Photovoltaic Electricity, Solar Water Heating and Geothermal Acclimatization: Forecast feasibility analysis for a Residence in Miami

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ABSTRACT

Renewable energy technologies have suffered great improvements during recent years; it has been encouraged by government subsidies and altruism. Thinking on renewable energy replacing the fossil fuels has to be framed by the causes implied by it within the market: They are price competitive. Increasing prices in energy combined with a reduction on the cost of alternative energy catalyzed by the reduction of consumption by other technological means set a scenario in perspective. This study evaluates the economic feasibility analysis of photovoltaic electricity in combination with solar water heating and geothermal acclimatization for a real typical case of study. Further, it forecast the behavior of the market for subsequent years until economic feasibility is achieved. A sensitivity analysis is also implemented to describe other possible outcome.

Keywords: Photovoltaics, Solar Water Heater, Geothermal Acclimatization, Economic Analysis, Life Cycle Analysis.

1. INTRODUCTION

The debate about energy dependence has been a very controversial issue, and with it, the means of obtaining energy has raised another component related to the sustainability of the planet more properly defined as Environmental Impact. The most critical factor of this Environmental Impact is given to Global Warming caused by rising levels of CO2 in the atmosphere.

The attention related to global warming potential has been directed to the major contributors: Transportation and Energy Production. However it is unavoidable to raise a concern after revising the contributions by sector (EPA 2009), the amount of GWP is higher for the production of electricity than for Transportation. Additionally Buildings in the US account for 39% of nationwide CO2 emissions (Ochsendorf, 2010), making it the greatest contributor in terms of GWP.

The generation of energy using large scale sun farms provide a mean of renewable energy, however this structure of industry demands the acquisition of land, the construction of transmission lines (with the consequent loses of efficiency) and the fixation of solar panels into a structure in addition to required access infrastructure. This elevates the competitiveness of small photovoltaic systems connected to an existing grid, as the fee for land and infrastructure is waived and the building itself provides the structure to fix panels. The customer owned generation has been perceived for a while as market with a high potential of expansion (Jones, 1992), and the increase on the prices of energy with the continuous reduction in cost on the implementation of a photovoltaic energy producing system, is setting the required mechanisms of increase in the demand that triggers innovation from the companies wanting to increase their share or position themselves in the market. As more companies enter into the competition attracted by the profitability of the market, the prices will have the tendency to decrease and then equilibrium in the market is naturally achieved. In the beginning, the major obstacle towards a wide implementation of the technology used to be the industrialization of the process of production that would lead to a price reduction due to the scale effect (Jones 1992), but with the development of the market, more industrialized and standardized processes have paved the road towards a mass implementation of the system.

This makes clear the necessity of evaluation of the feasibility of Building Energy Sufficiency for residences that comply with all the modern standards in terms of comfort ability. This study looks to evaluate the performance of combining Photovoltaic Energy Generation accounting for the savings in consumption achieved by installing a solar water heater and Geothermal Acclimatization. Also making use of Economic Forecasting, a series of future yearly scenarios will be constructed to find when it is expected to break even and have a real feasible project.

The advantage of having a self sufficient energy home is not limited to the economic factor; it implies a reduction on the emissions with Global Warming Potential produced by sourcing the energy from fossil fuels with its consequent dependency on foreign resources. Even though this study is limited by the extents of the case analyzed it provides an illustration of the mechanisms interacting in the integrated process of technology and economics towards sustainability; and the model looks to be synergic with the inertia of the actual market oriented society in which we are contextualized.

2. LITERATURE REVIEW

Recent studies on the life cycle assessment for residential buildings (Ochoa, Scott, 2009) provide evidence to conclude that the major amount of emissions produced by a building in the USA comes from the energy consumption during the operation stage. Conclusions drawn from this study includes the notion that acclimatization of buildings is the factor that consumes the major portion of the electricity or gas responsible of emissions with Global Warming Potential. Conclusions drawn from several Life cycle assessment projects in different parts of the country, implies that the emission cost of acclimatizing a home is bigger when it is required to cool it than when it is required to heat it.

