Financial Analysis of Residential PV and Solar Water Heating Systems

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Abstract

Renewable energy technologies (including solar) have enjoyed a period of rapid growth in recent years, through a combination of government subsidies and purchaser altruism. But renewable energy technologies cannot expect to replace fossil fuels on goodwill. They will have to become price competitive. Most studies on the economics of renewable energy systems fail to consider one of the most powerful trends in their favor: the rising cost of fossil fuels.

This study provides an economic analysis of residential solar systems (photovoltaic and water heating) using Michigan and Hawaii as examples. These two states represent extremes – Michigan has a weak solar resource and low utility rates, while Hawaii has a strong solar resource and the highest utility rates in the country. The study shows that residential grid-intertied PV systems are not currently economically attractive in Michigan under net metering, while higher utility rates and greater solar radiation in Hawaii make a PV system a reasonable investment on economics alone. It also shows that the new pilot feed-in tariff from Consumer's Energy makes PVs an attractive investment for those who can qualify for that program. Solar water heating systems are very financially attractive in Hawaii for homeowners using electricity, propane, or pipeline synthetic natural gas. Solar water heating is an attractive investment for Michigan homeowners using propane or electricity, especially since the Federal tax credit was expanded to include solar water heating systems. In either location, without government assistance, solar water heaters are more financially attractive than PV systems.

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Abbreviations

AC	Alternating Current – the type of electricity provided by utilities
ASES	American Solar Energy Society
CAGR	Compound Annual Growth Rate
CE	Consumer's Energy – a major Michigan utility with a pilot feed-in tariff program (FIT) for PV systems.
DC	Direct Current – the type of electricity produced by PVs
FIT	Feed-In Tariff. The output of a PV system is credited at a higher rate than retail price of electricity.
HI	Hawaii
IRR	Internal Rate of Return (a financial metric, see: section 3.3)
kWh	Kilowatt Hour
kW_p	Kilowatt-peak – PVs are sized by their peak output in kW
MI	Michigan
MISO	Midwest Independent Transmission System Operator (electricity wholesaler in Michigan)
MPSC	Michigan Public Service Commission (regulates the utility companies)
MWe	Megawatts Electric – the measure of the output of a power plant
NG	Natural Gas
NPV	Net Present Value (a financial metric, see: section 3.2)
NREL	National Renewable Energy Laboratories (part of the U.S. Department of Energy)
PV	Photovoltaic ("solar cells" generate electricity in sunlight)
SDHW	Solar Domestic Hot Water
SNG	Synthetic Natural Gas (pipeline gas in Oahu, Hawaii)

1. Introduction

1.1. Problem Statement

Demand for solar energy systems is currently driven by government subsidy programs and purchaser altruism. This largess will not continue forever; in order to become a viable industry, renewable energy systems must be perceived as attractive financial investments for their owners. Which systems, in which locations can justifiably make that claim today? How rapidly would utility electricity and fuel prices need to rise in the future to make currently available solar systems attractive today?

1.2. Study Objectives

In 1974, President Ford's Energy Resources Council believed that,

> "Solar energy would become a significant energy source after 1985 because of technological advances and the high recovery and storage costs of fossil fuels." [1]

Predictions that solar energy will be cost-competitive with conventional energy (i.e. fossil fuels and nuclear power) have continued ever since, with some claiming that cost-competitive solar energy has arrived (at least in some localities). [2] This study analyses that claim in the context of the U.S. homeowner.

This study attempts to answer the following questions:

1) Are residential solar energy systems, without government subsidy or other material support, financially attractive investments to homeowners – based on cash flow alone? Does the Federal tax credit for solar systems make them a good investment?
2) Michigan has relatively low utility rates and low solar isolation. If solar systems are not financially attractive in Michigan, might they provide an attractive investment in Hawaii, which has very high utility rates and abundant solar insolation?
3) How great an impact do assumptions about future utility rate increases have on financial metrics, specifically internal rate of return?
4) Are solar photovoltaic (a.k.a. "solar cells") or solar water heating more financially beneficial to a homeowner?
5) Does the Consumer's Energy pilot feed-in tariff program make PV systems financially attractive in Michigan?

1.3. Study Significance

This study will be useful to homeowners considering the installation of a solar energy system as a means of cutting their utility bills. While many of these

people are driven in part by ecological or patriotic motivations, financial reward is always a consideration. This may be the first study that considers future price increases in conventional energy as the prime independent variable driving the financial attractiveness of solar energy systems.

This study will also contribute to energy policy debates. Many subsidy programs are initiated with a stated objective of stimulating demand for solar energy systems, but may only succeed in subsidizing those who would purchase the system anyway (the “free rider” problem). The analytical approach shown here can be easily extended to show whether a given subsidy program would make the affected systems financially attractive.

1.4. Methodology

Residential solar system price data was collected from actual bids by contractors under marketing programs sponsored by the Michigan State Energy Office. The Federal solar tax credit is then considered separately to determine its impact on the financial viability of the systems. Standard financial analysis is applied to compute payback period and net present value (NPV). That analysis assumes (as is commonly done) that the price of the displaced energy (electricity or fuel) is fixed throughout the lifetime of the solar system. To reflect the impact of assumptions about future fuel and utility prices, internal rate of return (IRR) is calculated as a function of the rate of increase in the cost of the displaced energy form. These results are contrasted with the results of identical analysis for systems installed in Hawaii, where the solar resource is greater and the cost of fuel and utility power are much higher. For the Michigan PV system, the value of the displaced energy is also computed using the Consumer’s Energy pilot feed-in tariff.

1.5. Limitations

This study is specifically focused on residential PV and solar water-heating systems in the State of Michigan and Hawaii. These two systems appear to be the most commonly installed renewable energy systems. Solar heating systems also appear common in Michigan, but the financials of water heating applications are clearly better due to year round use and the much greater solar insolation during the summer - when heating is not needed.

The financials of small wind systems are also worthy of study, but are more difficult to generalize due to very high variations in the wind resource at different sites and the scarcity of data available.

Socialized externalities such as air pollution, global warming, tax breaks to the fuel extraction industries, and military defense of fuel supplies are not considered.

1.6. Study Layout

In chapter two, a literature review examines the approach of similar studies that have been published, noting that most of them fail to consider rising prices of conventional energy. Chapter three discusses the three financial metrics used

in this study – payback period, net present value, and internal rate of return. Special attention is given to the selection of a suitable "discount rate" to reflect the time-value of money. Chapter four applies these three financial metrics to residential PV systems located in Michigan. Annual system output is computed using the "PV Watts system", and savings are computed using current utility rates – with and without the federal tax credit. The IRR is computed across a range of potential future utility price escalation rates. It is also computed using the pilot feed-in tariff from Consumer's Energy. This analysis is repeated for an identical PV system located in Oahu, Hawaii – where the utility rates and fuel costs are much higher. Chapter five repeats this kind analysis for a domestic solar water heater both in Michigan and Oahu. For the solar water heater, the savings depend on how the home is heating water (electric, propane, or natural gas). Chapter six provides conclusions of the study and recommendations for further study.

