of a roof mounted system, the direction of the roof becomes important as does the age and condition of the roof. For example, if the roof is 15 years old the homeowner might want to consider a ground mounted system, or find out how much it will be to temporarily remove the solar panels to replace the roof, when needed. Shading of the roof or ground can be determined by using satellite photos or devices such as a Solar Pathfinder to see where and what time of year or day the proposed area will be shaded, if at all. It is important to read the contract. Within the contract, the total price should be specified, including how and when incentive payments will be credited, and the payment schedule and warranty terms of products and services need to be reviewed. The installation of a solar electric system should take from 2 to 3 days. The installation is not considered complete until it is tested and shown to meet the power production specifications of the panels (Hall 27).

Solar Energy Tour

As part of the part of the research, a solar energy home tour was attended. This was an opportunity to speak to local solar installers as well as homeowners who had PV and solar thermal installed on their homes. Literature was obtained as well and systems were discussed with two installers and one homeowner. The tour was held on October 18th 2008. Among the homes on the tour was the Dickenson Residence. They had recently installed a PV system with a solar thermal collector. Mrs. Dickenson was asked about the historical consumption compared to the present consumption. The historical electrical bills were available for viewing. The solar electric system did not produce the electricity equal to their annual consumption, because according to Mrs. Dickinson, the home has frequent guests. Not all PV systems are installed to make the house a net zero energy home. With the PV and solar thermal systems the Dickenson residence had an average bill of $57.00 (Dickinson). The $57.00 was lower than the electric bills prior to installing the system. The home was also equipped with 12 batteries, which allowed for on-site storage. As stated in the literature review, this allows for the home to run when the grid utility is down. ECS-Solar installed the system in 2007. There were 4 other homes on the tour that were not visited, but information on installed system sizes was obtained. Figure 2-1 is of the south facing roof of the Dickenson residence.

Figure 2-2. Dickenson PV and Solar Thermal System

The system has 28 200W SunPower PV Modules and a flat plat solar thermal collector. As is shown in the photographs, there is some shading from the tress to the south and west of the home. These photos were taken at 6:00 pm.

Rebates, Costs, and Paybacks

Andy Black says in an article titled, *Does it pay?,* that one of the most important things to consider when retrofitting a home with an active and passive solar system is the payback period. There are many factors that affect this answer. The factors include: local climate, utility rates, and incentives. In states where there are many sun hours/year and high utility rates, the payback period will be shorter, than states with few sun hours/year and low utility rates. Besides high electric rates and ample sun hours, other important factors for making solar an attractive investment include financial incentives and net-metering policies (Black 28). Ample sunlight is available in almost all of the lower 48 states. Where net metering laws exist, the solar energy produced offsets the cost of the electricity consumed. In some regions, solar systems are allowed to operate on a time-of-use rate schedule. This enables the users to sell back electricity to the utility at peak rates, which can be even more valuable. Time-of-use rates vary in electricity price based on the time of day, the time when there is great demand for electric. Solar electric systems tend to produce electricity during these higher rate periods (Black 28).

Direct Incentives

There are 4 major incentives for the city of Gainesville, Florida. The first is a federal tax credit for solar electric systems that went into effect January 1, 2006. The credit is for 30% of the system cost up to $2000 for residential systems. For PV systems, that typically means a $2000 credit on the purchaser's tax return for the year the system is installed (Black 28). The second incentive is the state of Florida rebate. This rebate is $4.00/W, up to $20,000 (Rolland Oct. 14, 5A). The total amount of state funding is limited, however, and the current waiting time for the rebate is one year. Depending on when the solar electric system is installed, there may be no state rebate funds available. The money for the rebate will be renewed by the state until the summer of 2011 (Jacobson personal communication). There are incentives that are from the city of Gainesville, Florida. Gainesville Regional Utility (GRU), a city-owned utility company is offering a $1.50/W rebate up to $7,500. With the $1.50/W rebate, the home is on net metering (Rolland Oct. 14, 5A). The second is a Feed-in-Tariff (FIT) that will pay the homeowner $0.32 per kilowatt hour (kWh). This FIT was implemented March 2009 (Rolland 1B Dec. 19, 1B). The homeowner can either use the FIT or the rebate with the purchase of the solar electric system but not both. With the FIT there are 2 meters. One of the meters measures electricity use in the home and the other meter measures PV output to the utility. Under the FIT the electricity produced by the PV panels is sold directly back to the utility, and does not power the house (Fults).

Feed In Tariff

Below are a series of articles on the FIT that ran from October 2008 – March 2009. The articles discuss the history of the FIT and the discussions of how it will be implemented in Gainesville. The discussions range from the sizes per year to the rate at which GRU will pay for the production.

October 14, 2008

In an article in the Gainesville Sun, the (FIT) is mentioned as part of a plan to encourage solar energy production. According to the article it is the first of its kind in North America. The FIT was first introduced in Germany, and Ed Regan, assistant general manager of Gainesville Regional Utility (GRU), discovered the incentive on a fact finding trip to Germany. GRU would buy all the energy produced by a PV system over the next 20 years at a guaranteed rate/kWh. With the implementation of the FIT, both net metering and the cash rebate will be eliminated. According to Regan the price has been calculated using the cost of the panel and the cost of maintenance and repair over 20 years. According to Regan, "You are allowed to beat the game, and a more efficient system would produce more energy and make more money (Rolland Oct. 14, 5A)."

November 20, 2008

"Is solar the right fit?" is the title of the front page article in the Gainesville Sun. The article states that this afternoon the city commissioners will vote on the FIT. "If the Gainesville FIT model works, there is a high chance that other cities will follow in adopting this policy – which would then lead to a breakthrough in the U.S. This was a statement from Bianca Barth, a climate policy officer with the World Future Council. Although California and Michigan have

FIT, they are considered watered down versions of the German model. With the Gainesville proposal, there are no bounds on the size of the system. According to the article, Ken McGurn, who recently installed 97 kW of PV on the top of the Sun Center downtown, says a $0.26/kWh will not be profitable compared to the current rebate of $1.50/W. Barry Jacobson states in the article that, if the price of the FIT is not increased from the proposed $0.26/kWh, it will not be worth installing PV (Rolland Nov. 20, 1A).

November 21, 2008

"GRU solar plan given city approval" is the title of an article that states that the city commissioners voted to adopt the FIT. All 5 members voted to allow the plan. The rate is still not agreed upon as stakeholders disagree on what a profitable rate is. According to the article, commissioners will have to vote at least two more times before the issue is decided. With this acceptance, the rate as of right now is $0.26/kWh which would yield an 11% return on investment. However, Barry Jacobson says that the price would need to be around $0.31/kWh to make a good return on investment. He further states that these numbers are speculative because they are based on future energy costs (Rolland Nov. 21).

December 19, 2008

In an article titled "City OKs higher buyback rate in solar program" it is stated that the higher buyback is $0.32/kWh of electricity produced. GRU had originally planned to pay its providers $0.26/kWh, but raised that rate with a unanimous vote by Gainesville city commissioners. This rate will be paid by Gainesville Regional Utility (GRU) for a period of 20 years. The original rate would have provided a rate of return of 5.87% for larger systems and only a 0.67% return for smaller systems. According to Ed Regan of GRU, "that is not a good investment at all". He went on to say further that $0.32/kWh would provide a 2.93% return on investment and up to 5% for more efficient or less expensive systems. The expense of the program will be passed on through the fuel tax exempt portion of the utility bills. The expected increase is $0.42 per bill (Rolland Dec. 19).

Along with rebates and the FIT, there are ways to measure economic value of the solar electric system. Among these are compound annual rate of return, cash flow, and increase in property resale value. Compound annual rate of return is another term for interest rate yield; which is a way of comparing one investment to another. For example, a savings account might pay 1% interest, and a long-term stock market has historically paid about 10.5%. The cash flow will be positive, either immediately or within a few years (Black 28). Many homeowners finance their solar systems using home-equity loans. The cash-flow calculation compares the savings on the electric bill to the initial cost of the loan. The interest for this loan is tax deductible, meaning the loan costs less. Home equity loans are also excellent sources of funds because interest rates on real estate-secured loans are relatively low and payment terms can be long. Inflation affects rates and thus effectively increases the savings from a generating system over time. However, according to Andy Black, "inflation doesn't affect loan rates, particularly with fixed-rate loans (Black 28)." This means as electric rates rise, the savings grow, but the cost of the loan stays relatively constant. As previously mentioned with the installation of a solar electric system comes an increase in property resale value (Black 28). This occurs because solar electric systems produce electricity making utility costs lower or non existent.

Increase in Equity

According to a 1998 article in *Appraisal Journal*, Rick Nevin and Gregory Watson say a home's value increases $20,000 for every $1000 reduction in annual operating costs from either energy efficiency or energy production (Black 28). They say, "The rationale is that the money from the reduction in utility bills can be spent on a larger mortgage with no net change in the monthly cost of ownership. Nevin and Watson calculate that historic mortgage costs have an after-tax effective rate of about 5%. If $1,000 of reduced operating costs is put toward debt service at 5% it can support an additional $20,000 of debt (Black)." According to this article, solar electric systems appreciate over time, rather than depreciate as they age. Nevin and Watson say that this is because of the increasing annual savings as electric rates rise. Furthermore, if electric rate inflation averages 5%, property resale value will increase 5% per year compounded (Black).

Paying for the Electric System

The cost of a PV system depends mainly on the size of the system in terms of the number of Watts of power the panels can produce. One thing to consider for system size and install is economies of scale. A large system may cost less per Watt than a small system. According to Claudia Eyzaguirre of Solar Today, the average system is installed for $8.00 - $10.00 per Watt (Eyzaguirre). Barry Jacobson, Vice-President of Solar Impact of Gainesville, FL, installs solar electric systems for $6.50/Watt (Jacobson). In an interview, he stated that this is possible because roofing and electrical contractors can do the installation, not just solar contractors. He also stated that the components are purchased for $4.00/W; there is a $2.00/W charge for the company, and a $0.50/W charge for the actual installation of the system. Solar Impact assists in filling out the proper rebate forms, as well as, pulling the proper permits (Jacobson). At a cost of $6.50/W and deducting the state and local rebates, a system can be installed for $1.00 per Watt. For the average installation price of $9.00 per Watt, the net initial cost would be $4.50/Watt after rebates.

According to Shawn Lorenz, ECS-Solar installs solar electric for $9.80/W. This is above the average and will add $4,000 to the average install price. This will make the net initial cost $21,500 for a 5kW system. Table 1-1 shows the difference in before and after rebate costs for the 3 install prices: Solar Impact, ECS-Solar, and the national average. The price shown in the table is for a 5 kW system because that is the maximum size that the current state and local rebates will pay for.

Table 1-1. Cost of a 5 kW System Before and After Rebates

Size in kW	Cost/Watt	Cost/kW	Cost/System	State Rebate	Local Rebate	Initial Cost
5	$ 6.50	$ 6,500.00	$ 32,500.00	$ 20,000.00	$ 7,500.00	$ 5,000.00
5	$ 9.00	$ 9,000.00	$ 45,000.00	$ 20,000.00	$ 7,500.00	$ 17,500.00
5	$ 9.80	$ 9,800.00	$ 49,000.00	$ 20,000.00	$ 7,500.00	$ 21,500.00

The differences in the costs before and after the rebates are significant even though the net difference is $2.50/W between Solar Impact and the national average, and $3.30/W between Solar Impact and ECS-Solar. The difference in the installed costs is $12,500.

Life Cycle Costing

According to Alphonse Dell'Isola, "life cycle costing (LCC) is the process of making an economic assessment of an item, area, system, or facility by considering significant costs of ownership over an economic life, expressed in terms of equivalent costs (Dell'Isola 111)." The purpose of LCC is to analyze equivalent costs of various alternative proposals. To make sure of this, the baseline used for the initial costs need to be the same as that used for all other costs; this includes maintenance, operating, repair and replacement, and salvage value. LCC is used to compare the alternatives by identifying and assessing economic impacts over the installed or design life of the alternatives. In order to make an educated decision the present and future costs need to be taken into account. According to Dell'Isola, "today's dollar is not equal to tomorrow's dollar. For example: $100 today at 10% interest is worth $673 in 20 years. The end number changes depending on the length of the term and the interest rate. Constant dollars must be used due to the fact that an LCC analysis uses various costs at different times (Dell'Isola 111).

The history of life cycle costing dates back to the energy crisis in the United States (Dell'Isola 111). LCC's are used to lower energy consumptions by utilizing the annual energy costs, and equating the impact against the initial costs. To compare these alternatives, equations and tables are used. Again the figures in the tables must have a common point in time. These costs are calculated by using the present worth method (PW). There are 2 PW equations that take future costs and convert them to present costs (Dell'Isola 115-116).

$$PWA = \frac{A(1+i)^n - 1}{i(1+i)^n} \tag{2-1}$$

i= interest rate period
n= number of interest periods
P= present sum of money
A= end of period payment or receipt in a uniform series continuing for the coming "n" periods, entire series equivalent to "P" at interest rate "i"
PWA = present worth of an annuity factor

$$PW = \frac{F}{(1+i)^n} \tag{2-2}$$

F= sum of money at the end of "n"
PW = present worth factor
n= number of interest periods
i= interest rate period

Equation 2-2 is referred to as the Single Present Value (SPV). It is the SPV that is used to calculate future costs, back to present worth. The sum from Equation 2-3 is then used to determine the LCC of the alternative. The LCC of an alternative includes the initial costs, energy costs, operation and maintenance costs (O&M), repair and replacement costs (R&R), and salvage and increase in resale costs. The equation below details the costs viewed as expenses and the costs that are viewed as assets. The categories that are added are the expenses and the ones subtracted are viewed as assets. The salvage value and resale value are the only variables in Equation 3 that are subtracted.

$$LCC = \textit{Initial Costs} + \textit{Energy Costs} + \textit{O\&M Costs} + \textit{R\&R Costs} - \textit{Salvage \& Resale} \tag{2-3}$$

1. Cold city or well water is diverted to the solar collector
2. Solar Collector
3. As water is needed the hot water flows down from the collector into the storage tank.

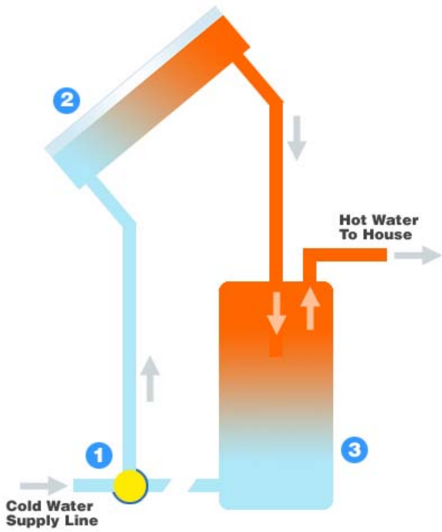


Figure 2-1. ICS System. Source: http://www.atlassolarinnovations.com/solar-waterheating-choices/

CHAPTER 3
METHODOLOGY

To allow for a more feasible active solar system in most existing residential buildings, electrical consumption must be reduced. The process by which consumption should be reduced starts with understanding how the home operates, meaning understanding the percentage of consumption for lighting, appliances, and electronics. The process of determining the percentage of consumption will result in an energy reduction template. The template will be used to reduce annual consumption with efficiency upgrades in the most economical manner. As part of the template, initial and life cycle costs of the upgrades will be considered when reducing consumption so the greatest return on investment with the shortest payback period is realized. In using the template, the kWh consumption per hour will be multiplied by the hours/year, to understand how much electricity is used. This is important because it might not make sense to upgrade an appliance that is seldom used. Once the template has been used, and the new annual consumption is estimated, an LCC of PV will be analyzed for economic feasibility. The analyses will determine the optimum size of the solar system for the home.

In the spreadsheet, each efficiency upgrade is given its own worksheet. The worksheet will contain the current annual consumption of the appliance or electronic, and the estimated annual consumption of the efficiency upgrade. Once the consumptions are compared an LCC table will be created to see which alternative has the lowest life cycle cost or consumes the least amount of electricity in a case where the LCC of the efficiency upgrade is higher than the alternative. The new estimated consumption from the efficiency upgrades will be entered into the *New Consumption* table, on the *Old vs. New Consumption* worksheet along with current appliances and electronics. The total consumption will then be entered into *Annual Consumption* cell in the *Sizes and Costs* worksheet.