Countries like Australia and New Zealand lead the development of houses with a very low level of emissions. Constructions made of compacted earth-cement and Straw Bale are providing great results in terms of increased efficiency in construction and performance in terms of lower energy use. These materials provide an excellent mean of thermal insulation, lowering the requirements of energy demanded to maintain comfort ability standards. The interaction with these technologies is not implemented in this paper but opens a new possibility for further studies.

Previous studies (Christian et al 2006) describe the overall cost of operating a house with a geothermal system and a grid connected photovoltaic generation system, a solar water heater was not implemented due to climate. From this study, it is clear that there is a positive balance of the investment during the operation of the building for the projects evaluated which are prototype houses.

Studies related to the economic life cycle evaluation of photovoltaic generation systems have been widely implemented. Studies give light in the evolution of the market as they will provide a picture of the technologies and its relation with price at the time they were published. Others have implemented a life cycle cost analysis and have been able to observe that an increasing price of energy will produce a positive balance towards feasibility of photovoltaic systems (Lisell and Mosey 2010). Further, models for the economic evaluation of solar panels has been implemented in which the feasibility analysis corresponds to the perspective of a high scale investor (Nofuentes et al 2002) not the final user as proposed in this study.

In the beginning of photovoltaic energy, a panel was not able to produce during its useful life an amount of energy equivalent at least to the net quantity of energy embodied (Georgescu-Rogen, 1979). It is only up to the nineties that technology evolved making possible to achieve solar panels with a net positive energy balance (Olivier, Jackson, 2000).

Production of energy by photovoltaic systems is subject that has been researched, expanded and implemented in several countries and it is subject of interaction with markets, proof of this is the difference noted in the price of production among European Countries and the USA (Eiffert, 2003).

This variation on prices indicates a divergence in the technologies and variations in the maturity of the industry as well. Prices are expected to keep decreasing (Green, 2002) in accordance with the general theory of learning by doing as has already been the case for the industry of photovoltaic electricity generation (Marnay et Al, 1997). During the decade of 1980, the introduction of amorphous silicon materials in the production of solar panels triggered a dramatic reduction on the cost of production of photovoltaic systems of about 90% (Hamakawa, 1998).

Geothermal Heating and Cooling is a subject that has been around for several years and was patented in the USA in 1982 by Herman B Wolf. Cooling mechanism is not radically different from the one already widely implemented, it corresponds to a simpler in nature but not in implementation solution. Another major advantage is the reduction on required maintenance

(Martin et Al, 1999), which implies a better performance of the equipment with fewer headaches for the owner. The expected reduction on the energy consumption coming from the implementation of a geothermal acclimatization system has been estimated in 57% (Stein, Meier, 1997). The Department of Energy – Building Energy Data (DOE-BED 2008) Indicates that about 43% of energy consumed in a residence is used for acclimatization.

Hot water consumes about 18% of the energy demanded monthly in a typical Household (DOE-BED 2008). It s the second household appliance that consumes more energy on a residence, so the implementation of a system providing a reduction in the consumption of electricity, would provide the means for economic feasibility in the whole project. The economic feasibility of a solar water heater has been widely studied and demonstrated (Huang, Lee 2002),

Solar water heaters have been around since the end of the 19^{th} Century, The first patent registered for this kind of device was made in 1899 by C.A. Davis. Many countries like Israel and Spain have set as mandatory the installation of solar water heaters in new construction; however the country leading the amount of installations is China followed by the European Union (REN21, 2009). In the United States, they reached their maximum peak of popularity during the decade of the 80's, thanks primarily to the implementation by the government of tax credits, incentives and rebates, but expansion was halted as system confronted problems related to looses during the night that will reduce considerably the amount of hot water usually required in the mornings, this in combination with the reduction and disappearance of incentives, almost kill the industry. The implementation of an electric resistance to the tank makes possible to offset the energy gap required for the system to perform at the required standards. A solar water heater has a typical lifespan of 40 years and the rate of maintenance is very low compared to traditional systems (Ramlow and Nusz, 2006). Different technologies operate with equivalent efficiency and cost. To introduce the different technologies and implementations is out of the scope of the present work but it is common to all systems that it is required to have sun for being able to achieve efficiency, so system feasibility should account for the potential of the location in terms of sunlight availability.