2. Literature Review

2.1. Dependence on Subsidies

During the last several decades there have been a plethora of renewable energy demonstration projects installed around the world, including the State of Michigan. For example, the Michigan State Energy Office has provided grants to fund at least 17 solar photovoltaic (PV) "demonstration projects" of 10 kW systems around the state. These projects have been financed with public funds to "demonstrate that solar energy works in Michigan". [3] But if renewable energy systems are to move out of the "demonstration stage", they need to be financially attractive to their potential buyers.

The growth of renewable energy industries has historically been driven by supportive public policy, including grants and subsidies. This is widely recognized, as shown in this quote by UniSun, a PV manufacturer:

> "Sales of grid-connected PV power systems have roughly doubled each year over the last half decade, aided in large part by economic incentive programs aimed at breaking down barriers to leveraging new energy technologies and at accelerating economies of scale that can translate into lower system costs." [4]

As a result of strong government support in Germany and Japan, 75% of global PV capacity installed in 2006 was in these two countries. [5] In the U.S., 87% of grid-tied PV capacity installed in 2006 was in California and New Jersey, owing to their generous rebate programs. [5] If these technologies do not become economically competitive, then public support will be unable to maintain their momentum as the cost of subsidies increases with the scale of the deployments. A study by the Cambridge Energy Research Associates titled *Will Clean Energy "Cross the Divide?"* put it this way:

> "The challenge for governments is to institute policies that get clean energy technologies off the drawing board and sustain them to the point that they

> become commercially viable and are able to wean themselves from the support – thereby allowing for a phase out, rather than in increase over time, in subsidies." [6]

Many state rebate programs have a capped allocation of funds, and the programs in both Wyoming and Washington, D.C. have hit their limits. [7] A 10 year market forecast by Navigant Consulting projects PV industry growth at a "conservative" 29% CAGR [Compound Average Growth Rate], or only 9% if government incentives decrease". [8] In fact, the feed-in tariff for solar system in Germany is set to decline every year, by at least 5%, and perhaps as much as 9.8% - at the whim of Parliament. [9] In the U.S., the current tax breaks for ethanol are costing the government $3.7 billion in foregone revenue and is set to double by 2010. But if the subsidy is unchanged, this could reach $18 billion by 2020 – and political support for such an enormous program is considered by some to be unlikely. [10] The future growth of renewable energy industries, therefore, is dependent on finding sufficiently large market niches in which they are economically competitive without government subsidies.

Subsidies for residential solar systems also bring up a significant equity issue. These systems are typically purchased by high-income families; should tax payers or rate payers be subsidizing their choices? Consider these criticisms from Howard Hayden's book, *Solar Fraud*:

> "Government agencies coerce utilities to use ratepayers' money to subsidize piddle-power projects, thereby avoiding direct taxation for which they could be justifiably blamed. All-too-comfortable lawyers, politicians, and actors obstruct projects that would provide abundant energy, and coerce the construction of expensive solar toys that can provide precious little energy in its place." [11], pg.13

The very presence of subsidies is used as proof that RE systems are not financially viable. As the RE industry continues to grow, we can expect such arguments to increase in frequency and volume.

2.2. Economics Drivers

Treated as a financial investment, the attractiveness of residential solar energy systems depends upon certain quantities:

1) The initial cost of the system
2) Maintenance costs of the system
3) The system lifetime
4) The amount and form of energy provided
5) The match between solar energy capture and load
6) Opportunity to sell energy to the utility - and the terms and pricing
7) The cost of supplying that energy by conventional means instead
8) The "discount rate" applied

Homeowners making purchasing decisions will likely consider other factors including: problems with trees causing shading, the effect on roof warranties or homeowners' insurance policies, and homeowner association rules. [12] While these are clearly important considerations, they vary by household and are difficult to generalize.

2.3. PV Economics Studies

There have been numerous studies done on the economics of renewable energy systems, especially grid-connected PV systems. [1-3] These studies generally take the current price of utility power as a given, and calculate how much renewable energy systems must lower costs to compete with that price. Renewable energy systems *are* continuing to become less expensive as the technology improves and as the industries mature - gaining the benefits of economies of scale. However, in recent years, this reduction in the cost of renewables has been dwarfed by the escalation in the cost of fossil fuels. This analysis will consider how rapidly utility electricity and gas prices must rise in the future to make existing renewable energy installations become economically competitive - today.

Most of the available studies on residential solar systems focus heavily on grid-connected PV systems and their initial cost. A recurring theme is that PV modules will become cheaper as volume increases and economies of scale take place, such that on-site PVs will eventually be competitive with grid-power. The UniSun website summarizes this well:

> "PV solar electricity power systems are durable long-lived products that consume no fuel and require minimal day-to-day maintenance. The levelized cost of PV-generated electricity is dominated by the up-front capital cost of a PV power system; hence PV buying decisions and market growth are strongly affected by PV product pricing. PV prices are commonly quantified in terms of the ratio of purchase price (e.g. in US$) per peak power output (e.g. in watts W.) PV prices have dropped steeply over the past three decades as technology and manufacturing improvements have been implemented… Absent incentives, current PV market prices translate to levelized electricity costs comparable to retail electricity prices in certain high-price markets. *When PV prices are reduced by an additional factor of 2-3*, electricity costs from distributed PV systems will be comparable to retail electricity prices in a wide spectrum of high-volume markets." [4] [emphasis added]

Setting objectives for system prices, one study by the National Renewable Energy Laboratory (NREL) computed the "breakeven turnkey cost" (in dollars per peak watt) for each state. Improvements in system cost hitting these objectives would make PV systems financially competitive with the grid. [13]

In his book *Solar Revolution*, Travis Bradford notes:

> "Three factors – real unsubsidized PV system cost, insolation, and cost of grid electricity – determine the likelihood of market growth and maturation in different locations in the industrialized world…" [2]

He goes on to display this relationship in graphical form, shown here as Figure 1.

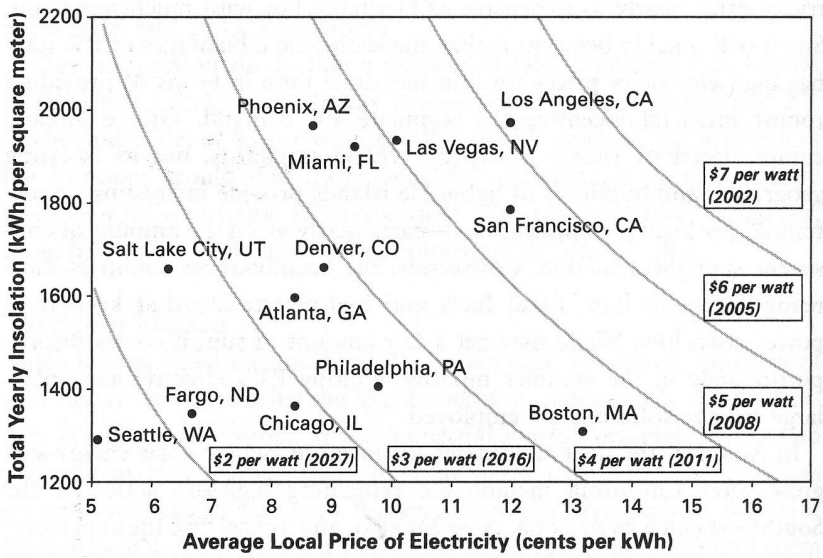

Figure 1: PV Isocost Curves for U.S. Cities
[2]

This illustrates how the combination of high solar insolation and high electricity costs make the cities in California the most cost-effective locations for PVs shown. If this graph reflects future utility price increases, the assumption is not explicit, nor is the rate of utility price increase given.