As a case study, the energy reduction template will be used on an existing town home in Gainesville, FL. The town home, unit 1410, shares its west masonry wall and has an exposed east wall of masonry on the first floor and 2x6 wood stud framing on the second.

The 10 steps of the template are:

1. Review of historical consumption
2. Record the area of the roof and document the orientation and shading
3. Behavioral change
4. Record consumption of appliances and electronics with a KILL A WATT meter and utility meter
5. Lighting upgrade
6. Clothes washer upgrade
7. HVAC upgrade
8. Solar Hot Water
9. Review of projected estimated consumption
10. Calculate the size of the PV and solar hot water system using a life cycle cost model.

Historical Data

The historical data was obtained using past electrical bills. These bills were entered into a spreadsheet so the consumption and the costs could be totaled. The *Historical kWh Data* template contains a *Month*, *Consumption*, *Rate*, *Electricity Costs*, and *Total Costs* column. Once these figures are entered, they are averaged and totaled at the bottom of the table. A yearly average of consumption and cost is estimated from the monthly averages by multiplying the monthly average by 12. Table 3-1 shows the template set up and the *Monthly* and *Yearly Average* cells at the bottom.

Roof Area

The area of the south facing roof of the unit was measured. The north facing roof was also measured in case the PV had to be installed on that side as well. The whole roof could be used, because the north side gets ample sun hours/day, especially in the summer months when the sun is positioned directly above the home. From the preceding literature review, it is known that south facing solar systems have a greater output due to the annual position of the sun in the sky. The pitch of the roof was also determined.

Behavioral Change

A change in behavior was the first step in the template that reduced electricity. Behavioral changes typically do not cost money, and they also do not cause a change in life style. The changes that took place in this case study were turning off lights and televisions when the room was unoccupied as well as running the clothes washer on cold water.

Consumption of Appliances and Electronics

To understand the consumption of the appliances and the electronics of the home a KILL A WATT meter was used to get a kWh/h consumption of the appliances and electronics in Table 3-2. The meter was plugged into the wall and the appliance or electronic was plugged into the meter. The meter was plugged into the wall for an hour with the appliance in the on position and for an hour with the appliance or electronic in the off position if applicable. A few appliances were based on minutes such as the microwave oven, and then converted to hours.

Lighting Upgrade

The consumption of lighting was recorded by using a table on the *Lighting* worksheet. The table itemized the home by rooms and lights per room. The number of light bulbs and W/light bulb were recorded. The consumption was calculated based on the number of hours/year the lights were in the on position. The hours/years were an estimate based on daily and weekly use. Table 3-3 below shows the *Existing Bulbs* template. A second lighting template was made for the CFLs that were chosen. The data for the lamps were entered in the *W/bulb* column and the *# of bulbs* column. Also the hours/day were altered as the lighting was affected by behavioral change. A new cost for lighting was calculated and an LCC with a study period of 10 years was calculated. Table 3-4 is an LCC template for the lighting.

Clothes Washer Upgrade

The clothes washer was chosen to be upgraded. The idea for the upgraded clothes washer was that it dries the clothes more than the existing washer. It uses more kWh/load than the existing washer but the dryer consumption would be reduced. Since the new washer consumes more electricity the savings in the dryer would have to compensate for to make the purchase feasible. The study period for the washer was 10 years. The energy for the existing washer was estimated on a per load basis. The annual number of loads for the existing clothes washer was then estimated based on the number of loads per week. The annual consumption for the new washer was obtained from Energy Star. Table 3-5 shows the washer consumption template. The only cells that need to have information entered are the *kWh/Load*, *Loads/Year*, *Cost/kWh*.

The *kWh/Year* and *Cost/Year* were then entered into an LCC template, Table 3-6, to determine the lowest life cycle cost. The new washer also had the purchase price entered into the LCC template. Once the LCC was performed for the clothes washer, the same was done for the clothes dryer. The dryer remained the same, just the kWh/year were reduced. The new washer/dryer combination were added together and the old washer/dryer combination were added together to determine the lowest LCC. The overall reduction in kWh was considered because of the reduction in the drying time. This was important to because of the PV installation.

HVAC Upgrade

An HVAC system, depending on the age and efficiency, may need to be upgraded. Also, an adjustment to the comfort range of the home may be advisable. The range of the home prior to the study was 68 – 77°F. During the case study, the range was broadened to 62 - 79°F. The equation for calculating HVAC consumption is:

# of tons x Btu/h x hours/year x 1/SEER x 1kW/1000W = kWh/year

This equation was used to set up a template to compare existing and new consumption for the HVAC system. Once they two were compared an LCC was performed, and the best alternative was chosen. Table 3-7 is the HVAC consumption equation and Table 3-8 is the LCC template for the HVAC.

Solar Hot Water

Solar water heating was examined to reduce the electrical consumption of the water heater. The existing hot water tank is 40 gallons. The consumption of the hot water heater was determined by the energy guide on the hot water heater. Hot water was reduced initially by the behavioral change and by 85% from the flat plate collector. A hot water consumption template was used and then an LCC template, to compare to existing to the solar hot water. Even though the solar hot water was broken out separately from the PV it is included in the PV LCC calculations and graphs. Table 3-9 shows the initial comparison with the consumption data, and Table 3-10 shows the LCC of the solar hot water compared to the existing. The study period for the hot water is 20 years. The only information that is needed in Table 3-9 is the *kWh/Year* and *Cost/kWh*.

New Estimated Consumption

Once the Step 8 is completed, the new consumption is totaled and compared with the existing consumption. The new consumption is transferred to the *Sizes and Costs* worksheet. The new consumption should contain all of the upgrades as well as the existing items.

Life Cycle Costing of PV

An LCC spreadsheet was created with two worksheets. The first worksheet, *Sizes and Costs*, is where the site specific information, i.e. consumption, percent of production, consumption rate, fuel and general inflation, and discount rate, is entered. The second worksheet, *Solar LCC*, was created with two tables, *PV Data* and *Financial Data*. The PV data includes: the size of the system, its rated output, the inverter efficiencies, the cost of operating and repairing the system over its life cycle, the consumption rate, and the FIT rate. The financial data includes: the initial cost, rebates, efficiency upgrade costs, consumption, inflations and discount rate, and increase in equity.

The *Consumption* cell, on the *Sizes and Costs* worksheet, is filled in with the new annual consumption from the *Old vs. New Consumption* worksheet. The *Percent of Production* cell allows the user to dictate the production to consumption ratio. The percentage entered may either be more or less than the consumption. The *Consumption Rate* cell is dependant upon the yearly average of the home. The discount rate is a percent that is entered for the present worth equations, and it is user specific. Fuel inflation is another site specific number that is based on the prospective rise in electrical costs. The higher the fuel inflation the less feasible PV becomes. General inflation is used for the calculating the costs of goods and services for the PV system. These goods and services will be implemented during the life of the PV. With these 6 cells filled in, Table 3-11, the life cycle cost comparison is calculated on the *Solar LCC* worksheet. The PV data information on the *Solar LCC* worksheet, Table 3-12, is used for the production information of the LCC calculation. The *kW System* cell on the *Solar LCC* worksheet is linked to the *Consumption* and *Percent of Production* cell. The following equation uses the data from the 1st four cells in *PV Data* to get the kWh/year.

kWh/Year = kW system x 5 hours/day x 30 days/month x 12 months/year

The *output/subsequent year*, *Inverter Efficiency*, and *Inverter output/subsequent year* cells are multiplied by the *kWh/year* to get the output for subsequent years during the life of the PV. The *O&M* cell is the operation and maintenance cost of the system. The operation and maintenance includes money for cleaning the panels. The *R&R* cell is for the repair and replacement of the system parts. Money for the inverter is generally the only repair and replacement that is needed. That typically occurs during the 10th year. The *$/kWh* cell is linked to the *Sizes and Costs* worksheet. The cell was put on this page as a quick reference. The *FIT $/kWh* cell is editable, so the user can enter in the proper FIT. The *FIT $/kWh* cell is used to calculate the gross and net sellback of production.

The initial cost information in *Financial Data* table is the gross cost of the PV and solar hot water systems. The PV cost is linked to an un-editable table in the *Sizes and Costs* worksheet. Table 3-13 shows the sizing and costing tables for the PV system based upon the annual consumption and percent of production inputs.

The cost of solar hot water is a hard number. The rebates include the state, federal and local. The PV state rebate is linked to the *kW system* cell, however it has an equation that will not allow the rebate to eclipse $20,000 if the PV size is greater than 5kW. The number of Watts is multiplied by $4.00 if the size of the PV system is 5kW or less. The other rebates are hard numbers. The discount rate and the inflation are linked to the *Sizes and Costs* worksheet. The *Energy Consumption* cell is also linked to *Sizes and Costs*. If the *Sizes and Costs* number is altered so is the energy consumption. Energy costs are calculated by multiplying the *$/kWh* cell by the *Energy Consumption* cell. The *Appliance Costs* cell is another cell with an equation that either equals “0” or the cost of the appliance upgrades. For this research the cell has a value greater than “0”. The *Increase in Equity* cell is $1,000/kWh of PV installed. The increase in equity was based on the production of 1kW of solar electric. A kW of solar electric produces 1,800kWh/year. With an energy rate of $0.12, the money earned equates to $216 annually and $4,320 over the 20 year period. The *Loss of Increase* cell is instituted for every year after the 1st year.

The *Reduction in Consumption* cell under *Solar Thermal Data* is there as a reference. The *Increase in Equity* cell is added to the total increase in equity for the active and passive solar installation.

Initial Cost = size of the system (in kW) x $/kW

kWh/Year = kW system x kWh/day x kWh/month x kWh/year

Total SF = (kW system x 1000 Watts) / Watts/Panel)) x SF/Panel

Size of the Photovoltaic (PV) System

The size of the PV system is dependent on the square foot area of the roof, the square foot area of the modules, and the output of the modules. For this study, 2 companies were examined. The first company, Sanyo, manufactures a 200W bi-facial module. The second company, SunPower Corporation, manufactures a 210W all Black module. Table 3-14 shows the square footage of the maximum system size for each company.

The 4.4 and 4.6 kW systems can have greater outputs depending on the site, which could decrease the physical size of the system or keep the size the same, and have a greater output. The Sanyo bi-facial module can have an increased efficiency up to 30% based on the reflectivity of the surface below and the tilt of the panel. The 30% is based on Sanyo tech sheets. If the reflectance value of the surface is high the output increases. The same is true for the SunPower all black panels, as their efficiency can increase from 16.9% to 22%, according to Shawn Lorenz. In an interview with Shawn he stated that SunPower has said that the panels have achieved 22% in tests but, they will not publish this as a rated output, because the conditions have to be perfect. Figure 3-1 shows the difference between the rated and the reported maximum site specific outputs.

Table 3-1. Historical Consumption and Cost Data

HISTORICAL kWh DATA				
Time Frame	Consumption	Rate	Electricity Costs	Total Costs
Aug-07			$ -	$ -
Sep-07			$ -	$ -
Oct-07			$ -	$ -
Nov-07			$ -	$ -
Dec-07			$ -	$ -
Jan-08			$ -	$ -
Feb-08			$ -	$ -
Mar-08			$ -	$ -
Apr-08			$ -	$ -
May-08			$ -	$ -
Jun-08			$ -	$ -
Jul-08			$ -	$ -
Aug-08			$ -	$ -
Sep-08			$ -	$ -
Monthly Average			$ -	$ -
Sept -07/Sept-08			$ -	$ -

Table 3-2. Hourly Consumptions

Appliances & Electronics	Consumption	
Lighting	0.04	kWh/h
Refrigerator	0.17	kWh/h
Plasma TV (on)	0.29	kWh/h
Plasma TV (off)	0.02	kWh/h
LCD TV (on)	0.15	kWh/h
Clothes Dryer	2.80	kWh/h
9" TV	0.05	kWh/h
Internet	0.01	kWh/h
Air Conditioning	2.40	kWh/h
Computer	0.05	kWh/h
Microwave Oven On	1.20	kWh/h
Microwave Oven Off	0.00083	kWh/h

Table 3-3. Existing Bulbs Template

Exisiting Bulbs									
Lighting	W/bulb	# of bulbs	Total Watts	Hours/day	Wh/day	Days/year	Wh/Year	kWh/Year	Costs for Lighting
dining room									$ -
kitchen									$ -
downstairs hallway									$ -
downstairs bathroom									$ -
upstairs bathroom									$ -
master bedroom fan									$ -
master bedroom									$ -
upstairs hallway									$ -
front bedroom									$ -
Total									$ -

Table 3-4. Lighting LCC Template

Compact Fluorescent Lighting LCC								
Year	Costs	kWh	cost/kWh	Cost	PW Costs	PW Energy Costs		
0	$ -		$ -	$ -	$ -	$ -		
1			$ -	$ -		$ -		
2			$ -	$ -		$ -		
3			$ -	$ -		$ -		
4			$ -	$ -		$ -		
5			$ -	$ -		$ -		
6			$ -	$ -		$ -		
7			$ -	$ -		$ -		
8			$ -	$ -		$ -		
9			$ -	$ -		$ -		
10			$ -	$ -		$ -		
Totals	$ -	-		$ -	$ -	$ -		
LCC					$ -	$ -	=	$ -

Existing Lighting LCC								
Year	Costs	kWh	Cost/kWh	Costs	PW Costs	PW Energy Costs		
0	$ -		$ -	$ -	$ -	$ -		
1	$ -		$ -	$ -	$ -	$ -		
2	$ -		$ -	$ -	$ -	$ -		
3	$ -		$ -	$ -	$ -	$ -		
4	$ -		$ -	$ -	$ -	$ -		
5	$ -		$ -	$ -	$ -	$ -		
6	$ -		$ -	$ -	$ -	$ -		
7	$ -		$ -	$ -	$ -	$ -		
8	$ -		$ -	$ -	$ -	$ -		
9	$ -		$ -	$ -	$ -	$ -		
10	$ -		$ -	$ -	$ -	$ -		
Totals	$ -	-		$ -	$ -	$ -		
LCC					$ -	$ -	=	$ -

Table 3-5. Clothes Washer Comparison

Existing Clothes Washer				
kWh/Load	Loads/Year	kWh/Year	Cost/kWh	Cost/Year
			$ -	$ -

New Clothes Washer				
kWh/Load	Loads/Year	kWh/Year	Cost/kWh	Cost/Year
			$ -	$ -

Table 3-6. Clothes Washer LCC

Existing Washer								
Year	Costs	kWh used	Cost/kWh	Costs	PW Costs	PW Energy Costs		
0	$ -		$ -	$ -	$ -	$ -		
1	$ -		$ -	$ -	$ -	$ -		
2	$ -		$ -	$ -	$ -	$ -		
3	$ -		$ -	$ -	$ -	$ -		
4	$ -		$ -	$ -	$ -	$ -		
5	$ -		$ -	$ -	$ -	$ -		
6	$ -		$ -	$ -	$ -	$ -		
7	$ -		$ -	$ -	$ -	$ -		
8	$ -		$ -	$ -	$ -	$ -		
9	$ -		$ -	$ -	$ -	$ -		
10	$ -		$ -	$ -	$ -	$ -		
Totals	$ -			$ -	$ -	$ -		
LCC					$ -	$ -	=	$ -

New Washer								
Year	Costs	kWh used	Cost/kWh	Costs	PW Costs	PW Energy Costs		
0	$ -		$ -	$ -	$ -	$ -		
1			$ -	$ -	$ -	$ -		
2			$ -	$ -	$ -	$ -		
3			$ -	$ -	$ -	$ -		
4			$ -	$ -	$ -	$ -		
5			$ -	$ -	$ -	$ -		
6			$ -	$ -	$ -	$ -		
7			$ -	$ -	$ -	$ -		
8			$ -	$ -	$ -	$ -		
9			$ -	$ -	$ -	$ -		
10			$ -	$ -	$ -	$ -		
Totals	$ -	-		$ -	$ -	$ -		
LCC					$ -	$ -	=	$ -

Table 3-7. HVAC Consumption Calculation

Existng 10 SEER 2-TON Unit												
Air Conditioning	# of tons	x	Btu/h	x	hours/year	x	1/SEER	x	1kW/1000W	=	kWh/year