3. CASE OF STUDY

A Residence in Miami of about 900sf with an SER13 AC consumes in the winter the equivalent to 600KWH per month while in the summer at maximum capacity this consumption jumps to 1200KWH per month. These values are the average values collected during a period of 3 years. The feasibility analysis of the study assumes that system is connected to the traditional electric grid to which it injects energy during the day and draws energy at night to produce a net zero consumption. This can also be achieved on disconnected systems but would require the installation of an accumulator (Battery) that would increase the cost in a manner that will put it out of range in economic terms.

The introduction of geothermal systems for acclimatization is changing the perspective of consumption of these devices. A radical reduction of about 57% on energy consumption for cooling systems is achieved. The Department of Energy – Building Energy Data (DOE-BED 2008) Indicates that about 43% of energy consumed in a residence is used for acclimatization.

If a geothermal system is installed, the consumption would be reduced and according to the general expectancy would be adjusted to 620KWH in the winter and 878KWH in the summer. The over cost of installing a geothermal system has been estimated at $5250 (1.5Ton @ $3500/Ton).

A solar water heater sized for the needs of the case would have an over cost of $2700 compared to installing a traditional electric resistance system. This kind of system will produce a reduction on electricity demanded to heat water of about 50%. The inclusion of this system will reduce the demand loads to 498KWH in the winter and 756KWH on the summer (combined with geothermal acclimatization calculated before).

The actual efficiency of a solar panel is around 0.08KWH/sf/day and the cost in the US installed is around $65/sf. With a peak usage factor of 1.5, it would be required an area of 470sf of panels. The demand required for the system will be achieved typically by a system of 4600 Watts with an actual market cost of $17388. In general, there is no salvation value at the end of the project life cycle, and it is assumed that life cycle for all components installed is the same: 25 years.

Forecasted cost corresponds to a regression analysis based on the actual conditions in the market and tabulation of values in previous studies (Richter, 2008) for the cost per kilowatt produced. Values tabulated for regression were expressed in 2011 dollars to avoid the distortion produced by inflation, and once forecasted were converted back to their equivalent cost in the specific year.

Additionally the cost of electricity from the grid for this kind of consumption is $0.10/KWH. This value is the typical value obtained from an electricity bill in south Florida. Cost of electricity for the initial model is assumed to increase at the inflation rate each year. This maybe conservative in general terms but would make sense if the demand for energy from fossil fuel remains constant as alternative technologies arise to fill the new gap.

Putting together the numbers at a fixed rate of 5.5% (Typical market rate) and assuming an inflation rate of 2.75% (USA-2010), the project would not be feasible. This means that after 25 years (expected life span of combined system) it will be more expensive to obtain energy from solar panels than being connected to the grid. This is true for the actual year 2011.

4. THEORY

The price of photovoltaic systems does not escape to the reality of market interaction. Price of solar panels is reducing constantly in time as a result of improvements in technology and production of scale. The nature of the market of geothermal acclimatization operates different as technology is a combination of existing ones and technology for implementation is relatively widely available.

By preparing a forecasting of the market conditions on the near future (inflation), using the available data related to historic cost; a financial analysis was prepared for several following years until it was found that the project of installation of a system as described is an economic feasible project.

5. MODEL

A financial model comprehending the cash flow of the project was created using the respective inflation rates and market mortgage rates. Inflation has been forecasted for several years using a general expectation model based on the previous average, inflation to be used during the life of the project correspond to the average forecasted rate for those years. It has been noted that as the United States Economy evolves, the inflation rates tend to get lower. This is a typical indicator of a developed economy, however the goal in terms of inflation set by the government implies a positive stable value over time as a mean of control to avoid falling in a liquidity trap as Japan did in the beginning of the 90's. This actual case provides more validity to the results predicted by the forecasting analysis (Average 2.62, Standard Deviation 10.33%)

The prices of the solar panels has been evaluated using the equivalent $/KWh (dollars per Kilowatt-Hour Installed), this price has been calculated using a regression analysis based on historic values. Prices of energy increase according to inflation.