Bradford also notes that PV prices have declined 18% with each doubling of installed volume. [2] NREL's study of PV pricing determined the "direct manufacturing cost" falls 17% with each doubling of annual production. [14] An article by the Chairman of the American Solar Energy Society (ASES) computes the future cost of PVs out to 2050, assuming this relationship continues. [15] This approach may be reasonable in a period of rapidly declining solar technology prices and relatively stable electricity prices. But that is not the environment of the past decade.

Recent history does not seem to support the idea that ever larger volumes of PVs will translate into ever lower end-user prices. The PV industry has experienced rapid growth exceeding 40% in 2007 [16] and an average of 44% per year over the previous 6 years. [5] Yet prices have not gone down over the last ten years. Maycock and Bradford published a table of PV pricing, shown here as Figure 2.

Year	1996	1998	2000	2002	2004	2005	2006
Actual average model price ($US\$/W_p$)	4	4	3.5	3.25	3.25	3.5	4

Figure 2: History of Retail PV Prices
[5]

This reversal of trend is confirmed by SolarBuzz.com, which closely tracks the price of PV modules. The graph in Figure 3 clearly shows that retail PV prices were rising for several years, whether measured in U.S. dollars or Euros.

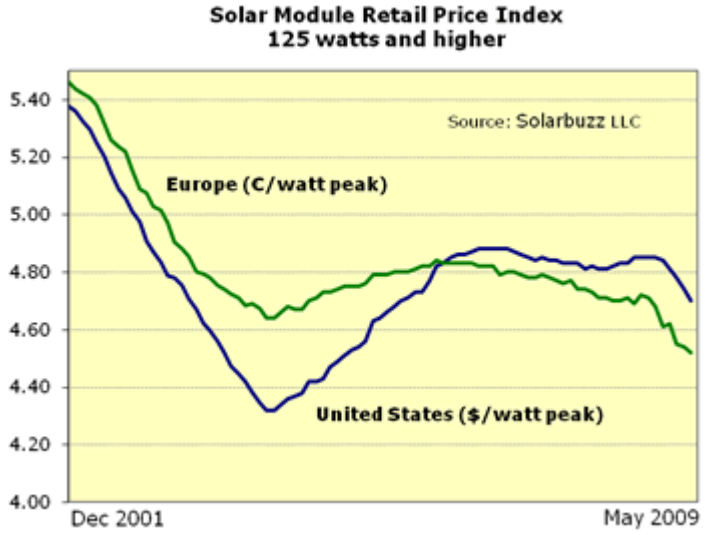

Figure 3: Transatlantic PV Pricing History
[17]

This recent upward trend has been blamed on shortages of refined silicon, which are expected to be resolved soon as more refining capacity comes on line. It's not surprising that such rapid growth would create bottlenecks in the supply chain, but this illustrates that increasing production does not lead invariably to price reductions. Unisolar believes that further price declines cannot be achieved with further scale-up, but that whole new technologies (i.e. thin-film PVs) are necessary to bring PV pricing down further.

> "Current PV prices already reflect economies of scale possible with traditional PV manufacturing technology; significant price reductions require new technologies. Significant reductions in PV power system prices require sharp reductions in PV module costs. PV modules based on solar cells fabricated from crystalline silicon wafers currently dominate PV markets, but significant cost reductions are unlikely with silicon wafer-based technologies due in large part to the underlying cost of silicon wafers." [4]

Oddly, most of these studies treat utility electricity prices as a constant. One report specifically notes, "It is important to note that the payback period will depend heavily on future electricity prices." [18], but it makes no attempt to include that critical variable. The NREL report explicitly included electricity price inflation, with a value of 2% per year [13] Another study by Deutsche Bank notes that U.S. electricity prices have increased an average of 4.5% per year over the last seven years; it assumes that trend will continue and predicts that grid connected PVs will be competitive with utility supplied power in 5 years. [19] But price competitive with utility power where? Utility prices and solar insolation levels both vary widely with location. Averages can be deceiving.

2.4. Future Utility Rates

From 1990 - 2007, average residential electricity prices in Michigan have increased from 7.83 cents/kWh to 10.21 cents/kWh; an average rate of only 1.6% per year. This is less than the general rate of inflation. [20] However, even a rate of 1.6% per year applied over the 30-year lifetime of solar energy system will result in a 60% higher electric rate at the end. But there are other good reasons to believe that future utility pricing may increase at rates greater than the past.

Fully 76% of the increase in residential electricity prices over the last 17 years happened in the last two years, jumping from 8.40 cents/kWh to 10.21 cent/kWh; a two-year leap of 22%! [20] The state's two largest utilities have rate cases pending before the MPSC. Consumers Energy's request would increase residential rates by 9.5%, and Detroit Edison's request would increase them by 6.4%. [21]

It appears that capital investment in power plants is likely to be greater in the future than in the past. Michigan's power generation is based on a combination of aging coal plants and uneconomical natural-gas plants. From Michigan's 21st Century Energy Plan:

> "It is important to remember that Michigan's baseload generating units are now an average of 48 years old. Modeling for the Plan assumed that older, less efficient units, totaling approximately 3,500 MW of capacity, will be retired by 2025. Most of these retirements are baseload units for which there are no known plans for replacement.
>
> In recent years, new electric generation in Michigan has been confined to natural gas fueled facilities…These units were built by independent power producers. Many IPPs have recently gone through bankruptcy as natural gas prices over the past several years made even the most efficient of these units uneconomic to run for more than a few hours each year. Market prices driven by natural gas costs expose Michigan to volatile electricity price" [22]
>
> "Michigan's generating capacity, statewide, is presently approximately 27,000 MW. Each MW of capacity from a baseload coal plant is projected to cost approximately $1.6 million (excluding financing costs)." [22]

In October, 2008, the Michigan Legislature passed a Renewable Portfolio Standard (RPS), which requires that the utilities produce or purchase 10% of their power from renewable sources by 2015. [23]

Governor Granholm estimates that this will require an expenditure of $6 billion by Michigan utilities. [24]

Residential rates in Michigan are also likely to head higher as a result of state regulatory changes, aimed at eliminating, or a least reducing, the subsidy home-owners receive from other utility customers.

> "Residential service is heavily subsidized by commercial customers, and may be subsidized by industrial customers… The Commission has recognized the necessity of moving to cost based rates and has begun this process in recent orders." [22]

The report also included a specific recommendation:

> "The Commission should move rates toward each customer class's cost of service." [22]

Emissions regulations are also likely to cause higher electric rates. New Federal regulations requiring utilities to reduce emissions of mercury go into effect in 2010, while more stringent Michigan regulations on mercury emissions have been ordered. [25] A recent court case is forcing the EPA to enforce these regulations. [26]

Additionally, it is considered quite likely that the U.S. Congress will pass some kind of CO_2 emission legislation this year or next. [27] In fact, three of the largest U.S. investment banks will not make loans for coal burning power plants unless they are economically viable under stringent federal caps on CO_2. [28] Michigan's coal-fired power plants produce 40% of the state's total CO_2 emissions. Anticipating national CO_2 regulation, the MPSC's 21st Century Energy Plan assumes an impact of 1.5 – 2.0 cents/kWh in added costs, an impact too great to ignore. [22]

The financial analysis of a solar electric system requires consideration of future electricity rates. With so many factors affecting future electricity rates, any single escalation rate assigned would be subject to reasonable challenge. Instead, this study treats the escalation rate of electricity prices as the *primary* variable affecting the financial return of systems available for purchase and installation today.