20 SEER 2-TON Unit												
Air Conditioning	# of tons	x	Btu/h	x	hours/year	x	1/SEER	x	1kW/1000W	=	kWh/year

Table 3-8. HVAC LCC Template

Existng 10 SEER 2-TON Unit LCC								
Year	Costs	kWh used	Cost/kWh	Costs	PW Costs	PW Energy Costs		
0	$ -		$ -	$ -	$ -	$ -		
1	$ -		$ -	$ -	$ -	$ -		
2	$ -		$ -	$ -	$ -	$ -		
3	$ -		$ -	$ -	$ -	$ -		
4	$ -		$ -	$ -	$ -	$ -		
5	$ -		$ -	$ -	$ -	$ -		
6	$ -		$ -	$ -	$ -	$ -		
7	$ -		$ -	$ -	$ -	$ -		
8	$ -		$ -	$ -	$ -	$ -		
9	$ -		$ -	$ -	$ -	$ -		
10	$ -		$ -	$ -	$ -	$ -		
Totals	$ -	-		$ -	$ -	$ -		
LCC					$ -	$ -	=	$ -

20 SEER 2-TON Unit LCC								
Year	Costs	kWh	Cost/kWh	Costs	PW Costs	PW Energy Costs		
0	$ -		$ -	$ -	$ -	$ -		
1			$ -	$ -	$ -	$ -		
2			$ -	$ -	$ -	$ -		
3			$ -	$ -	$ -	$ -		
4			$ -	$ -	$ -	$ -		
5			$ -	$ -	$ -	$ -		
6			$ -	$ -	$ -	$ -		
7			$ -	$ -	$ -	$ -		
8			$ -	$ -	$ -	$ -		
9			$ -	$ -	$ -	$ -		
10			$ -	$ -	$ -	$ -		
Totals	$ -	-		$ -	$ -	$ -		
LCC					$ -	$ -	=	$ -

Table 3-9. Hot Water Comparison Template

Existing Water Heater		
kWh/Year	Cost/kWh	Cost/Year
	$ -	$ -

Solar Thermal Water Heater		
kWh/Year	Cost/kWh	Cost/Year
	$ -	$ -

Table 3-10. Hot Water LCC Template

			Electric Hot Water					
Year	Costs	kWh used	Cost/kWh	Costs	PW Costs	PW Energy Costs		
0	$ -		$ -	$ -	$ -	$ -		
1	$ -		$ -	$ -	$ -	$ -		
2	$ -		$ -	$ -	$ -	$ -		
3	$ -		$ -	$ -	$ -	$ -		
4	$ -		$ -	$ -	$ -	$ -		
5	$ -		$ -	$ -	$ -	$ -		
6	$ -		$ -	$ -	$ -	$ -		
7	$ -		$ -	$ -	$ -	$ -		
8	$ -		$ -	$ -	$ -	$ -		
9	$ -		$ -	$ -	$ -	$ -		
10	$ -		$ -	$ -	$ -	$ -		
11	$ -		$ -	$ -	$ -	$ -		
12	$ -		$ -	$ -	$ -	$ -		
13	$ -		$ -	$ -	$ -	$ -		
14	$ -		$ -	$ -	$ -	$ -		
15	$ -		$ -	$ -	$ -	$ -		
16	$ -		$ -	$ -	$ -	$ -		
17	$ -		$ -	$ -	$ -	$ -		
18	$ -		$ -	$ -	$ -	$ -		
19	$ -		$ -	$ -	$ -	$ -		
20	$ -		$ -	$ -	$ -	$ -		
Totals	$ -			$ -	$ -	$ -		
LCC					$ -	$ -	=	$ -

			Solar Hot Water					
Year	Costs	kWh used	Cost/kWh	Costs	PW Costs	PW Energy Costs		
0	$ -		$ -	$ -	$ -	$ -		
1	$ -		$ -	$ -	$ -	$ -		
2	$ -		$ -	$ -	$ -	$ -		
3	$ -		$ -	$ -	$ -	$ -		
4	$ -		$ -	$ -	$ -	$ -		
5	$ -		$ -	$ -	$ -	$ -		
6	$ -		$ -	$ -	$ -	$ -		
7	$ -		$ -	$ -	$ -	$ -		
8	$ -		$ -	$ -	$ -	$ -		
9	$ -		$ -	$ -	$ -	$ -		
10	$ -		$ -	$ -	$ -	$ -		
11	$ -		$ -	$ -	$ -	$ -		
12	$ -		$ -	$ -	$ -	$ -		
13	$ -		$ -	$ -	$ -	$ -		
14	$ -		$ -	$ -	$ -	$ -		
15	$ -		$ -	$ -	$ -	$ -		
16	$ -		$ -	$ -	$ -	$ -		
17	$ -		$ -	$ -	$ -	$ -		
18	$ -		$ -	$ -	$ -	$ -		
19	$ -		$ -	$ -	$ -	$ -		
20	$ -		$ -	$ -	$ -	$ -		
Totals	$ -			$ -	$ -	$ -		
LCC					$ -	$ -	=	$ -

Table 3-11. User Cells

User Cells		
Annual Consumption		0
% of PV Generation		100%
Consumption Rate	$	-
Discount Rate		0.0%
General Inflation		0.0%
Fuel Inflation		0.0%

Table 3-12. PV and Solar Thermal Data

PV Data				Financial Data		PV		Solar Thermal	
kW system		0.00		Cost	$	-		$	2,500.00
hours/day		5		State Rebate		$0		$	500.00
days/month		30		Federal Rebate	$	2,000		$	2,000.00
months/year		12		Local Rebate	$	-		$	500.00
kWh/year		-		Discount Rate		0.0%			
output/subsequent year		0.99		General Inflation		0.0%			
Inverter Efficency		0.95		Fuel Inflation		0.0%			
Inverter output/subsequent year		0.99		Energy Consumption		0			
O & M	$	30	every year	Energy Costs	$	-	/year		
R & R	$	1,200	every 10 years	Appliance Costs	$	-			
$/kWh	$	-		Increase in Equity	$	1,000	/kW installed		
FIT $/kWh	$	0.320		Loss of Increase		4.0%	/year		
Solar Thermal Data									
Reduction in Consumption			85%	Increase in Equity				$	2,000.00

Table 3-13. Initial Cost and Size Calculations

PV Cost			
Size of System	Cost per Watt*	Cost Per kW	Initial Cost
0.00	$ 6.50	$ 6,500.00	$ -

PV SYSTEM PRODUCTION			
kW System	kWh per Day	kWh per Month	kWh per year
0.00	0.00	0.00	-

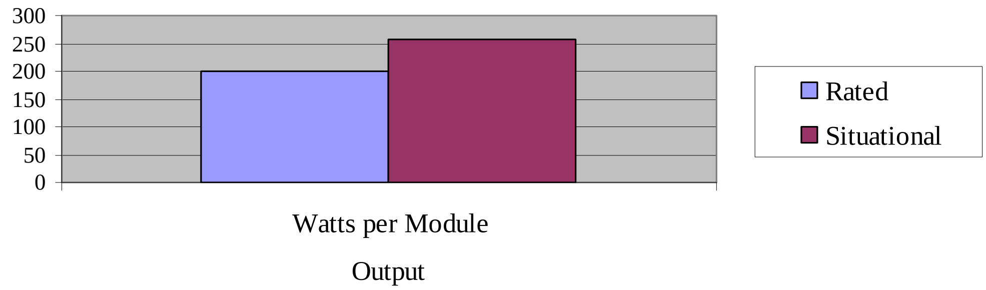
PV SYSTEM SIZE			
kW System	No. of Watts	No.of Panels	Total SF
0.00	-	0	0

Table 3-14. Panel Size

Sanyo Bifacial				
kW System	No. of Watts	Watts per Module	SF of Modules	Total SF
4.4	4400	200	14	308

SunPower 210				
kW System	No. of Watts	Watts per Module	SF of Modules	Total SF
4.6	4600	210	14	307

A



B

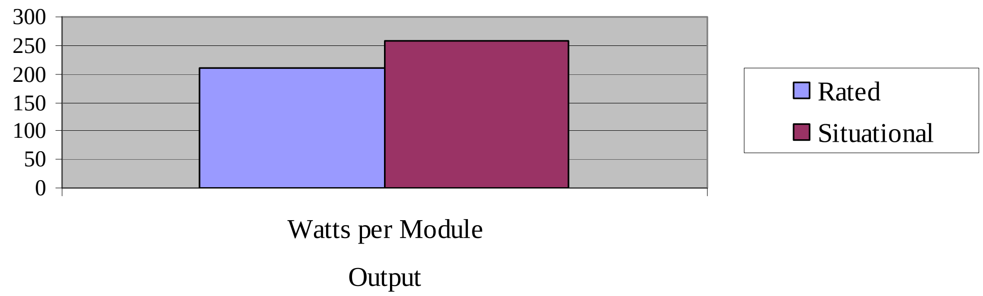


Figure 3-1. Output Differential (A – Sanyo Bifacials) (B – Sunpower)

CHAPTER 4
RESULTS FROM THE CASE STUDY

The case study was analyzed using the methodology described in Chapter 3. The town home is oriented on a north/south axis, with the east/west walls having the largest area. It is an end unit that has an exposed east wall and a shared west wall. The conditioned area is 1,145 square feet. The unit is two stories and measures 40'L x 16'W. The floor is concrete slab on grade, and has a laminate wood flooring system. All first floor walls are 8" concrete masonry units. The interior is finished gypsum board placed on 1" furring strips. The exterior side of the wall has a stucco finish. The top floor east, south, and north walls for unit 1410, are 2"x6" stud framing with 5/8" T-111 siding. The shared West wall is 8" CMU with 1" furring strips. There are (2) 8' x 6' single pane sliding glass doors on the North wall, one up and one downstairs. The south wall has a 2' x 3' window on the first floor and a 3' x 6' window on the top floor. Both windows are single pane. There is no insulation on any of the walls with furring strips in either unit.

The energy reduction template, through the 9 steps, resulted in a net zero energy home. Consumption had been reduced which allowed for and economically feasible PV installation. The results from the template were recorded to determine the LCC of the efficiency upgrades and solar hot water. The LCC of the PV was later calculated.

Case Study 1410

Historical Data

Data were collected from Gainesville Regional Utility from September 2007 – 2008. The consumption (kWh), electrical costs, and total costs were recorded to figure out the average cost per kWh for each month. Table 4-1 shows the data as well as the calculation results for the case study. The kWh consumption and electrical costs were summed to obtain a total for the previous year. The rate was calculated by dividing the electrical cost by the monthly kWh usage. The total costs include the storm water fee, Florida gross receipts tax, and city utility tax.

Roof Area

The area of the south facing roof of the unit was determined to be 308 ft^2. The north facing roof is the same dimension, for a total of 616 ft^2. The whole roof could be used, because the north side gets ample sun hours/day, especially in the summer months when the sun is positioned directly above the home. From the preceding literature review, it is known that south facing solar systems have a greater output due to the annual position of the sun in the sky. The roof has a pitch of 22° and light colored shingles. Figure 4-1 is a series of photos taken throughout the day of October 12, 2008 for the case study. October 12th was a clear day, with no visible clouds, providing the roof surface 8 hours of direct sunlight from 10:15 am – 5:15 pm. The image shows that some shading does occur on the south facade from the palm tree and the adjacent roof.

Behavioral Change

During October 2008 cold water was used for clothes washing as well as lights were turned off in unoccupied rooms. This led to an energy reduction of 526 kWh from September 2008 and 400 kWh from October 2007. It also led to a financial savings of $88.14 and $49.79 respectively.

Record Consumption of Appliances and Electronics

The consumption data that were obtained through the reading of the electric meter, and the KILL A WATT meter were recorded in a manner that allowed the homeowner to see where the greatest consumption occurred and on what days of the week it occurred. Figure 4-2 shows the relative percent of energy consumption of the appliances and electronics as compared to each other. This is an estimate. These numbers could change with seasons and lifestyle. The numbers reflect the energy consumption for an hour, or a specific duration, such as a load of dishes or laundry. If the number of hours or loads changes, so does the chart.

The HVAC and water heater accounted for 64% of the total energy consumption. The consumption of the systems respectively was 4,431 and 3,906 kWh. According to records the air handler had been replaced in October of 2007, which may have altered the HVAC consumption, but through the equation stated in the methodology the HVAC number that was recorded for this case study was 4,431 kWh. Table 4-2 details the consumption estimate breakdown of Figure 4-2.

The appliances cell has an asterisk because included in the appliances are the clothes and dishwasher, computers, microwave oven and stove. These were combined because the consumptions were minimal and appeared as 1 and 2% on Figure 4-2. The combined energy consumption of the aforementioned appliances was 585 kWh. Of that total, computers consumed the most with 197 kWh, and the microwave oven the least with 26 kWh. Figure 4-3 and Table 4-3 show the energy use by the appliances in the consolidated group.

Of the smaller appliances, the microwave oven and the clothes washer are the only one that does not consume 100 kWh, as it is also the appliance that is used the least. The computers are two laptops that are plugged in while in use, and turned off when not. Table 4-4 shows the hourly consumption estimates of small appliances and electronics. These yearly numbers were extrapolated to estimate their respective electrical consumption.

In Table 4-4 the appliance energy use is shown in kWh/h. These appliances and electronics were measured for 1 hour. The HVAC consumption was measured by hand to get the kWh/h consumption and then extrapolated over the year. With regards to the clothes washer and dryer, as well as the dishwasher, the energy consumption was recorded per load. It was done this way because these three appliances operate on a per load basis. The three appliances also have settings, as far as time and temperature, but for the study the maximum time and temperature were recorded because those were the settings used for the appliances during the period from September 2007 – September 2008. With regards to the clothes and dish washers, the temperature did not effect the energy consumption of the machines, just the energy consumption of the hot water heater. However, for the clothes dryer, temperature does effect the energy consumption along with time. According to the table, the dryer consumes 2.8kWh/load. Load time is variable, depending on where the dial is turned to on the setting. The dial can be turned to no heat, at which point the dryer would consume less. The only other appliance to not be recorded under a kWh/h energy use was the microwave oven. The KILL A WATT meter was used for the microwave oven. Since the appliance operated on a minute to minute basis, it was recorded that way. The days of the year that the microwave is not in use it consumes 0.02kWh/day. That equates to 7.3 kWh/year or $0.89 cents. For the microwave oven to operate under the behavior that it has been, it costs the homeowners $2.54 per year. Table 4-5 and Figure 4-4 show the costs of the unit 1410's appliances over the course of the 13 month case study.

The HVAC and the water heater were a combined cost of $1,025.29, which equates to 63% of the total energy consumption of unit 1410. The next highest consuming appliance was the refrigerator with an annual energy cost of $169.06, which is 10.4% of the total energy cost. The 3 televisions had a combined cost of $131.70, and the cost of lighting was $138.86. The major consuming appliances had an annual operating cost of $1,554.36 which amounted to 95% of the energy use. The other five categories totaled $71.99, and 4% of the energy use. The HVAC, Hot Water Heater, Televisions, Dryer, Lights, and

Refrigerator (The Big Six) needed to be examined for ways to lower energy consumption. Some of these ways could be behavioral, and other ways could be to replace existing appliances.

Lighting Upgrade

The first action that was taken was replacing all the existing incandescent light bulbs with CFL's. Each lamp cost $4.00 and a total of 14 bulbs were purchased. Also, once the bulbs were installed, the numbers of hours the lights were in the on position decreased, because of a change in behavior. Tables 4-6 and 4-7 show the lighting breakdown per room before and after the lighting and behavioral change. Included in the breakdown are the numbers of bulbs, Watts per bulb, hours per day the bulbs are on, days per year, and the costs to light the rooms of unit 1410.

The total cost of the CFL's was $56.00. When the purchase is added to the operating cost the projected annual cost is $84.93. If the bulbs burn out this year then the cost savings will be $53.93. If the bulbs last 10 years and the behavior of lighting the unit stay the same, then the savings, with an assumed inflation in energy of 3% will be $1,232.61. The assumed 3% inflation in energy comes from an LCC spreadsheet from Harry Kegelmann. Table 4-8 shows the life cycle cost (LCC) of the compact fluorescent bulbs and the existing bulbs. The results of the LCC show that over a ten year period the difference in cost is $951.41. The $56 cost is paid back in the first six months of the first year.