The life cycle of use of the system has been estimated in 25 years, this is the typical life cycle time of a photovoltaic system before maintenance is required, no maintenance was accounted for geothermal acclimatization nor solar water heater as the useful life of these devices exceeds the expected life of the solar panels but will not achieve the useful life of a typical building (50 years), this implies that necessarily, an upgrade will be needed during the useful life of the building, so it makes sense to perform these upgrades at the same time in the middle of the life cycle.

6. RESULTS

System as installed will produce a positive cash flow staring year 2018 if variables behave accordingly. In general, the financial feasibility is determined by having a project that will be able to pay for the cost of implementation. A summary of results is shown on table 1 for the forecasted years.

Year	Net Worth
2011	$ 5,462.01
2012	$ 4,462.50
2013	$ 3,642.09
2014	$ 2,839.43
2015	$ 2,055.27
2016	$ 1,291.40
2017	$ 550.07
2018	$ (178.87)

Table 1 – Present Value Net Worth of Investment Project.

7. Sensitivity Analysis

Sensitivity Analysis is mainly used to describe the variation of the outcome of the model as the input variables change. In the case of study, the input variables to be scrutinized are Inflation, Opportunity Rate, and Price of Photovoltaics; while the output variable will be the year in which, if the system is installed, a break point is achieved.

It was observed that I higher inflation will make the project to break even faster; as it was observed that the final debt is closer to zero when implemented in year 2017. As in the model, the price of electricity is tied to the inflation, it is correct to conclude that an increase in the price of electricity over the expected inflation rate will make project feasible in a shorter time. As opposite, a decrease in inflation or the cost of electricity will lead the project to the zero loses-profit point in a longer period of time.

As any project, an increase in the opportunity rate will decrease the final expected profit, using a 6% APR (compared to 5.5%APR set initially in the model), the project will achieve zero net value when project is implemented in year 2020. In contrast if mortgage rates have the tendency to be reduced, the feasibility of the project is closer in time to the present.

When maintaining the value of the photovoltaic system constant, while having the remaining variables changing over time, it was observed that system will achieve equilibrium when installed in 2028. In general terms, a reduction in the rate of increment of efficiency over time will delay the equilibrium point in the project.

8. Conclusions

According to the results, the project of installation of a system of solar panels to power the case of study residence with a geothermal system for acclimatization would break even at year 2018. Accounting for the actual government rebate available equivalent to 30% of the photovoltaic system cost, project would be feasible in economic terms as of now. This situation has been noted already by government agencies and states like California are starting to decrease the stimulus or remove their available rebate programs.

Another limitation on the implementation of the system is the nature of the cash flow for the project. Even though project can be feasible in economic terms, the amount of money disbursed to cope with payments is superior to the equivalent savings during several years after the project has started. In the case of the project in question, it was found that once it breaks even, it starts producing a positive cash flow starting the first year it is installed.

The case of energy, as illustrated, has shown how the market mechanisms operate to solve a situation of scarcity of resources. The increasing cost of energy has encouraged the development of an alternative market that has the technology as its principal agent. It is expected that the development of this market keeps its pace and that the realization of energy independence is a reality around the corner.

It was also observed on the model that in general the price in dollars per the kilowatt remained around 20 dollars during the year span analyzed. Developments in technology have produced a reduction in price enough to cover for the inflation plus a small margin; this is a good illustration of the sticky nature of prices.

From the sensitivity analysis is adequate to conclude that a system implemented as described will be feasible in economic terms in no more than 10 years, if conditions of the market in terms of inflation and interest rates remain behaving as expected, in what can be described as a pessimistic environment, it will take no longer than 20 years for systems to achieve operability with zero financial loses.

9. AUTHORIZATION AND DISCLAIMER

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