2.5. Residential Solar Thermal Market

The U.S. market for "medium-temperature" solar thermal systems has also been growing rapidly, but only recently, as can be seen in Figure 4.

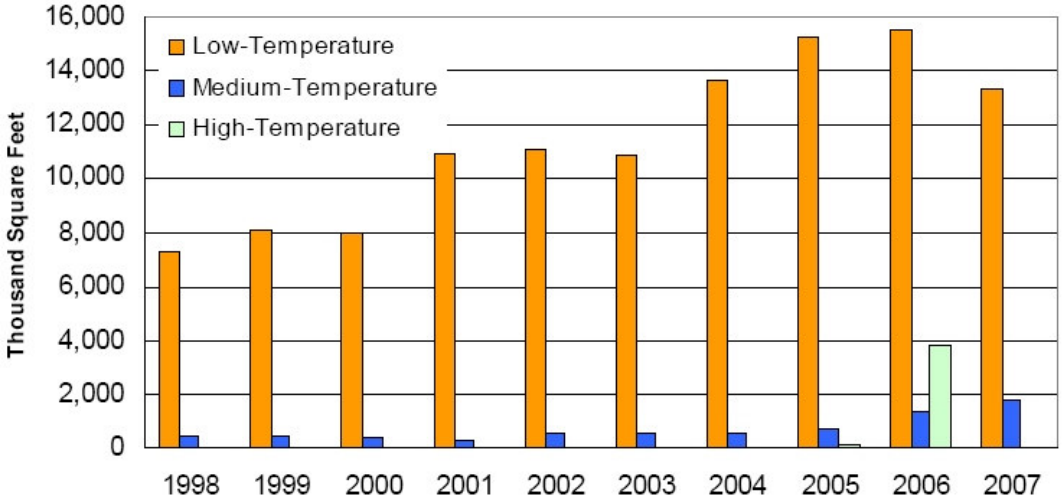

Figure 4: Total Solar Thermal Collector Shipments, 1997-2007
[29]

Low temperature collectors are used to heat swimming pools. Note that medium temperature collectors, used for residential or commercial water heating are growing in sales even as low temperature collector sales dropped in 2007. But with this technology, growth does not equate to lower prices. Higher costs for materials such as copper and aluminum, along with a shortage of trained workers pulled up the price of a flat-plat collector from $15.93 to $16.0 per square foot (5.5%). [30]

Because of the cold climate, solar swimming pool heaters are relatively rare in Michigan. Most Michigan systems are medium-temperature collectors used for solar domestic hot water (SDHW) systems. The U.S. DOE/EIA breaks out statistics for medium temperature collectors by technology.

Figure 5 shows U.S. solar collector shipments in 2007 for residential use by thousands of square feet and collector type. Within this medium temperature type (i.e. excluding pool heaters), flat plat collectors dominate the market.

	Air	ICS / Thermosiphon	Flat Plate	Evacuated Tube	Concentrator	Total
1000 ft2	15	231	1,304	243	5	1,798
% of total	0.8%	12.8%	72.5%	13.5%	0.3%	100.0%

Figure 5: U.S. Solar Thermal Collector Shipments (000s of ft^2)
[30]

As shown in Figure 6, U.S. sales of “medium temperature” (covered) flat plate collectors shot up in 2006 and 2007.

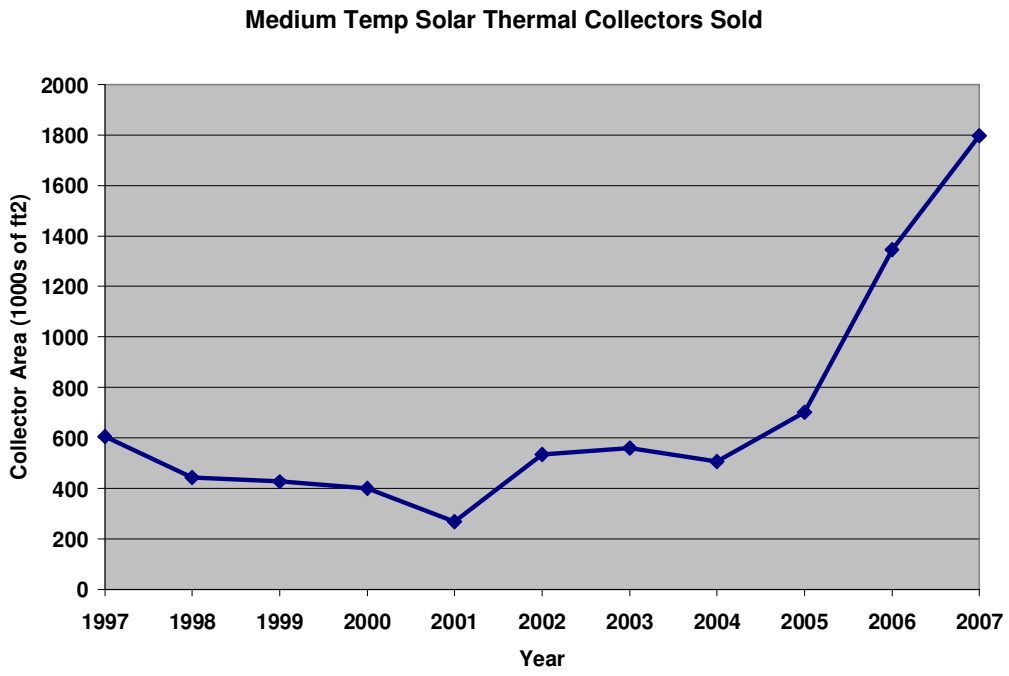

Figure 6: U.S. Shipments of Medium Temperature Solar Collectors
[31]

Figure 7 shows historical costs for “medium temperature” (covered) flat plat collectors. Unlike photovoltaics, there is no apparent trend to the normalized cost of collectors.