Clothes Washer Upgrade

The current clothes washer uses 97kWh/year, which is an Energy Star rating. The replacement of the clothes washer would allow for the dryer to consume less energy because the clothes are drier before they are placed inside the dryer. The dryer consumes 725kWh/year and costs $89.02. This number could be reduced by 75%, by using less time to dry clothes. This means that every 4 new loads equal 1 old load. The dryer would then consume 181.25kWh/year and have a cost of $22.25/year. Table 4-9 shows the old vs. the new energy use along with costs for the dryer.

Even though the dryer consumes less; the new washer will consume more. A washer can be purchased that will use a comparable amount of energy, but the initial cost is high. The clothes washer that was picked was Frigidaire AFT8000FE. The washer consumes 128.52kWh/year. This number is 55.04kWh/year more than the existing washer, or $6.81/year. Table 4-10 illustrates the increase in consumption and cost for the new washer.

Even though the washer will consume more energy, over the life of the appliance it will save energy and cost. Table 4-11 and 4-12 shows the life cycle cost of the respective washers and dryers. This reduction will allow for either a smaller PV system to be placed on the roof, or the proposed PV system that will sell back more electricity. The greater sellback will result in a quicker payback, for the PV and the upgrades.

This LCC comparison shows that over the life of the new washer it is more expensive than keeping the existing washer and paying more in electricity for the dryer. The difference in the PW value is $119.66 in favor of the existing washer. This LCC does not deal with the water consumption savings, but according to Energy Star this washer uses less water. The area of the table that is not shown is the consumption savings which are part of the PV LCC. The energy savings are in favor of the new washer, because the consumption of the dryer is reduced 75%. The dryer consumption is reduced from 725kWh/year to 181 kWh/year, a savings of 544kWh/year. The new washer will provide energy and cost savings, with regard to CO_2 emissions and PV production. Figure 4-4 shows the savings in consumption and CO_2 between the alternative and the existing.

The difference in kWh consumed annually, washer and dryer combined, is 488 and over the 10 year study is 4,880. According to Jason Fults of Drops and Watts, who stated at a lecture, 1 kWh equals 1.54 lbs of CO_2, that is a savings in CO_2 emissions of 751.52 and 7,515.2 lbs respectively.

HVAC Upgrade

The HVAC system, which was estimated to consume 4,430kWh/year, can be reduced by 50% by upgrading the outside unit. The upgraded unit would be a 20 SEER, 2-ton unit compressor and heat pump. A change in behavior is not required to achieve the energy reduction, but before the purchase of the unit is made the temperature range of the thermostat and comfort level could be broadened. Table 4-13 shows numbers for the current compressor and heat pump, as well as the 20 SEER replacement unit, and Table 4-14 is a LCC comparison of the 2 units.

The 20 SEER, 2-Ton unit has a lower life cycle cost by $2,664.88. The price of the new unit and the first year consumption, even though expensive, is $129.54 more than the cost of electricity and maintenance for the existing unit for the first year. With the GRU rebate of $300, it allows for the discounted payback to occur in the second year.

Solar Hot Water

The hot water heater, which consumes 3,906 kWh annually, can have the consumption cut to 586 kWh by weighing solar thermal. Table 4-15 shows the energy use and cost savings with the solar thermal install.

The cost of the solar thermal system is $2,500 for a 40ft^2 ICS system using a flat plate collector. The first year savings is $407.70, and with a proposed 3% fuel and 1.5% general inflations the payback is in 5 years. There is little maintenance costs because the system is passive. Table 4-16 shows the LCC and savings over a 20 year study period. The table shows that the solar hot water alternative has a lower LCC by $4,204.13. The solar hot water system saves $11,691.44 during the 20 year span, assuming a 3% fuel inflation and consistent hot water use. Figure 4-6 shows the cost of hot water cost comparison over the study period.

The table and graph shows that at the 20 year mark the cost does not go above $200. This is still 27% of the cost that occurred in the study period from September 2007 – 2008.

Review of Consumption Reduction

The time for which the template was applied resulted in the following reductions. These numbers only represent a change in lighting and clothes washing on cold/cold with the existing washer. The month of October 2008, the month the case study started, the consumption was 826 kWh. The previous October had a consumption of 1,226 kWh. That was a decrease of 400 kWh, and had a cost savings of $49.79. November resulted in the same trend, with a consumption of 641 kWh down from 954 kWh the previous year, and a cost savings of $34.54. December's use was recorded at 651 kWh which was 165 kWh less than the December 2007. The cost savings were $12.29. January 2009 showed a decrease in consumption of 334 kWh, and again a cost savings of $40.21. Table 4-17 shows the 2007-2009 monthly comparisons since Case Study 1410 started.

There has been a total energy savings of 1,212 kWh, and a total cost savings of $136.83. If a 4.07 kW PV system were to be installed it could produce 1,212 kWh and the home could be net zero energy. Table 4-18 shows the size of the system that would need to be installed prior to the reduction in electrical and the size of a system after the reduction.

With the installation of the solar thermal system the size of the system will reduce, as will the load. Table 4-18 shows the production of the new PV system and the reduction in electricity for hot water that solar thermal system provides. The solar thermal system would have reduced the 2,800 kWh to 2,100 kWh. This would allow the system to be a reduced size because the load is reduced. The kW size of the new system and square foot area is shown in Table 4-19.

The solar thermal collector replaces 700 kWh of electricity for the 4 months using 40 ft^2 of roof surface area. A photovoltaic system would need more area to perform the same task. Table 4-20 shows how the square footage of each technology differs.

The solar thermal works out to be half of the size of the PV system. There is one flat-plate collector that is installed, which is equivalent to 5 PV panels that need to be installed.

With the upgrades examined and replaced, the new PV system can now be calculated. With the results of the calculations, a comparison of size, output, and costs can be made to compare LCC of a net zero energy home with PV and an LCC of the home with upgrades only. The first comparison, in Table 4-21 is of the upgraded 1410 vs. the old 1410. The consumption difference between new and old is 6,828 kWh. That is a cost savings of $839.84. Figure 4-7 shows the savings in electricity only over 20 years, assuming that the new behavior and weather remain constant.

Of the Big 6: the replacing of the HVAC, water heater, clothes washer, interior lighting led to the reduction of 6,828 kWh. Those 4 categories eliminated the need for 3.79kW of PV. That equates to a savings of $24,657, at an installed rate of $6.5/W, and the need for 253ft^2 of roof area. The new consumption of 6,394 requires a 3.55 kW system and requires a roof area of 265ft^2, and 40ft^2 for the flat plate collector for solar hot water heating for a total area of 305ft^2.

To achieve the energy reduction, $1,367 was spent on upgrades. The solar hot water system is not included in upgrades as it is part of the installed system. The LCC comparison for the home energy use was conducted and it was determined that the upgrades were the better option even though there was an initial cost. Using the 6,394 kWh as the new energy consumption an LCC was performed. It showed that the new energy use had a cost of $13,639.36 and the old energy use had a cost of $20,232.20 during a 20 year study period, for a difference of $6,592.

LCC of PV with Solar Thermal Systems

The life cycle cost of the PV, combined with a solar thermal system, was calculated and compared to the life cycle cost of the case study after efficiency upgrades but without solar systems. The PV and solar thermal system had a lower life cycle cost than the baseline house with no system. Table 4-22 shows the LCC of the comparison. There is an extended worksheet in the appendix that shows the annual energy use and costs.

The PV LCC has a cost of $1,999.57 compared to the non-PV baseline LCC, which is $13,694.06. The difference is $11,694.49. Table 4-23 shows the LCC comparison as if the energy use remained constant with the historical data, and the size of the PV system remained the same.

The LCC of the PV without efficiency upgrades is still lower than the LCC of the baseline house without efficiency upgrades. Unit 1410 would not be a net zero energy home. However, even though both PV comparisons are lower, the $1,356 spent on appliance upgrades lowered the LCC from $26,802.08 to $1,999.57. That difference equates to $24,802.51 over the 20 year study period. Figure 4-8 shows the payback period in years for the reduced consumption, and Figure 4-9 shows the discounted payback time.

Figure 4-7 shows the different payback periods for the respective sellbacks. If there was zero energy use, the PV would have a payback period of 4 years. The triangle line, the net PV sellback, shows a payback period of 7 years. Figure 4.9 shows the present worth payback is in the 8th year. Below, Figure 4-10 shows the payback period for the PV using the historical consumption data, with the same size PV system, 3.55kW used in the 1st LCC. Figure 4-11 shows the discounted payback for the same system.

The payback for the PV does not happen if the historical consumption were to remain constant. The size of the PV would have to be increased to see a payback. There is not enough south facing roof area to do this. The north side can have PV installed on it, but at an increased cost/kWh. The LCC study below, in Table 4-24 shows the feasibility of a larger system. This kW and solar thermal system maximizes out the square footage of the entire roof. The size of the system is increased from a 3.55 kW system to a 7.35 kW system, where the solar thermal system remains the same.

This system has an LCC of $13,009.59, with the historical consumption. With the increase in the size of the system a payback would occur. In year 13 the costs are recovered by the production of the system. Figure 4-12 shows the payback period, and Figure 4-13 shows the discounted payback of the system. The gross sellback takes longer, because the initial cost is increased.

Sensitivity Analyses

A series of sensitivity analyses were performed to determine the optimum size of the PV system with an increased consumption ranging from 7,000 kWh to 13,000 kWh increments of 1,000 kWh. A series was also performed to examine the percentage of production compared to the reduced consumption. This series went from 100 to 150% in increments of 10%. Also, the production was reduced from 100 to 50% in increments of 10%. It is important to realize that there may not be a need for 100% production that it may in fact be more or less.

The LCC comparison table shows the relationship between the size of the system, producing 100% of the consumption and the LCC. The 7,000 kWh consumption in the table is the only LCC that contains the efficiency upgrades cost. The added cost makes it higher than 8,000 or 9,000 kW system.

Table 4-32 shows that as the consumption increases so does the LCC even when the production to consumption ratio does not change. The main reason the costs increase at a greater rate once the system is larger than 5kW is because the state rebate stops at 5kW. Figures 4-20 and 4-21 show the increase in the LCC of each system using linear graphs. In Figure 4-21, the graph starts increasing on a low slope, and after the 5kW mark, the slope increases.

Increase and Decrease Production at the Reduced Consumption Rate

The production increase and decrease ranged from 200 to 50% to determine if the optimum size of the system should be greater or smaller to produce the lowest LCC. Table 4-33 below shows the LCC comparison or the sizes, and Figure 4-22 graphs them.

The table and graph show that the greater the percent of production the lower the LCC. The more electricity produced, the more electricity there is sold back. At 140% sellback the graph changes slope. This is because there is a change in the size of the system, from under 5kW to over 5kW.

Table 4-1. Historical kWh Data

HISTORICAL kWh DATA				
Time Frame	Consumption	Rate	Electricity Costs	Total Costs
Aug-07	1,336	0.110	$ 147.61	$ 167.60
Sep-07	1,781	0.115	$ 204.13	$ 229.41
Oct-07	1,226	0.124	$ 151.77	$ 172.50
Nov-07	954	0.117	$ 111.79	$ 128.76
Dec-07	816	0.112	$ 91.51	$ 106.57
Jan-08	1,016	0.119	$ 120.91	$ 138.73
Feb-08	778	0.110	$ 85.91	$ 100.43
Mar-08	825	0.113	$ 92.83	$ 108.01
Apr-08	972	0.117	$ 113.92	$ 131.65
May-08	1,154	0.125	$ 144.65	$ 164.48
Jun-08	1,270	0.130	$ 164.59	$ 186.11
Jul-08	1,014	0.129	$ 130.75	$ 148.83
Aug-08	1,166	0.136	$ 158.11	$ 178.43
Sep-08	1,352	0.139	$ 187.88	$ 210.85
Monthly Average	1,102	0.123	$ 135.29	$ 155.17
Sept -07/Sept-08	14,324	0.123	$ 1,758.75	$ 2,004.76

Figure 4-1. Time Elapse Photo of Case Study

Table 4-2. Appliance and Electronic Consumption Estimate

Appliances and Electronics	Annual kWh Estimate
HVAC	4,431
Water Heater	3,906
Televisions	1,071
Appliances*	585
Dryer	726
Lights	1,129
Refrigerator	1,374
Total	13,222

*Washer, Computers, Dishwasher, Microwave Oven, Stove

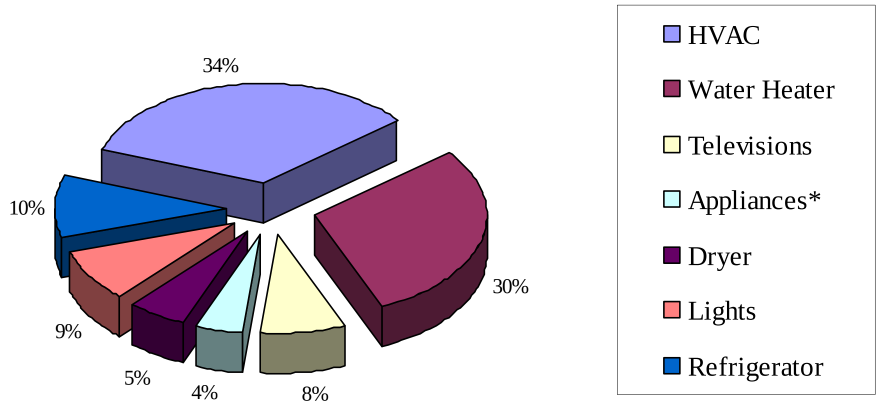


Figure 4-2. Annual HVAC and Appliance Energy Consumption Estimate

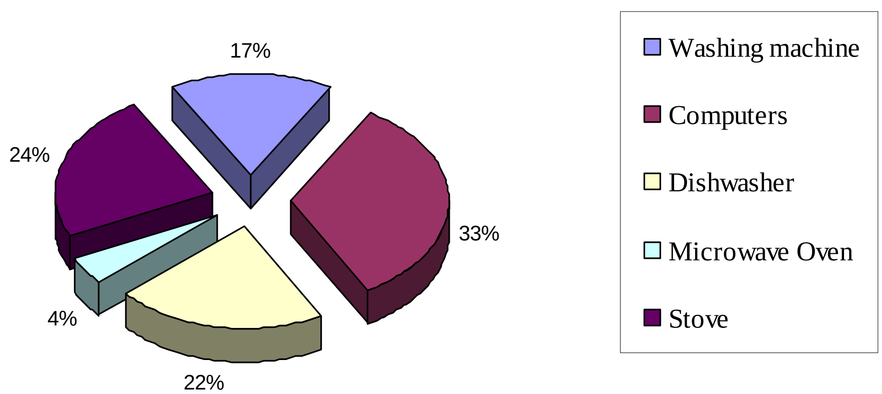


Figure 4-3. Annual Appliance Consumption Estimate

Table 4-3. Appliance Breakdown Estimate

Appliance	Annual kWh Estimate
Washing machine	97
Computers	197
Dishwasher	126
Microwave Oven	26
Stove	138
Total	585

Table 4-4. Hourly Consumption of Appliances and Electronic Equipment

Appliances & Electronics	Consumption	
Lighting	0.04	kWh/h
Refrigerator	0.17	kWh/h
Plasma TV (on)	0.29	kWh/h
Plasma TV (off)	0.02	kWh/h
LCD TV (on)	0.15	kWh/h
Clothes Dryer	2.80	kWh/h
9" TV	0.05	kWh/h
Internet	0.01	kWh/h
Air Conditioning	2.40	kWh/h
Computer	0.05	kWh/h
Microwave Oven On	1.20	kWh/h
Microwave Oven Off	0.00083	kWh/h

Table 4-5. Appliance Energy Use and Costs

Appliances and Electronics	Annual kWh	Annual Costs	
HVAC	4,431	$	544.98
Water Heater	3,906	$	480.49
Televisions	1,071	$	131.70
Dryer	726	$	89.27
Lights	1,129	$	138.86
Refrigerator	1,374	$	169.06
Washing machine	97	$	11.99
Computers	197	$	24.18
Dishwasher	126	$	15.55
Microwave Oven	26	$	3.23
Stove	138	$	17.03
Total	13,222	$	1,626.35