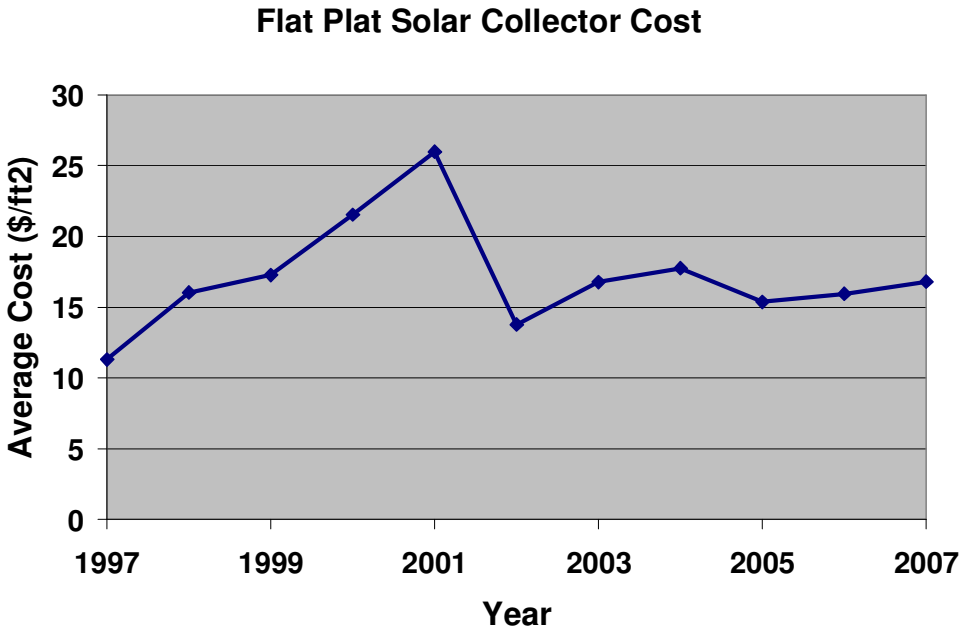

Figure 7: Price History of U.S. Covered Solar Thermal Collectors
[32]

2.6. Future Retail Fuel Prices

While the residential price of electricity has been growing only slowly (until 2006), the price of both propane and natural gas have increased dramatically. Figure 8 shows that, on an energy basis, natural gas has been consistently cheaper than propane, which has been consistently cheaper than electricity, and all three have climbed in price rapidly in the last six years.

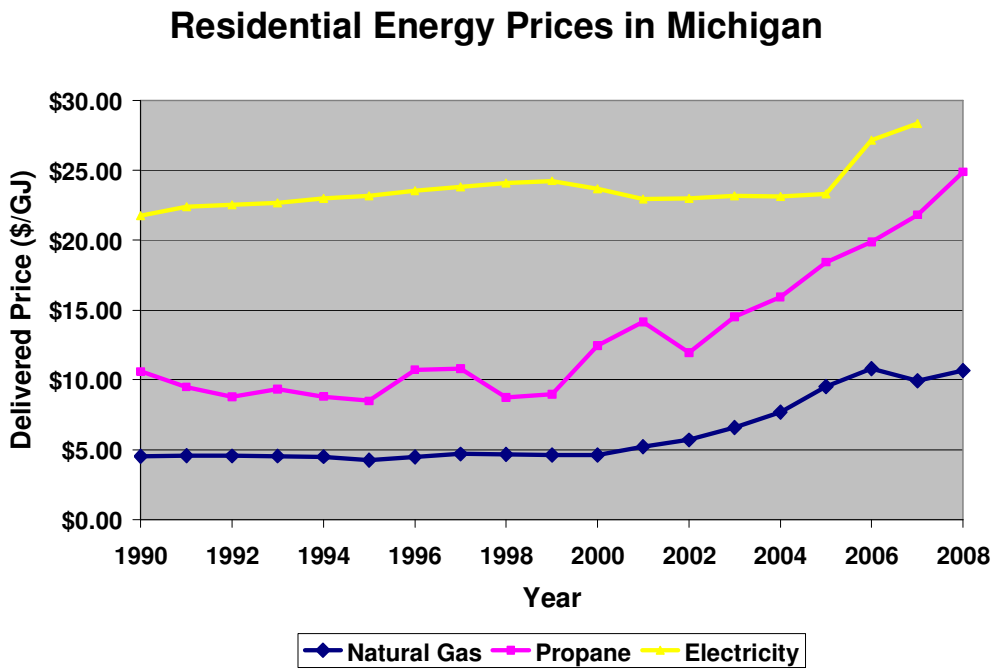

Figure 8: Residential Energy Price History in Michigan
[34-36]

Because the price of fuels and electricity are so volatile, the most significant factor in the financial analysis of SDHW systems is the future price of the fuel the system displaces.

3. Economic Analysis Metrics

The prospective owner of a renewable energy system may have many reasons for the purchase. They may wish to do their part for the environment, or to lead others by example. But one criterion that is likely to be high on the list of most individuals is personal financial benefit of the investment. There seem to be far more publications extolling, and even quantifying the environmental benefits of these systems than the financial benefits. This is likely due in part because the economic analysis is less certain. The annual output of a properly operating PV or SDHW system can be computed with a fair degree of accuracy, though limited by variations in solar insolation. The financial analysis builds on these uncertainties with the uncertainty of future fuel/electricity prices, and variations in individual's financial situations. But the techniques for actually doing the analysis are well established.

Organizations, whether private, public, or non-profit, are often faced with the opportunity to generate a stream of future benefits (cash payments or avoided costs) by investing a sum of money in the present. There are a variety of techniques to evaluate such situations, collectively called cash flow analysis.

3.1. Payback Period

The simplest financial metric is simple payback period. This is simply the number of years in the future when the sum of the expenses (negative cash flows) is equal to the sum of the income/savings (positive cash flows). If the expense is all up-front, and the income/savings are consistent year-to-year, payback period can be calculated with simple division:

Payback Period = Investment / income or savings

This form of the metric is widely used due to its simplicity, despite its limitations. [37] Since the future savings generated by a solar system are unlikely to be constant and because it ignores the time-value of money, this metric is not really suitable for this kind of analysis. It is really best suited to projects with high risks. [38] Yet it will be included in this analysis because of it's pervasiveness in buyer's minds.

3.2. Net Present Value

The most recognized metric for capital projects such as a solar system is Net Present Value (NPV). This is more complex than payback, but provides better information. It may be unclear what payback period is acceptable, but NPV provides the actual dollar value of completing a project.

NPV also recognizes the time value of money – that a dollar today is worth more than a dollar next year or next decade. While this fact is obvious to most people, explicitly accounting for it in calculations is foreign to many homeowners. NPV is simply the sum of all cash flows (positive and negative), discounting future cash flows for the time value of money. NPV can be calculated by the formula in Figure 9.

$$\mathrm{NPV} = \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$$

Figure 9: Equation for Net Present Value

[39]

Where

t - the time of the cash flow
n - the total time of the project
r - the discount rate (the rate of return that could be earned on an investment in the financial markets with similar risk.)
C_t - the net cash flow (the amount of cash) at time t.

This analysis includes the calculation of NPV for sample solar systems. But the result is highly dependent on the discount rate used.

3.2.1. Selecting a Discount Rate

In corporate cash flow analysis, the discount rate is often set as the company's weighted average cost of capital – the cost of borrowing money from banks and raising it from investors. In some cases, a risk premium may be added, though this appears somewhat controversial. [39] In the case of a homeowner, the appropriate discount rate depends on their particular financial circumstances. Accordingly,

> "The discount rate should be the APR [Annual Percentage Rate] of the highest risk-adjusted rate of return that you can obtain by investing your money, or the lowest rate at which you can borrow money, whichever is higher." [40]

About 8.3% of Americans are carrying balances in excess of $8,000 on their credit cards, with an average interest rate of 13.5%. [41] With such a high discount rate, these households will likely find making an investment in a solar system less attractive than paying off their high interest rate debts.