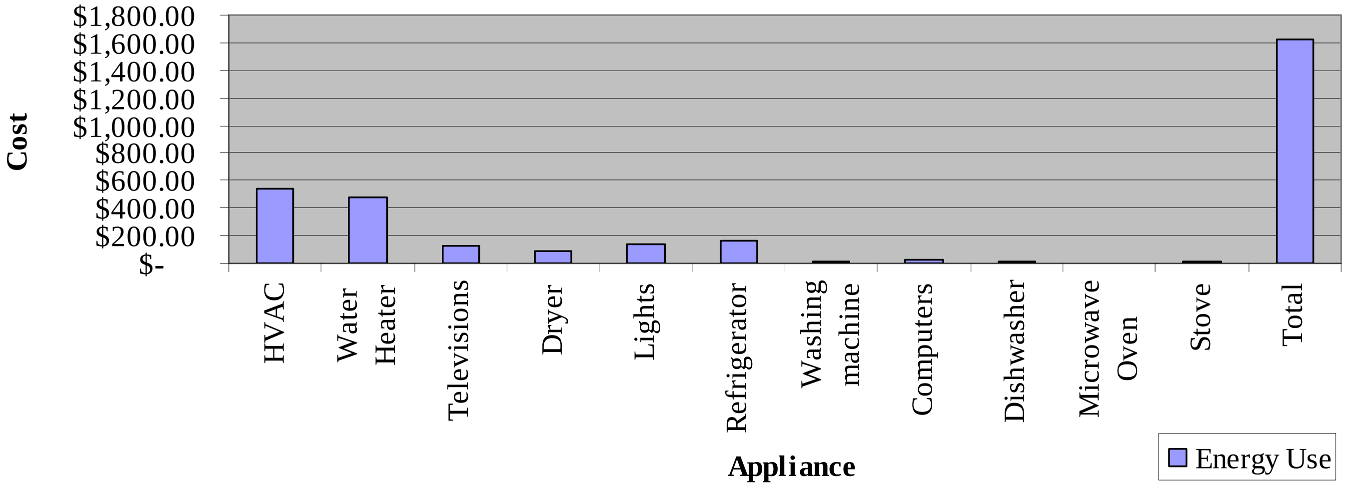


Figure 4-4. Annual Costs

Table 4-6. Lighting Energy Use

Exisiting Bulbs										
Lighting	W/bulb	# of bulbs	Total Watts	Hours/day	Wh/day	Days/year	Wh/Year	kWh/Year	Costs for Lighting	
dining room	60	3	180	7	1260	355	447,300	447.30	$	55.02
kitchen	40	2	80	3	228	355	80,940	80.94	$	9.96
downstairs hallway	13	2	26	2	52	355	18,460	18.46	$	2.27
downstairs bathroom	30	3	90	1	99.09	355	35,177	35.18	$	4.33
upstairs bathroom	60	4	240	2	480	355	170,400	170.40	$	20.96
master bedroom fan	60	4	240	3	720	355	255,600	255.60	$	31.44
master bedroom	15	1	15	3	45	355	15,975	15.98	$	1.96
upstairs hallway	40	2	80	3	240	355	85,200	85.20	$	10.48
front bedroom	14	2	28	2	56	355	19,880	19.88	$	2.45
Total	332	23	979	25.951	3180.1	355	1,128,932	1,128.93	$	138.86

Table 4-7. New Lighting Energy Use with Behavioral Change

Compact Fluorescent Lamps									
Lighting	W/bulb	# of bulbs	Total Watts	Hours/day	Wh/day	Days/year	Wh/Year	kWh/Year	Costs for Lighting
dining room	13	3	39	6	234	355	83,070	83.07	$ 10.22
kitchen	40	2	80	1.5	120	355	42,600	42.60	$ 5.24
downstairs hallway	13	2	26	0.5	13	355	4,615	4.62	$ 0.57
downstairs bathroom	7	3	21	1	21	355	7,455	7.46	$ 0.92
upstairs bathroom	13	4	52	1.5	78	355	27,690	27.69	$ 3.41
master bedroom	13	4	52	1.5	78	355	27,690	27.69	$ 3.41
upstairs hallway	13	2	26	0.25	6.5	355	2,308	2.31	$ 0.28
front bedroom	14	2	28	4	112	355	39,760	39.76	$ 4.89
Total	126	22	324	16.25	662.5	355	235,188	235.19	$ 28.93

Table 4-8. LCC Existing Incandescent Bulbs and Consumption vs. CFL’s and Consumption

Compact Fluorescent Lighting LCC								
Year	Costs	kWh	Cost/kWh	Cost	PW Costs	PW Energy Costs		
0	$ 56.00	235	$ 0.12	$ 28.88	$ 56.00	$ 28.88		
1		235	$ 0.13	$ 29.74		$ 28.33		
2		235	$ 0.13	$ 30.64		$ 27.79		
3		235	$ 0.13	$ 31.55		$ 27.26		
4		235	$ 0.14	$ 32.50		$ 26.74		
5		235	$ 0.14	$ 33.48		$ 26.23		
6		235	$ 0.15	$ 34.48		$ 25.73		
7		235	$ 0.15	$ 35.52		$ 25.24		
8		235	$ 0.16	$ 36.58		$ 24.76		
9		235	$ 0.16	$ 37.68		$ 24.29		
10		235	$ 0.17	$ 38.81		$ 23.82		
Totals	$ 56.00	2,352		$ 369.85	$ 56.00	$ 260.18		
LCC					$ 56.00	$ 260.18	=	$ 316.18

Existing Lighting LCC								
Year	Costs	kWh	Cost/kWh	Costs	PW Costs	PW Energy Costs		
0	$ 2.00	1,129	$ 0.12	$ 138.61	$ 2.00	$ 138.61		
1	$ 2.03	1,129	$ 0.13	$ 142.77	$ 1.93	$ 135.97		
2	$ 2.06	1,129	$ 0.13	$ 147.06	$ 1.87	$ 133.38		
3	$ 2.09	1,129	$ 0.13	$ 151.47	$ 1.81	$ 130.84		
4	$ 2.12	1,129	$ 0.14	$ 156.01	$ 1.75	$ 128.35		
5	$ 2.15	1,129	$ 0.14	$ 160.69	$ 1.69	$ 125.91		
6	$ 2.19	1,129	$ 0.15	$ 165.51	$ 1.63	$ 123.51		
7	$ 2.22	1,129	$ 0.15	$ 170.48	$ 1.58	$ 121.16		
8	$ 2.25	1,129	$ 0.16	$ 175.59	$ 1.52	$ 118.85		
9	$ 2.29	1,129	$ 0.16	$ 180.86	$ 1.47	$ 116.58		
10	$ 2.32	1,129	$ 0.17	$ 186.29	$ 1.42	$ 114.36		
Totals	$ 21.73	11,289		$ 1,636.73	$ 18.68	$ 1,248.92		
LCC					$ 18.68	$ 1,248.92	=	$ 1,267.59

Table 4-9. Dryer Consumption and Cost Comparison

Exisitng Clothes Dryer				
kWh/Load	Loads/Year	kWh/Year	Cost/kWh	Cost/Year
2.88	252	725.00	$ 0.11	$ 78.96

Existing Clothes Dryer w/ New Washer				
kWh/Load	Loads/Year	kWh/Year	Cost/kWh	Cost/Year
0.72	252	181.25	$ 0.11	$ 19.74

Table 4-10. Washer Consumption and Cost Comparison

Existing Clothes Washer				
kWh/Load	Loads/Year	kWh/Year	Cost/kWh	Cost/Year
0.29	252	73.08	$ 0.12	$ 8.97

New Clothes Washer				
kWh/Load	Loads/Year	kWh/Year	Cost/kWh	Cost/Year
0.51	252	128.52	$ 0.12	$ 15.78

Table 4-11. LCC Existing Washer and Dryer

Existing Clothes Dryer								
Year	Costs	kWh used	Cost/kWh	Costs	PW Costs	PW Energy Costs		
0	$ -	725	$ 0.12	$ 89.02	$ -	$ 89.02		
1	$ -	725	$ 0.13	$ 91.69	$ -	$ 87.32		
2	$ -	725	$ 0.13	$ 94.44	$ -	$ 85.66		
3	$ -	725	$ 0.13	$ 97.27	$ -	$ 84.03		
4	$ -	725	$ 0.14	$ 100.19	$ -	$ 82.43		
5	$ -	725	$ 0.14	$ 103.20	$ -	$ 80.86		
6	$ -	725	$ 0.15	$ 106.29	$ -	$ 79.32		
7	$ -	725	$ 0.15	$ 109.48	$ -	$ 77.81		
8	$ -	725	$ 0.16	$ 112.77	$ -	$ 76.32		
9	$ -	725	$ 0.16	$ 116.15	$ -	$ 74.87		
10	$ -	725	$ 0.17	$ 119.63	$ -	$ 73.44		
Totals	$ -	7,250		$ 1,140.12	$ -	$ 802.05		
LCC					$ -	$ 802.05	=	$ 802.05

Existing Washer								
Year	Costs	kWh used	Cost/kWh	Costs	PW Costs	PW Energy Costs		
0	$ -	73	$ 0.12	$ 8.97	$ -	$ 8.97		
1	$ -	73	$ 0.13	$ 9.24	$ -	$ 8.80		
2	$ -	73	$ 0.13	$ 9.52	$ -	$ 8.63		
3	$ -	73	$ 0.13	$ 9.81	$ -	$ 8.47		
4	$ -	73	$ 0.14	$ 10.10	$ -	$ 8.31		
5	$ -	73	$ 0.14	$ 10.40	$ -	$ 8.15		
6	$ -	73	$ 0.15	$ 10.71	$ -	$ 8.00		
7	$ -	73	$ 0.15	$ 11.04	$ -	$ 7.84		
8	$ -	73	$ 0.16	$ 11.37	$ -	$ 7.69		
9	$ -	73	$ 0.16	$ 11.71	$ -	$ 7.55		
10	$ -	73	$ 0.17	$ 12.06	$ -	$ 7.40		
Totals	$ -	731		$ 114.92	$ -	$ 80.85		
LCC					$ -	$ 80.85	=	$ 80.85
			Dryer	Washer				
Total LCC			$ 802.05	$ 80.85			=	$ 882.90

Table 4-12. LCC Existing Dryer w/ New Washer

Existing Clothes Dryer								
Year	Costs	kWh used	cost/kWh	Costs	PW Costs	PW Energy Costs		
0	$ -	725	$ 0.12	$ 89.02	$ -	$ 89.02		
1	$ -	725	$ 0.13	$ 91.69	$ -	$ 87.32		
2	$ -	725	$ 0.13	$ 94.44	$ -	$ 85.66		
3	$ -	725	$ 0.13	$ 97.27	$ -	$ 84.03		
4	$ -	725	$ 0.14	$ 100.19	$ -	$ 82.43		
5	$ -	725	$ 0.14	$ 103.20	$ -	$ 80.86		
6	$ -	725	$ 0.15	$ 106.29	$ -	$ 79.32		
7	$ -	725	$ 0.15	$ 109.48	$ -	$ 77.81		
8	$ -	725	$ 0.16	$ 112.77	$ -	$ 76.32		
9	$ -	725	$ 0.16	$ 116.15	$ -	$ 74.87		
10	$ -	725	$ 0.17	$ 119.63	$ -	$ 73.44		
Totals	$ -	7,250		$ 1,140.12	$ -	$ 802.05		
LCC					$ -	$ 802.05	=	$ 802.05

Existing Clothes Dryer w/ New Washer								
Year	Costs	kWh used	Cost/kWh	Costs	PW Costs	PW Energy Costs		
0		181	$ 0.12	$ 22.25	$ -	$ 22.25		
1		181	$ 0.13	$ 22.92	$ -	$ 21.83		
2		181	$ 0.13	$ 23.61	$ -	$ 21.41		
3		181	$ 0.13	$ 24.32	$ -	$ 21.01		
4		181	$ 0.14	$ 25.05	$ -	$ 20.61		
5		181	$ 0.14	$ 25.80	$ -	$ 20.21		
6		181	$ 0.15	$ 26.57	$ -	$ 19.83		
7		181	$ 0.15	$ 27.37	$ -	$ 19.45		
8		181	$ 0.16	$ 28.19	$ -	$ 19.08		
9		181	$ 0.16	$ 29.04	$ -	$ 18.72		
10		181	$ 0.17	$ 29.91	$ -	$ 18.36		
Totals	$ -	1,813		$ 285.03	$ -	$ 200.51		
LCC					$ -	$ 200.51	=	$ 200.51

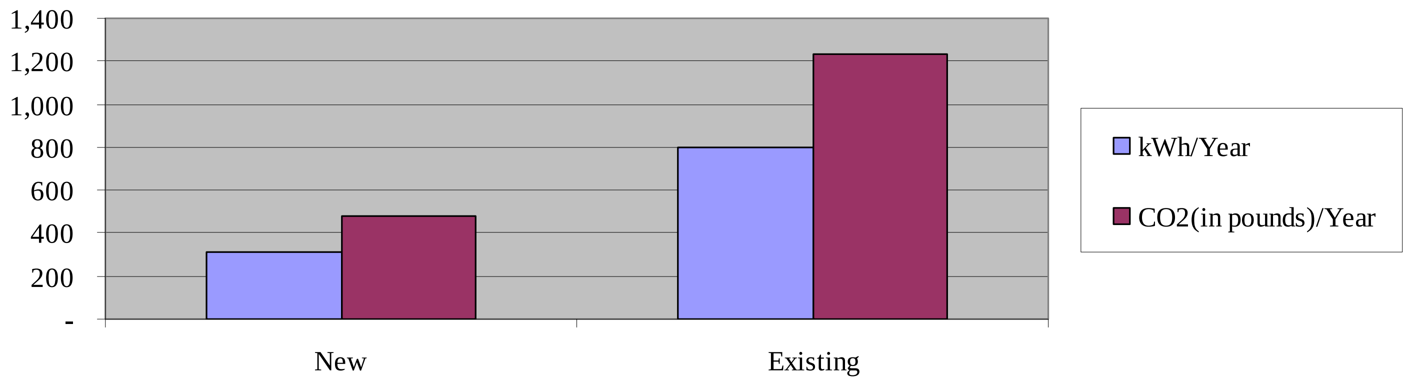


Figure 4-5. Washer/Dryer Comparisons

Table 4-13. Energy Consumption

Existng 10 SEER 2-TON Unit												
Air Conditioning	# of tons	x	Btu/h	x	hours/year	x	1/SEER	x	1kW/1000W	=	kWh/year
	2		24,000		1,846		0.10		0.001		4,430

20 SEER 2-TON Unit											
Air Conditioning	# of tons	x	Btu/h	x	hours/year	x	1/SEER	x	1kW/1000W	=	kWh/year
	2		24,000		1,500		0.05		0.001		1,800

Table 4-14. HVAC LCC Comparison

Existng 10 SEER 2-TON Unit LCC								
Year	Costs	kWh used	Cost/kWh	Costs	PW Costs	PW Energy Costs		
0	$ 50.00	4,430	$ 0.12	$ 543.98	$ 50.00	$ 543.98		
1		4,430	$ 0.13	$ 560.30	$ -	$ 533.62		
2	$ 51.51	4,430	$ 0.13	$ 577.11	$ 46.72	$ 523.45		
3		4,430	$ 0.13	$ 594.42	$ -	$ 513.48		
4	$ 53.07	4,430	$ 0.14	$ 612.25	$ 43.66	$ 503.70		
5		4,430	$ 0.14	$ 630.62	$ -	$ 494.11		
6	$ 54.67	4,430	$ 0.15	$ 649.54	$ 40.80	$ 484.70		
7		4,430	$ 0.15	$ 669.03	$ -	$ 475.46		
8	$ 56.32	4,430	$ 0.16	$ 689.10	$ 38.12	$ 466.41		
9		4,430	$ 0.16	$ 709.77	$ -	$ 457.52		
10	$ 58.03	4,430	$ 0.17	$ 731.06	$ 35.62	$ 448.81		
Totals	$ 323.60	44,304		$ 6,967.18	$ 254.93	$ 4,901.27		
LCC					$ 254.93	$ 4,901.27	=	$ 5,156.19

20 SEER 2-TON Unit LCC								
Year	Costs	kWh	Cost/kWh	Costs	PW Costs	PW Energy Costs		
0	$ 500.00	1,800	$ 0.12	$ 223.52	$ 500.00	$ 223.52		
1		1,800	$ 0.13	$ 227.64		$ 216.80		
2		1,800	$ 0.13	$ 234.47		$ 212.67		
3		1,800	$ 0.13	$ 241.50		$ 208.62		
4		1,800	$ 0.14	$ 248.75		$ 204.65		
5		1,800	$ 0.14	$ 256.21		$ 200.75		
6		1,800	$ 0.15	$ 263.90		$ 196.92		
7		1,800	$ 0.15	$ 271.81		$ 193.17		
8		1,800	$ 0.16	$ 279.97		$ 189.49		
9		1,800	$ 0.16	$ 288.37		$ 185.88		
10		1,800	$ 0.17	$ 297.02		$ 182.34		
Totals	$ 500.00	18,000		$ 2,833.16	$ 500.00	$ 1,991.31		
LCC					$ 500.00	$ 1,991.31	=	$ 2,491.31

Table 4-15. Energy Reduction and Cost Savings

Existing Water Heater		
kWh/Year	Cost/kWh	Cost/Year
3,906	$ 0.12	$ 479.65

Solar Thermal Water Heater		
kWh/Year	Cost/kWh	Cost/Year
586	$ 0.12	$ 71.95

Table 4-16. Electric and Solar Hot Water LCC Comparison

Electric Hot Water

Year	Costs	kWh used	Cost/kWh	Costs	PW Costs	PW Energy Costs		
0	$ -	3,906	$ 0.12	$ 479.65	$ -	$ 479.65		
1	$ -	3,906	$ 0.13	$ 494.04	$ -	$ 470.51		
2	$ -	3,906	$ 0.13	$ 508.86	$ -	$ 461.55		
3	$ -	3,906	$ 0.13	$ 524.12	$ -	$ 452.76		
4	$ -	3,906	$ 0.14	$ 539.85	$ -	$ 444.13		
5	$ -	3,906	$ 0.14	$ 556.04	$ -	$ 435.67		
6	$ -	3,906	$ 0.15	$ 572.73	$ -	$ 427.38		
7	$ -	3,906	$ 0.15	$ 589.91	$ -	$ 419.24		
8	$ -	3,906	$ 0.16	$ 607.60	$ -	$ 411.25		
9	$ -	3,906	$ 0.16	$ 625.83	$ -	$ 403.42		
10	$ -	3,906	$ 0.17	$ 644.61	$ -	$ 395.73		
11	$ -	3,906	$ 0.17	$ 663.95	$ -	$ 388.20		
12	$ -	3,906	$ 0.18	$ 683.86	$ -	$ 380.80		
13	$ -	3,906	$ 0.18	$ 704.38	$ -	$ 373.55		
14	$ -	3,906	$ 0.19	$ 725.51	$ -	$ 366.43		
15	$ -	3,906	$ 0.19	$ 747.28	$ -	$ 359.45		
16	$ -	3,906	$ 0.20	$ 769.69	$ -	$ 352.61		
17	$ -	3,906	$ 0.20	$ 792.79	$ -	$ 345.89		
18	$ -	3,906	$ 0.21	$ 816.57	$ -	$ 339.30		
19	$ -	3,906	$ 0.22	$ 841.07	$ -	$ 332.84		
20	$ -	3,906	$ 0.22	$ 866.30	$ -	$ 326.50		
Totals	$ -	82,036		$ 13,754.63	$ -	$ 7,887.21		
LCC					$ -	$ 7,887.21	=	$ 7,887.21

Solar Hot Water

Year	Costs	kWh used	Cost/kWh	Costs	PW Costs	PW Energy Costs		
0	$ 2,500.00	586	$ 0.12	$ 71.95	$ 2,500.00	$ 71.95		
1	$ -	586	$ 0.13	$ 74.11	$ -	$ 70.58		
2	$ -	586	$ 0.13	$ 76.33	$ -	$ 69.23		
3	$ -	586	$ 0.13	$ 78.62	$ -	$ 67.91		
4	$ -	586	$ 0.14	$ 80.98	$ -	$ 66.62		
5	$ -	586	$ 0.14	$ 83.41	$ -	$ 65.35		
6	$ -	586	$ 0.15	$ 85.91	$ -	$ 64.11		
7	$ -	586	$ 0.15	$ 88.49	$ -	$ 62.89		
8	$ -	586	$ 0.16	$ 91.14	$ -	$ 61.69		
9	$ -	586	$ 0.16	$ 93.87	$ -	$ 60.51		
10	$ -	586	$ 0.17	$ 96.69	$ -	$ 59.36		
11	$ -	586	$ 0.17	$ 99.59	$ -	$ 58.23		
12	$ -	586	$ 0.18	$ 102.58	$ -	$ 57.12		
13	$ -	586	$ 0.18	$ 105.66	$ -	$ 56.03		
14	$ -	586	$ 0.19	$ 108.83	$ -	$ 54.96		
15	$ -	586	$ 0.19	$ 112.09	$ -	$ 53.92		
16	$ -	586	$ 0.20	$ 115.45	$ -	$ 52.89		
17	$ -	586	$ 0.20	$ 118.92	$ -	$ 51.88		
18	$ -	586	$ 0.21	$ 122.49	$ -	$ 50.90		
19	$ -	586	$ 0.22	$ 126.16	$ -	$ 49.93		
20	$ -	586	$ 0.22	$ 129.94	$ -	$ 48.97		
Totals	$ 2,500.00	11,719		$ 2,063.19	$ 2,500.00	$ 1,183.08		
LCC					$ 2,500.00	$ 1,183.08	=	$ 3,683.08

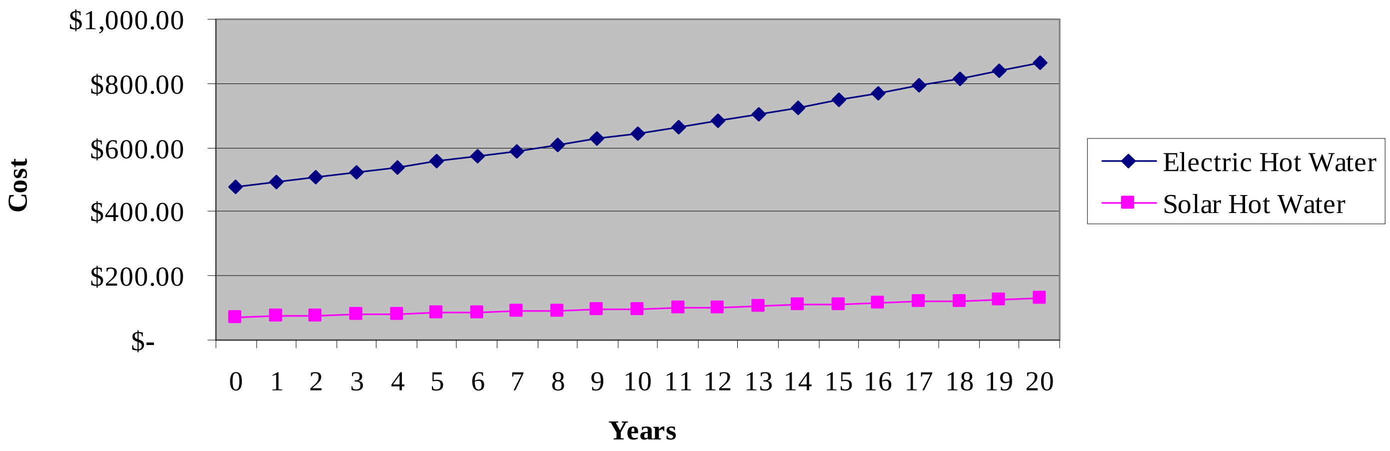


Figure 4-6. Costs vs. Years between the Hot Water Systems

Table 4-17. Historical vs. Present Consumption

Time Frame	Consumption	Total Costs	Time Frame	Consumption	Total Costs
Oct-07	1226	$ 172.50	Oct-08	826	$ 122.71
Nov-07	954	$ 128.76	Nov-08	641	$ 94.22
Dec-07	816	$ 106.57	Dec-08	651	$ 94.28
Jan-08	1016	$ 138.73	Jan-09	682	$ 98.52
Total	4012	$ 546.56	Total	2800	$ 409.73

Table 4-18. Size of PV – before and after reduction

kW System	kWh per Day	kWh per Month	kWh per 4 Months
6.7	34	1,005	4,020
4.7	24	705	2,820

Table 4-19. Reduced Consumption kW System

kW System	kWh per Day	kWh per Month	kWh per 4 Months
3.5	17.5	525	2100

Table 4-20. PV vs. Solar Thermal

PV SYSTEM				
kW System	kWh per Day	kWh per Month	kWh per 4 Months	Total SF
1.2	6	180	720	80

SOLAR THERMAL SYSTEM				
System	kWh per Day	kWh per Month	kWh per 4 Months	Total SF
Flat-Plate Collector	6	175	700	40

Table 4-21. Old Energy Use vs. New Energy Use

New Energy Use		Old Energy Use	
Appliances and Electronices	Annual kWh	Appliances and Electronices	Annual kWh
HVAC	1,800	HVAC	4,431
Water Heater	586	Water Heater	3,906
Televisions	1,071	Televisions	1,071
Dryer	181	Dryer	726
Lights	765	Lights	1,129
Refrigerator	1,374	Refrigerator	1,374
Washing machine	129	Washing machine	97
Computers	197	Computers	197
Dishwasher	126	Dishwasher	126
Microwave Oven	26	Microwave Oven	26
Stove	138	Stove	138
Total	6,394	Total	13,222

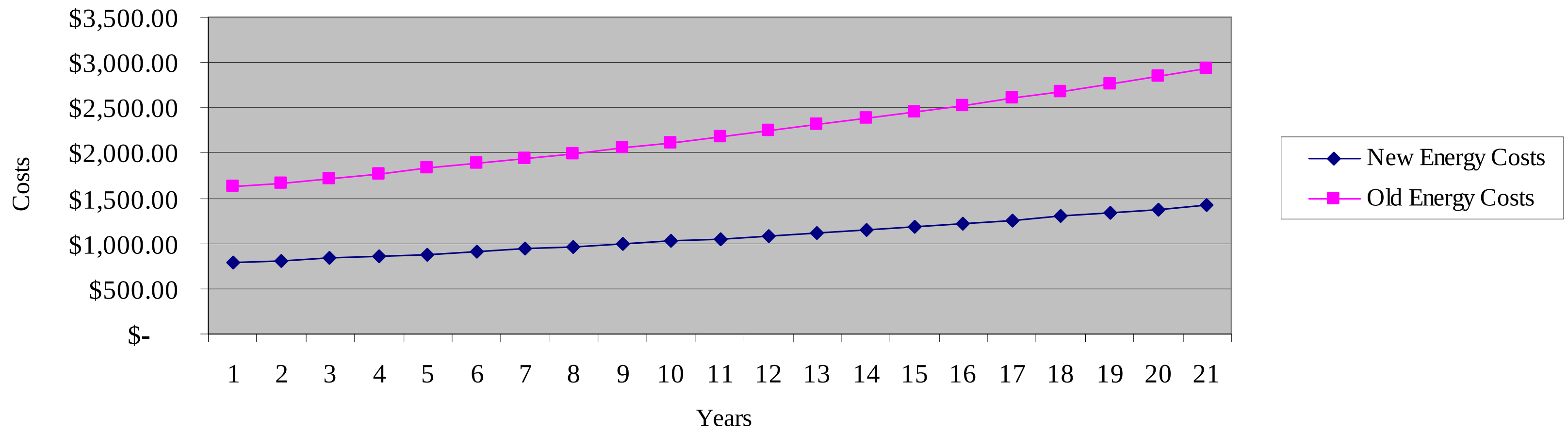


Figure 4-7. Home Energy Costs Comparison

Table 4-22. PV and Solar Thermal LCC Comparison

PV and Solar Thermal LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 1,999.57	$ 26,944.44	$ 18,734.66	$ 428.37	$ 854.97	$ 13,694.06	$ 15,597.97	$ 955.00	$ 4,634.64

Energy Use LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 13,694.06		$ -	$ -	$ -	$ 13,694.06		$ -	$ -

Table 4-23. LCC Comparison using Historical Consumption

PV and Solar Thermal LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 26,813.39	$ 25,561.37	$ 18,718.56	$ 428.37	$ 854.97	$ 28,318.86	$ 4,280.60	$ 954.28	$ 4,396.75

Energy Use LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 28,318.86		$ -	$ -	$ -	$ 28,318.86		$ -	$ -

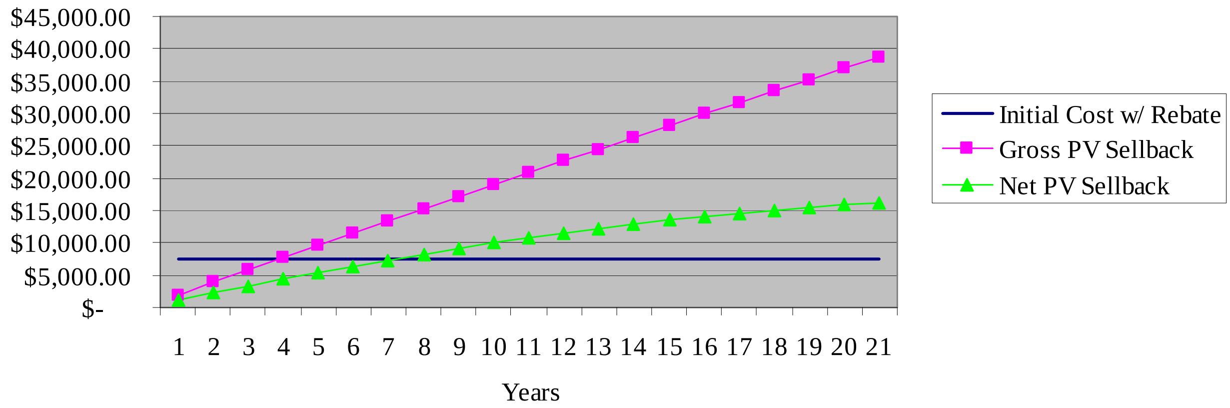


Figure 4-8. Gross and Net Payback Time for Solar Systems with Efficiency Upgrades