Homeowners with no debt or only a mortgage have a much lower discount rate. Fixed rate mortgages are in the 5-6% range, and U.S. treasury bonds are paying 3.6-4.4%. But unlike credit card debt, or the future utility savings of a solar energy system, taxes have an impact. The mortgage interest is tax-deductable, and the bond interest payments are taxable income. So the after-tax effect is the nominal rate reduced by the household's marginal tax rate (10-35%) plus the state marginal income tax rate, if applicable. [42]

While this may seem a rational approach, actual homeowner behavior shows that most people demand a much higher rate of return than their cost of capital. One study showed that the implied discount rate of actual purchases varied from 39% for very low-income families, to only 5% for above-average income households. [38]

3.2.2. Inflation

Inflation may be treated in one of two ways. The analysis should either use current dollars (including future cash flows where inflation may increase values), or use constant-dollar figures throughout. What is essential is to be consistent throughout the analysis. If constant dollars are used, then the discount rate must be a real discount rate (removing inflation) via the formula in Figure 10.

$$d_r = [\ (1+d_n) / (1+e)] - 1$$

Figure 10: Formula for "Real" Discount Rate

[38]

Where:

d_n – nominal discount rate
d_r = real discount rate
e = inflation rate

This analysis will use nominal dollars and nominal discount rates throughout. In this analysis, most future cash flows are savings on utility bills. So the applicable inflation rate in this analysis is the change in utility rates, which may be quite different that general inflation.

3.3. Internal Rate of Return

The Internal Rate of Return (IRR) of a series of cash flows is the discount rate that would set the NPV to zero. This metric is commonly used for project accept/reject decisions. The decision maker can compare the calculated IRR to their own risk-adjusted opportunity cost of capital, or "hurdle" rate, to see if the project produces a better return than other investments of capital. [38]

The advantage of using IRR vs. NPV is that the analysis can be done without choosing a specific discount rate. Since homeowners have dramatically different discount rates (as described in section 3.2.1), this allows a more general report of findings that are useful to a broad audience.

4. Cash-Flow Analysis of Residential PV

4.1. Residential PV in Michigan

Photovoltaics represent an almost ideal energy generation technology. They release no emissions (during operation), they're silent, virtually maintenance free, domestic, and nearly immune to terrorist attacks. Aside from the intermittency of solar insolation itself, their big drawback is cost. It is widely observed that PVs are simply not cost effect. Consider this quote from the "Your Money" column in *The New York Times*:

> "With a $2,000 federal tax credit and generous rebates from states like New Jersey and California, it has never cost less to install a solar power system. And it still makes no economic sense. You might want photovoltaic solar panels to generate your own electricity out of a belief that you will save the planet. But, as is the case with hybrid vehicles, you certainly should not do it to save money." [43]

Note that since that was written, the $2,000 limit on the federal tax credit has been lifted, so the credit is 30% of the purchase price, with no dollar limit.

Of the 50 states, Michigan has less solar insolation than any but Washington or Alaska. Many states offer rebates on PVs systems of up to 50%, while Michigan offers none. And utility rates for electricity here are well below the national average. Just how bad is an investment in PVs in Michigan? What follows is a best case scenario for two locations; one with common, but relatively low utility rates, and the second location paying the highest utility rates in the state.

Michigan currently does not offer net metering, so power sold back to the utility receives a rate much lower than the retail price. However, the Michigan legislature just passed an energy bill which will force the utilities to provide full

net metering. The bill also raises residential rates and lowers commercial and industrial rates, removing a long-time subsidy. [44]

4.1.1. Current Utility Rate

Most homes in Michigan are serviced by one of the two large investor-owned utilities – Detroit Edison or Consumer's Power. The average residential electric rate for these utilities is 11.2 cents/kWh (plus a 6% state sales tax). But averages can be deceiving; homes in the remote "upper peninsula" of Michigan are served by small cooperatives with rates as high as 16.5 cents/kWh (plus sales tax). [45] Clearly, a PV system is more economically attractive to homeowners paying higher utility rates. For the Michigan high-rate scenario, we assume the homeowner is in one of these high-rate areas.

4.1.2. Purchase Price

It is difficult to gather retail pricing data; solar contractors are reticent to reveal their pricing to competitors and future customers. But the State Energy Office has run a program providing marketing support for solar systems in Michigan for the last 3 years. Contractors agree to install a standard system with certain specifications to customers within a given county for the year. The contractor winning the marketing support is selected by competitive bid. The PV system with the lowest cost per rated watt was a 2.4 kW system (the largest one), for a price of $18,900 (including 6% Michigan sales tax); or $7.86/$W_p$. This falls in the range of values reported in various literatures. Author Travis Bradford reports an installed grid-connected price of $7/ W_p as the "cheapest" in the U.S. [2] Systems installed under State of New York incentive in 2004 ranged from $6.60 - $12.60/ W_p for a 4.5 kW system, with an average of 8.45/ W_p. [46] The American Solar Energy Society reported this summer that the average installed price for a residential PV system is $10/$W_p$ for a system less than 2 kW, and $8/$W_p$ for a larger system. [47]

4.1.3. Discount Rate

A best-case scenario for solar will be the one with the lowest discount rate. Consider a high income family making $400,000+ per year with no debts. They may buy a PV system, or invest in a 30-year treasury bill, which pays 4.41%.[48] At that income level, their marginal Federal Income Tax rate is 35%, and the Michigan income tax rate is 4.35%, for a combined tax rate of 39.35%. Therefore their after-tax income on the Treasury bill is only (1-.3935)(4.41%) = 2.67%. This could be considered a minimum nominal discount rate (before inflation).

4.1.4. System Output

System output is calculated using National Renewable Energy Laboratory's (NREL) PV-Watts software available at: http://rredc.nrel.gov/solar/codes_algs/PVWATTS/version1. This simple-to-use online calculator provides the output of a PV system at any of the 9 solar

insolation data collection points across the State of Michigan. Figure 11 shows how little variation there is in the solar resource across Michigan.

Solar Measurement Site	Avg Annual Insolation, tilt = latitude (kWh/m2/day)
Alpena	4.2
Detroit	4.2
Flint	4.1
Grand Rapids	4.2
Houghton	4.1
Lansing	4.2
Muskegon	4.2
Sault Ste. Marie	4.2
Traverse City	4.1

Figure 11: Solar Insolation in Michigan

[49]

In addition to calculating the D.C. output of a PV system, the PVWatts software allows "derating" factors to account for losses – including line losses, inverter losses, etc. Figure 12 shows default derating factors, which were used for this study.

Calculator for Overall DC to AC Derate Factor

Component Derate Factors	Component Derate Values
PV module nameplate DC rating	0.95
Inverter and transformer	0.92
Mismatch	0.98
Diodes and connections	0.995
DC wiring	0.98
AC wiring	0.99
Soiling	0.95
System availability	0.98
Overall DC to AC derate factor	0.77

Figure 12: PVWatts Derating Factors

[50]

4.1.5. Michigan "Typical Rate" NPV

In this scenario, we assume a high-income home owner paying a typical rate to Consumers Energy installs the lowest-cost PV system quoted in the State Energy Office program. The array is oriented to maximize annual system output. Three scenarios are considered: one with no subsidies, one with the Federal 30% tax credit, and one under the pilot feed-in tariff from Consumer's Energy. Under this experimental feed-in tariff (FIT), residential customers with a

PV system designed to feed its entire output into the grid receive a payment of $0.65/kWh for up to twelve years, if the system is in-service before the end of 2009. [51] This system's full output is assumed to receive retail rates for 30 years under Michigan's net metering law, or the FIT rate for 12 years. The analysis assumes the system under the FIT incurs a fixed $6.50/month service charge (the amount of the charge is uncertain as of this writing). Figure 13 is the output of a spreadsheet showing a standard NPV calculation.