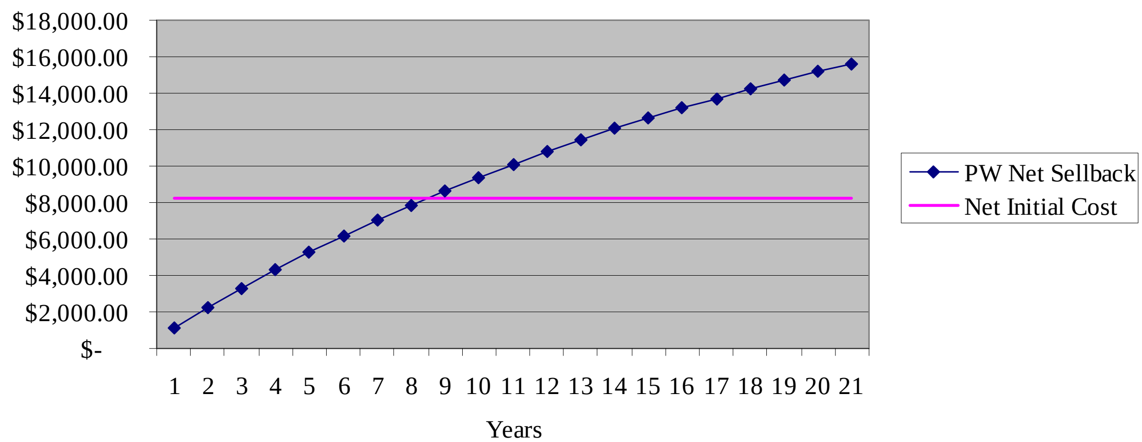


Figure 4-9. Discounted Payback Time for Solar Systems with Efficiency Upgrades

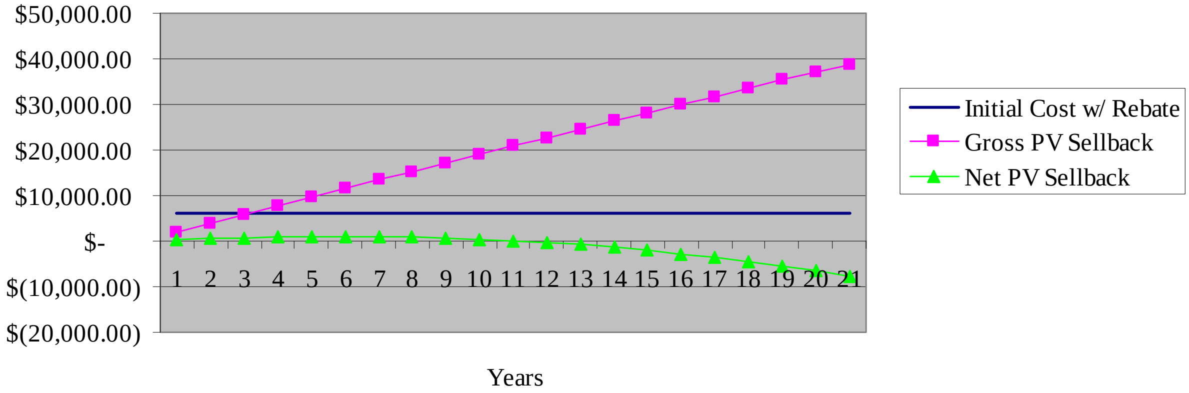


Figure 4-10. Payback for Solar Systems without Efficiency Upgrades

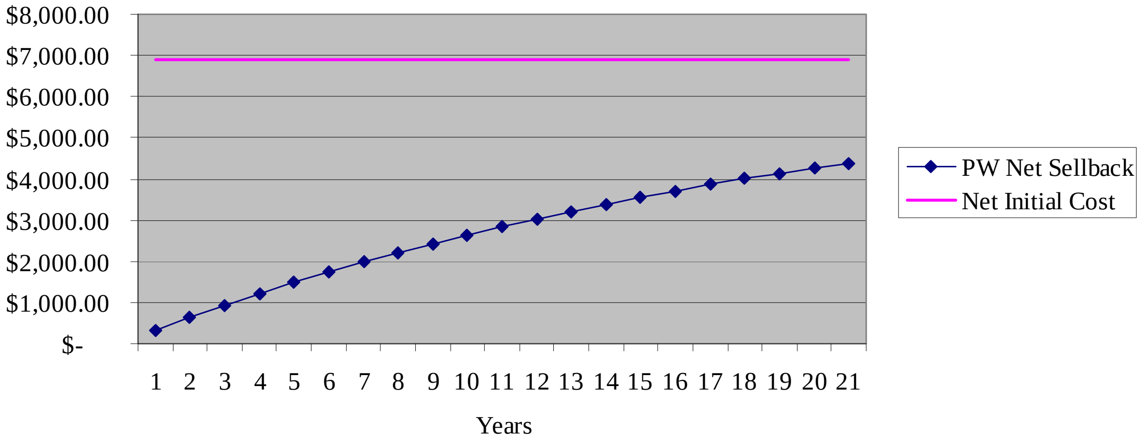


Figure 4-11. Discounted Payback for Solar Systems without Efficiency Upgrades

Table 4-24. Historical Consumption w/ Larger PV System

PV and Solar Thermal LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 13,008.69	$ 50,246.11	$ 24,333.33	$ 428.37	$ 854.97	$ 28,318.86	$ 32,256.09	$ 1,607.51	$ 8,642.70

Energy Use LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 28,318.86		$ -	$ -	$ -	$ 28,318.86		$ -	$ -

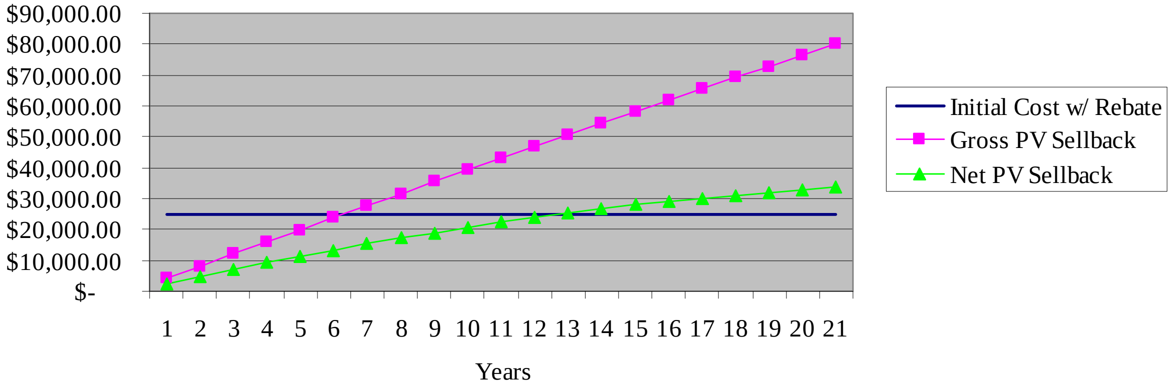


Figure 4-12. PV Payback Time of the Larger Solar System without Efficiency Upgrades

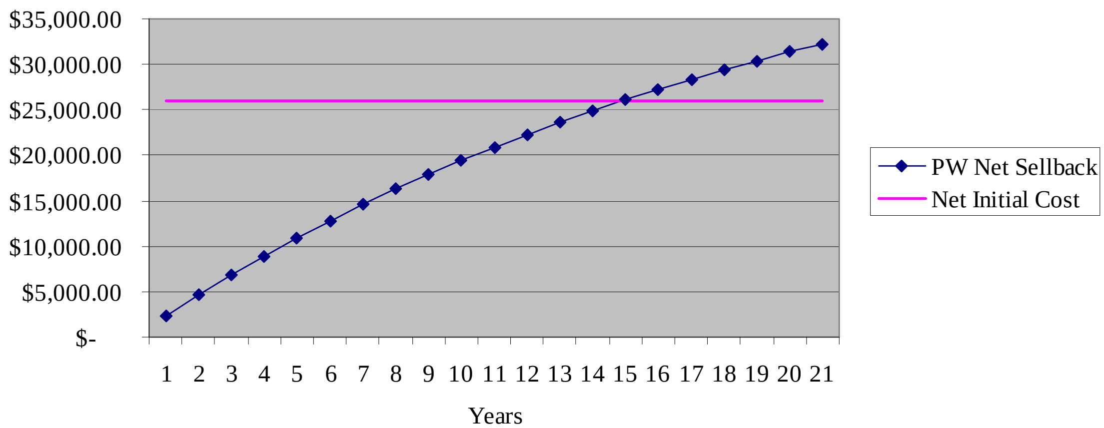


Figure 4-13. Discounted Payback – Historical Consumption w/ 7.35kW system

Table 4-25. LCC – 7,000 kWh/annually

PV and Solar Thermal LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 1,148.72	$ 27,777.78	$ 20,037.04	$ 428.37	$ 854.97	$ 14,992.59	$ 17,077.04	$ 1,012.93	$ 4,777.98

Energy Use LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 14,992.59		$ -	$ -	$ -	$ 14,992.59		$ -	$ -

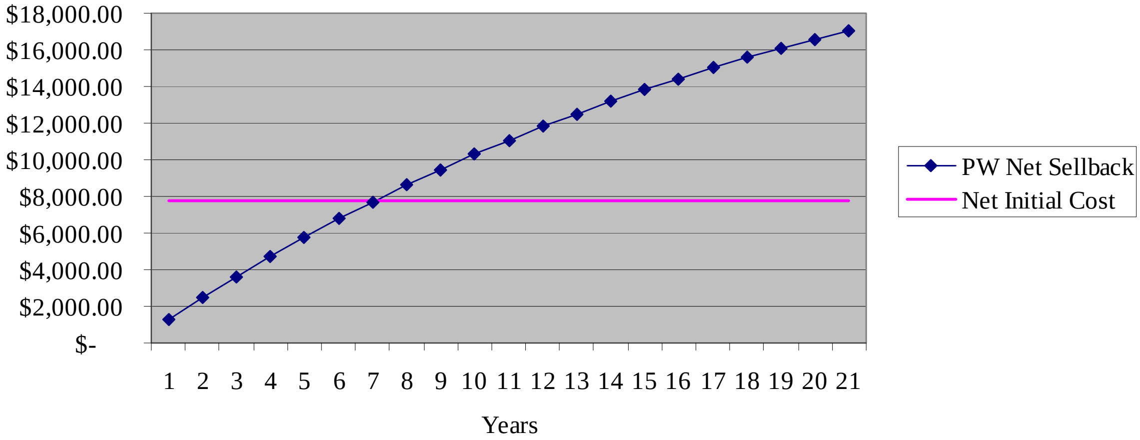


Figure 4-14. Discounted Payback – 7,000 kWh/annually

Table 4-26. LCC – 8,000 kWh/annually

PV and Solar Thermal LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 1,597.20	$ 31,388.89	$ 22,185.19	$ 428.37	$ 854.97	$ 17,134.39	$ 19,516.62	$ 1,108.49	$ 5,399.12

Energy Use LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 17,134.39		$ -	$ -	$ -	$ 17,134.39		$ -	$ -

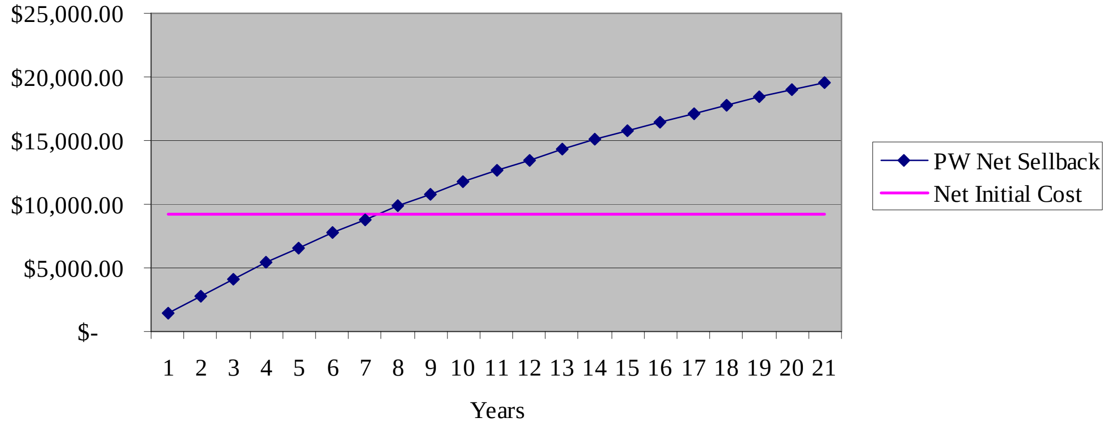


Figure 4-15. Discounted Payback – 8,000 kWh/annually

Table 4-27. LCC – 9,000 kWh/annually

PV and Solar Thermal LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 2,045.69	$ 35,000.00	$ 24,333.33	$ 428.37	$ 854.97	$ 19,276.19	$ 21,956.19	$ 1,204.05	$ 6,020.26

Energy Use LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 19,276.19		$ -	$ -	$ -	$ 19,276.19		$ -	$ -

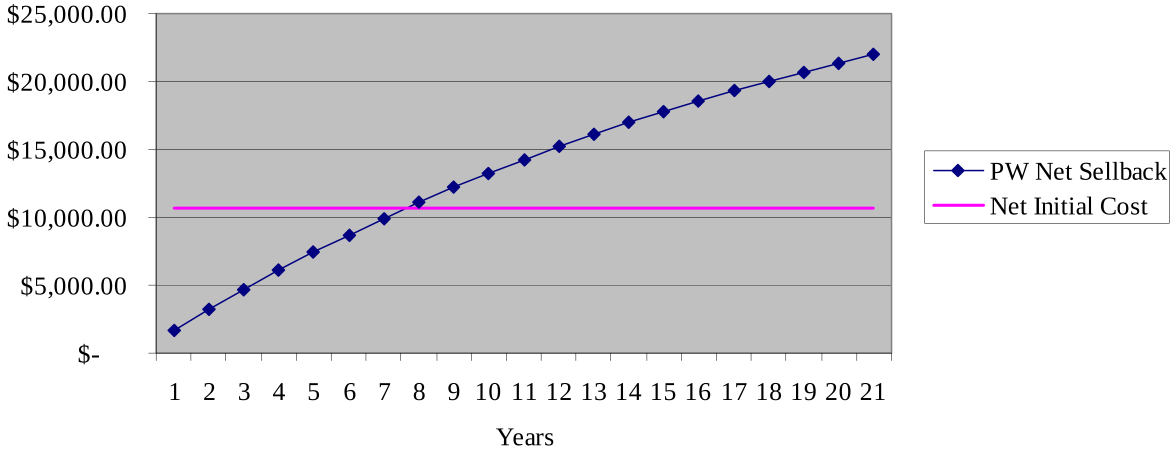


Figure 4-16. Discounted Payback – 9,000 kWh/annually

Table 4-28. LCC – 10,000 kWh/annually

PV and Solar Thermal LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 4,642.33	$ 38,611.11	$ 24,333.33	$ 428.37	$ 854.97	$ 21,417.99	$ 24,395.77	$ 1,299.61	$ 6,641.40

Energy Use LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 21,417.99		$ -	$ -	$ -	$ 21,417.99		$ -	$ -

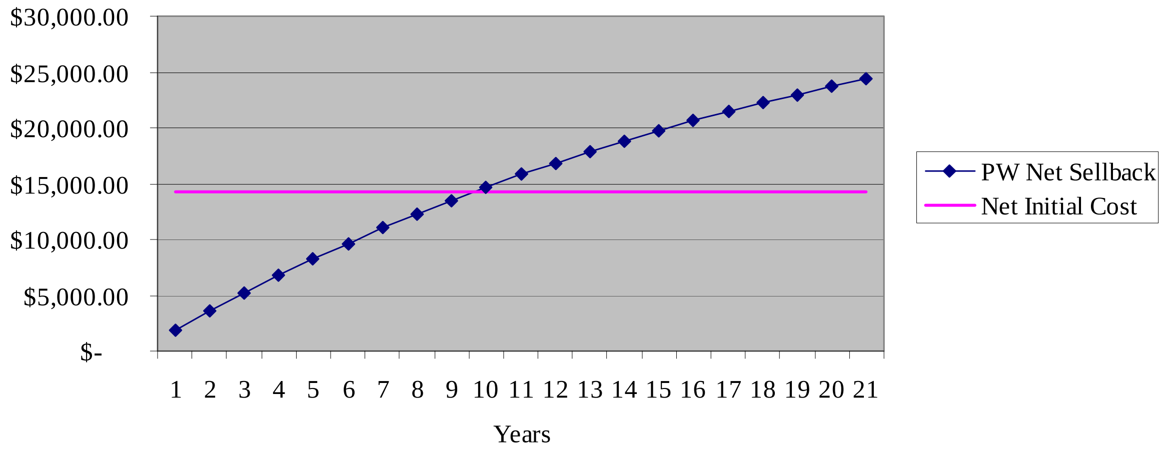


Figure 4-17. Discounted Payback – 10,000 kWh/annually

Table 4-29. LCC – 11,000 kWh/annually

PV and Solar Thermal LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 7,238.96	$ 42,222.22	$ 24,333.33	$ 428.37	$ 854.97	$ 23,559.79	$ 26,835.35	$ 1,395.17	$ 7,262.54

Energy Use LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 23,559.79		$ -	$ -	$ -	$ 23,559.79		$ -	$ -

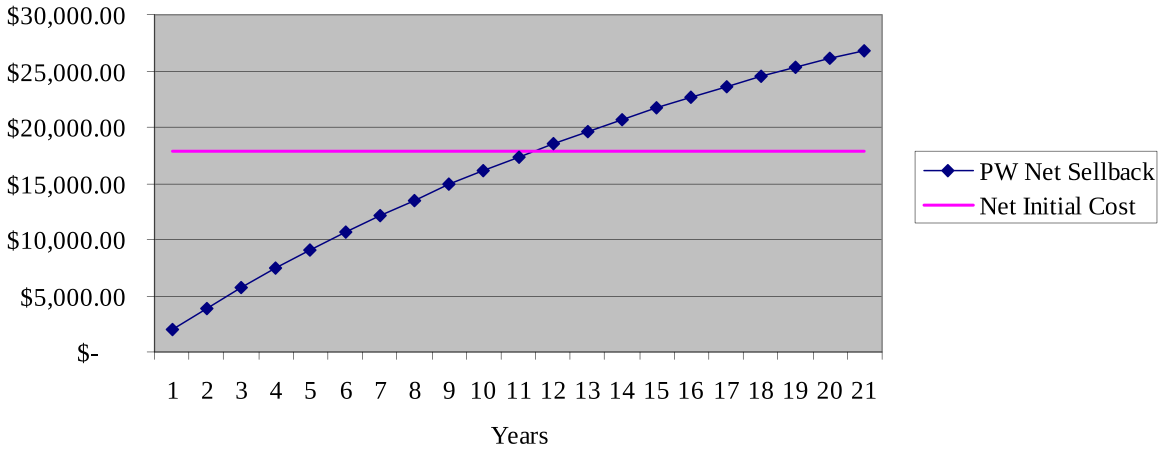


Figure 4-18. Discounted Payback – 11,000kWh/annually

Table 4-30. LCC – 12,000 kWh/annually

PV and Solar Thermal LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 9,835.60	$ 45,833.33	$ 24,333.33	$ 428.37	$ 854.97	$ 25,701.59	$ 29,274.92	$ 1,490.73	$ 7,883.67

Energy Use LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 25,701.59		$ -	$ -	$ -	$ 25,701.59		$ -	$ -

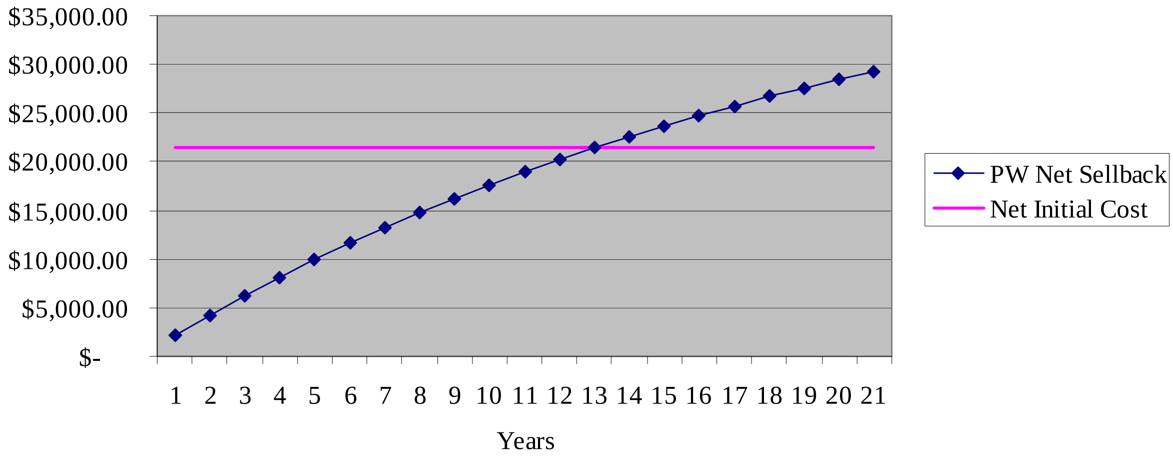


Figure 4-19. Discounted Payback – 12,000 kWh/annually

Table 4-31. LCC – 13,000 kWh/annually

PV and Solar Thermal LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 12,432.23	$ 49,444.44	$ 24,333.33	$ 428.37	$ 854.97	$ 27,843.39	$ 31,714.50	$ 1,586.29	$ 8,504.81

Energy Use LCC								
LCC	Cost	Rebates	O & M	R & R	Gross Energy Costs	Net Sellback	Increase in Equity	Salvage Value
$ 27,843.39		$ -	$ -	$ -	$ 27,843.39		$ -	$ -

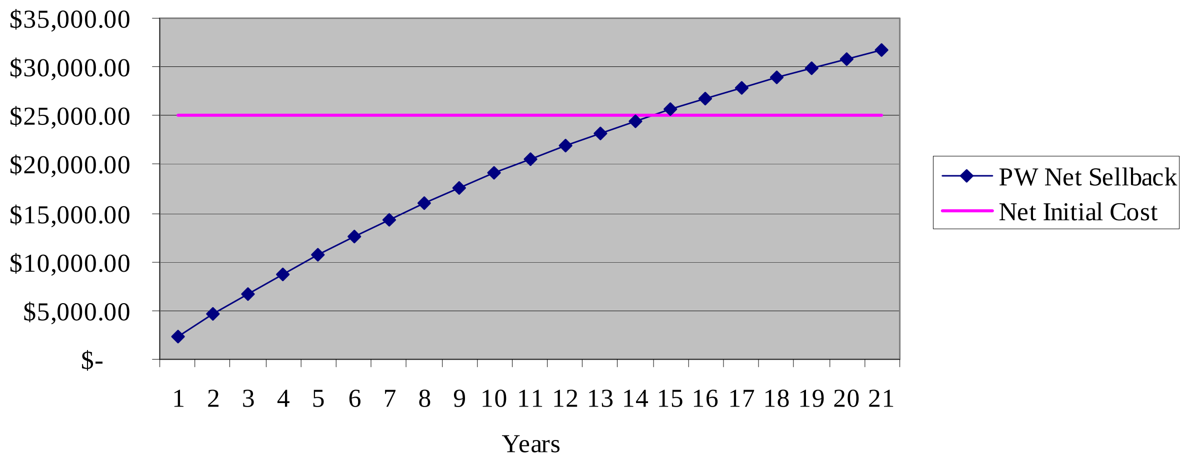


Figure 4-20. Discounted Payback – 13,000 kWh/annually

Table 4-32. Sensitivity Analysis Summary

Consumption in kWh	Size of PV	LCC
7,000	3.89	$ 1,148.72
8,000	4.44	$ 1,597.20
9,000	5.00	$ 2,045.69
10,000	5.56	$ 4,642.33
11,000	6.11	$ 7,238.96
12,000	6.67	$ 9,835.60
13,000	7.22	$ 12,432.23

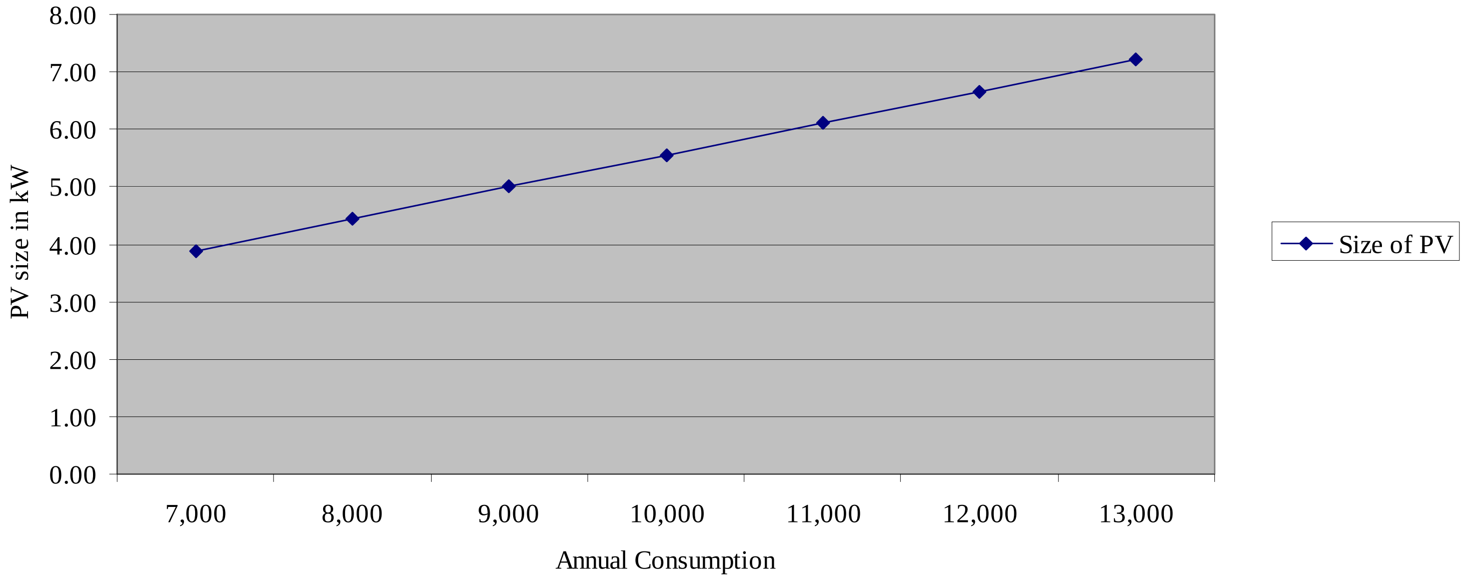


Figure 4-21. Size of system to produce 100% of consumption

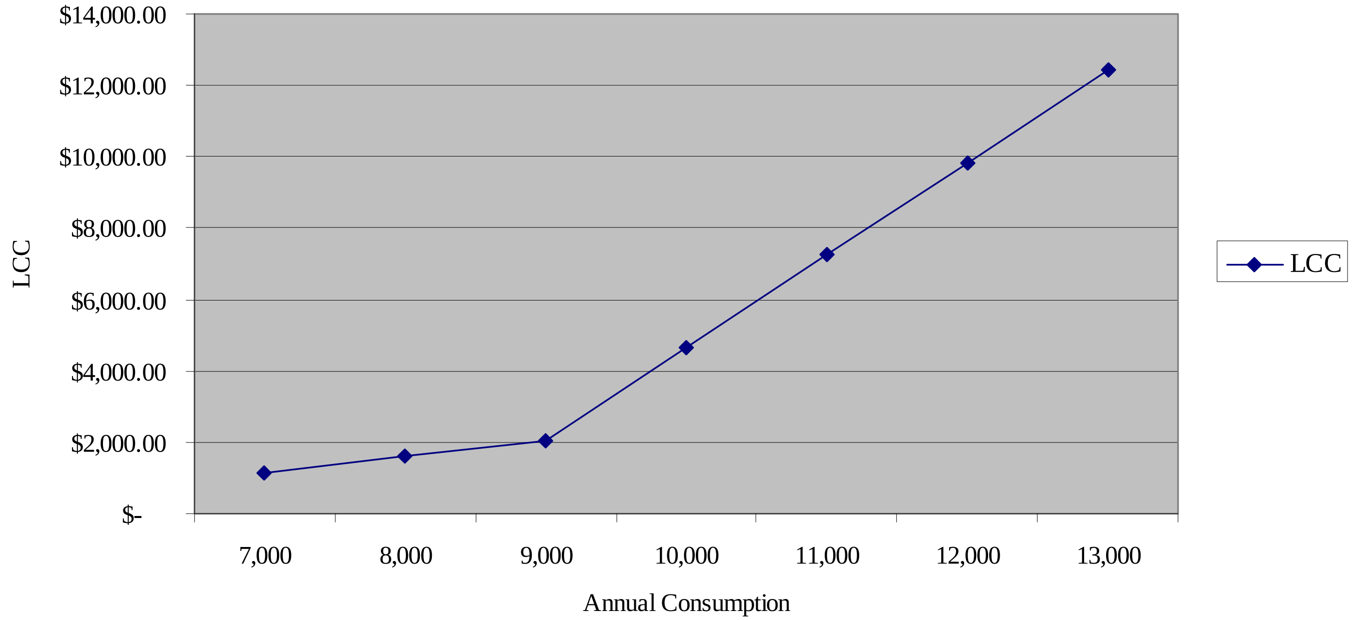


Figure 4-22. LCC of System for 100% of Consumption

Table 4-33. Percent Production Analysis Summary

Percent Production	Size of PV	LCC
200	7.1	$ (11,259.41)
190	6.75	$ (10,493.38)
180	6.39	$ (9,727.35)
170	6.04	$ (8,961.32)
160	5.68	$ (8,195.29)
150	5.33	$ (7,429.26)
140	4.97	$ (6,558.42)
130	4.62	$ (4,418.92)
120	4.26	$ (2,279.43)
110	3.91	$ (139.93)
100	3.55	$ 1,999.57
90	3.20	$ 4,139.06
80	2.84	$ 6,278.56
70	2.49	$ 8,418.06
60	2.13	$ 10,557.55
50	1.78	$ 12,697.05

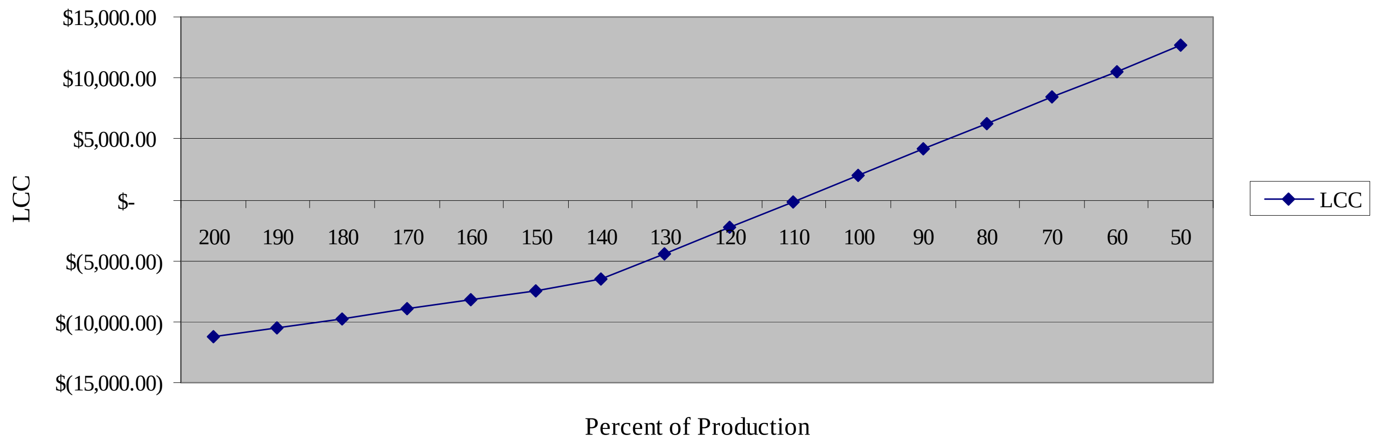


Figure 4-23. LCC for Sensitivity Analyses

CHAPTER 5
CONCLUSIONS

Today's homeowners need to have knowledge of the electrical consumption of their home. The method by which electrical consumption is reduced is site specific. In general, the means of reducing consumption is less expensive compared to not reducing consumption. Once educated on where most of the consumption occurs, decisions can be made on what and how much money should be spent on upgrades using LCC tables to see whether or not the upgrade is feasible. As stated previously, the new alternative may have a greater LCC, but the consumption maybe less. It is because of this fact, that a greater LCC for an efficiency upgrade can make the PV more feasible, thus making the overall LCC lower. The reduction of energy is important for solar electric installation, and should be done before sizing the PV for the current consumption.

With regards to the size of the PV, a sensitivity analysis became important when comparing the sizes related to the production to consumption ratio. Installing a larger size system that produces more electricity than consumed proved to be less expensive over the life of the system, even though there was a greater expense initially.

The energy reducing template was important in reduction of electricity, which allowed for a PV system to be installed on the south facing roof. The reduction template also proved to be effective in making the home a net zero energy home. The LCC template was set up so the consumption was entered and the size and LCC of the PV and the solar thermal was calculated.

CHAPTER 6
RECOMMENDATIONS

For future studies of life cycle costing of PV and solar thermal, examining different manufacturers of PV and different solar thermal systems for a specific site might influence the optimum systems. Colder climates might need different systems to deal with the weather. The energy reducing template could be used in other homes, but there may be a change made to the spreadsheet, to include other items in the home. Also this template could be used to compare homes built over different periods of time, by looking at the principal building materials. Two buildings/homes from different periods, in the same area, would allow for the examination of construction methods, and how those methods affect the consumption with regards to the envelope. There is more than one technology that allows a home to be a net zero energy home, and those could be explored. The key would not be to try to cover every aspect of consumption, but simply, a specific area.

This template could be used with commercial buildings, but just on a larger scale. Commercial buildings have historical data and typically a set occupancy schedule. It would also have different system options systems that are not seen in residential.

Further research could be done on the envelope of the home. This area could be explored more with hand calculations as well as an energy model to alter the glazing type and size, as well as insulation. The glazing and insulation could then be put into an LCC table and compared with the existing materials.

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BIOGRAPHICAL SKETCH

Kevin received his M.S.B.C. from the University of Florida in the summer of 2009. He first attended the University of Florida in the fall of 2002, as a transfer student from Daytona Beach Community College, now Daytona State College. He received his Bachelor of Design in Architecture from the University of Florida in the spring 2006. He is currently pursuing a Ph.D. in building construction with a continued focus in solar technologies for residential and commercial applications.