Rated System Output (kWp)	**2.4**
Over-all AC to DC derating factor	**0.77**
Array Tracking?	**fixed tilt**
PV array tilt (degrees from horizontal)	**33**
Annual Output (kWh-AC / year)	**2773**

	No Incentives	**With Fed Tax Credit**	**With CE FIT & Tax Credit**
Initial Purchase Price (incl taxes)	**$18,900**	**$13,230.0**	**$13,230.0**
Utility Price ($/kWh, including sales tax)	**$0.111**	**$0.111**	**0.65**
Value of annual output	**$308.93**	**$308.93**	**$1,724.45**
Simple payback period (years)	**61**	**43**	**8**
Alternative investment yield (30-year treasury)	**4.41%**		
Marginal income tax rate	**39.35%**		
Discount rate (after-tax investment yield)	**2.67%**		
System Lifetime (years)	**30**	**30**	**12**
Present value of savings in utility bills	**$6,318**	**$6,318**	**$17,503**
Net Present Value (NPV)	**($12,582)**	**($6,912)**	**$4,273**
Internal Rate of Return (IRR)	**-4%**	**-2%**	**8%**
Cost of Energy ($/kWh)	**$0.33**	**$0.23**	**$0.47**

Figure 13: NPV for PV in Central Michigan
(Source: Author, 2009)

The analysis shows that with no subsidies, the simple payback period is 61 years, a quick indicator of a poor investment. Not surprisingly, the NPV is negative (despite the low discount rate). Likewise the internal rate of return is negative. The fact that the cost of energy is well above the utility price also indicates the poor financial value of this investment.

The inclusion of the 30% federal tax credit improves the results somewhat, but the PV system is still a poor investment. But with the tax credit and the feed-in tariff from Consumer's Energy, the system pays for itself and provides a solid return in only twelve years! After the twelve year FIT contract is up, the PV system will still be generating valuable output.

Clearly the "typical" Michigan home owner will not be motivated to purchase a PV system based on the resulting cash-flows alone, unless they can qualify for the experimental feed-in tariff. But new technologies generally begin in small niche markets, not the generic markets. Some Michigan home owners have much higher utility rates; we'll consider that case next.

4.1.6. Michigan "High Rate" NPV

Averages can be deceiving, as many homeowners don't pay the *average* utility rate – some pay less, some pay more. For the best-case scenario, we assume a high-income home owner paying the state's *highest* electric rates installs the lowest-cost PV system quoted in the State Energy Office program. The array is oriented to maximize annual system output. This system's full output is assumed to displace electricity that would have otherwise been purchased from the utility. A standard NPV calculation follows is shown in Figure 14.

Rated System Output (kWp)	**2.4**
Over-all AC to DC derating factor	**0.77**
Array Tracking?	**fixed tilt**
PV array tilt (degrees from horizontal)	**38**
Annual Output (kWh-AC / year)	**2732**

	No Incentives	**With Fed Tax Credit**
Initial Purchase Price (incl taxes)	**$18,900**	**$13,230.0**
Utility Price ($/kWh, including sales tax)	**$0.175**	**$0.175**
Value of annual output	**$477.83**	**$477.83**
Simple payback period (years)	**40**	**28**
Alternative investment yield (30-year treasury)	**4.41%**	
Marginal income tax rate	**39.35%**	
Discount rate (after-tax investment yield)	**2.67%**	
System Lifetime (years)	**30**	**30**
Present value of savings in utility bills	**$9,772**	**$9,772**
Net Present Value (NPV)	**($9,128)**	**($3,458)**
Internal Rate of Return (IRR)	**-2%**	**1%**
Cost of Energy ($/kWh)	**$0.34**	**$0.24**

Figure 14: NPV for PV in the Michigan UP
(Source: Author, 2009)

The analysis shows that without subsidies, the simple payback period is 40 years, a quick indicator of an unattractive investment. Not surprisingly, the NPV is negative (despite the low discount rate). Likewise the internal rate of return is negative. The fact that the cost of energy is above the utility price also indicates the poor financial value of this investment. With the federal 30% tax credit, the results are better, but still not attractive. The feed-in tariff scenario doesn't apply, since the FIT is available only to Consumer's Energy customers.

But this analysis, while typical, contains an absurd hidden assumption – that the price of utility power is a constant. While future utility prices are difficult to predict, a fixed price over the coming decades is very poor assumption that can surely be improved upon. Considering future utility price increases reflects a powerful benefit of RE systems – while the bulk of the expenses are upfront, the result is an energy supply with a fixed cost basis.

The power of future rate increases is illustrated in the Figure 15, which shows the IRR in the same best-case scenario, but with varying utility price escalation rates. For comparison, between 1970 and 2004 the average utility price for electricity in Michigan has increased at a compound annual growth rate (CAGR) of 3.75%.

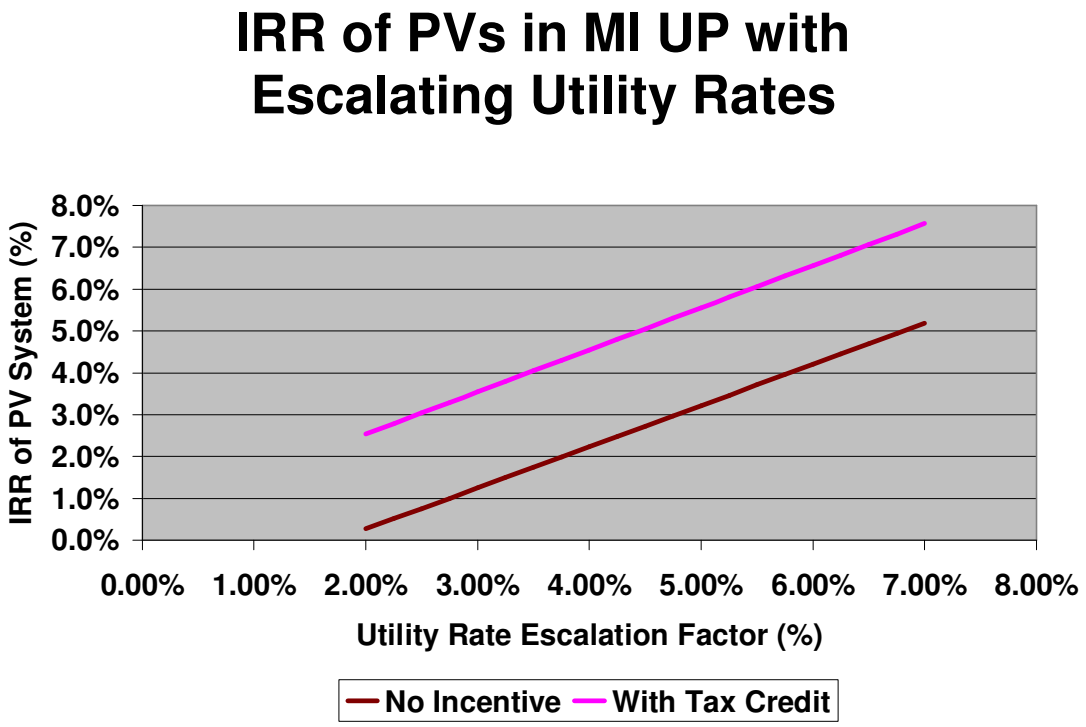

Figure 15: IRR for PV in the Michigan UP
(Source: Author, 2009)

This paints a somewhat different story. With no subsidies and assuming utility rates escalate at the historical 3.75% per year, we get an IRR of only 2% - still below the best-case discount rate. But with the 30% Federal tax credit included, the IRR would be 4.3% - which some homeowners might find acceptable.

So a utility customer in the highest priced utility in Michigan may consider a PV system to be an attractive financial investment only if they have a long planning horizon and a low discount rate. Most Michigan residents pay electric rates 40% lower, which clearly make PV uneconomical – for now.

4.2. Residential PV in Hawaii

PV systems are more financially attractive to homeowners in Hawaii for two reasons:

1) Utility prices across Hawaii are substantially higher than Michigan.
2) Hawaii has higher solar insolation levels – boosting system output by 26%.

Hawaii consists of a series of islands with utility rates that vary widely. In January 2006, residential rates varied from 19 cents/kWh on Oahu to 31 cents/kWh on Molokai. [52] Oahu's rates and solar insolation are used here because it is home to 71% of Hawaii's population [53], solar systems on other Hawaiian islands with higher utility rates would be more financially attractive. For this analysis, the Oahu 2008 rate of 23.2 cent/kWh is used. [54]

The cost of living in Hawaii is generally higher than in the continental U.S., so it's not surprising that the installed cost of a PV system there is higher as well. A government report of PVs in Hawaii determined that the average cost of 2-3 kW residential PV systems installed was $9/Watt .[52] For our 2.4kW system example, this is $22,600 or 14% more than the cost of the Michigan system in 2007.

The analysis in Figure 16 for PV in Hawaii uses all the same figures as the PV system in Michigan, except for system cost, solar insolation, and utility rate.

Rated system output (kWp)	**2.4**
Over-all AC to DC derating factor	**0.77**
Array tracking?	**fixed tilt**
PV array tilt (degrees from horizontal)	**21**
Annual output (kWh-AC / year)	**3504**
	0
Initial purchase price (incl taxes, no incentives)	**$21,600**
Purchase price after 30% federal tax credit	**$15,120**
Utility price ($/kWh, including sales tax)	**$0.271**
Value of annual output	**$949.58**
Simple payback period (years)	**23**
	0
Alternative investment yield (30-year treasury)	**4.41%**
Marginal income tax rate	**39.35%**
Discount rate (after-tax investment yield)	**2.67%**

Without Federal Tax Credit

System lifetime (years)	**25**	**30**	**40**
Present value of savings in utility bills	**$17,151**	**$19,420**	**$23,151**
Net Present Value (NPV)	**($4,449)**	**($2,180)**	**$1,551**
Internal Rate of Return (IRR)	**1%**	**2%**	**3%**
Cost of energy ($/kWh)	**$0.34**	**$0.30**	**$0.25**

With 30% Federal Tax Credit

System lifetime (years)	**25**	**30**	**40**
Present value of savings in utility bills	**$17,151**	**$19,420**	**$23,151**
Net Present Value (NPV)	**$2,031**	**$4,300**	**$8,031**
Internal Rate of Return (IRR)	**4%**	**5%**	**6%**
Cost of energy ($/kWh)	**$0.24**	**$0.21**	**$0.18**

Figure 16: NPV for PV in Oahu, HI
(Source: Author: 2009)

With no subsidies, the simple payback period at 23 years is much better than the Michigan UP 40 year payback, but still quite long. With no subsidies, IRRs of 1-3% look unattractive. With the tax credit included, a homeowner with a long time horizon and low discount rate might be interested.

But once again, this analysis assumes the utility rate is constant for the lifetime of the system, a very poor assumption. Unlike Michigan, Hawaii generates 75% of it's electricity with oil [55] – which has been rocketing in price. Between 1990 and 2006, Hawaii electric rates increased at a compounded rate of 5.27% per

year, jumping 13% in 2006 alone. [56] The utility on Oahu, the Hawaiian Electric Company, has requested an additional rate increase of 5.2% for 2009. [57]

The graph in Figure 17 shows the IRR of a residential PV system in Hawaii, varied by the assumed future escalation rate of utility electricity.

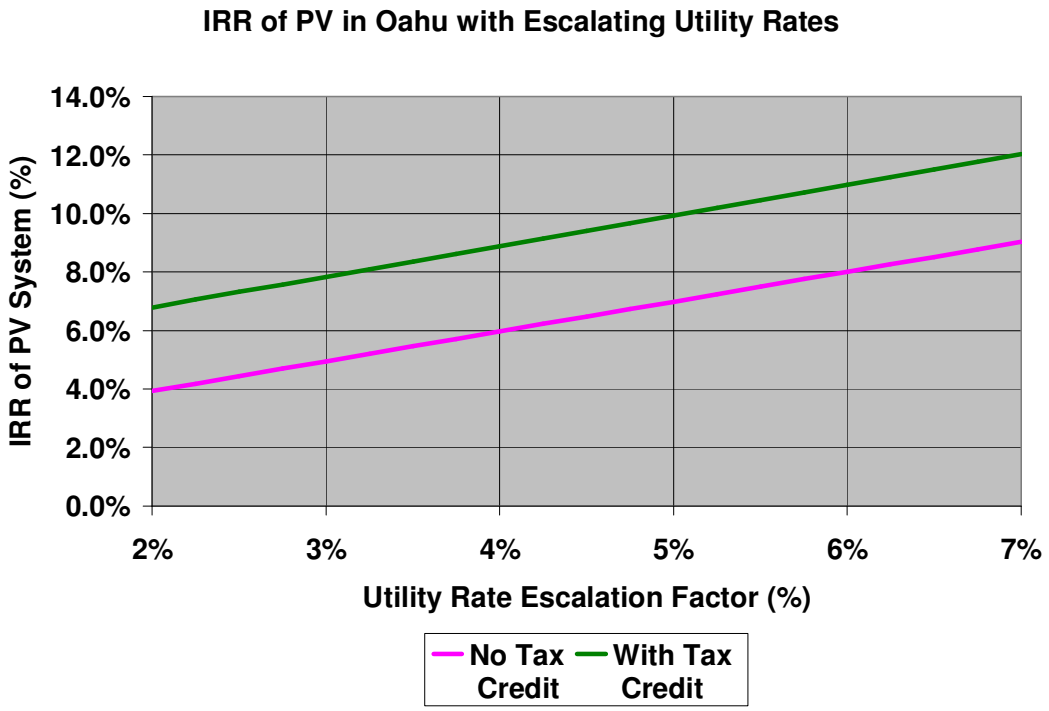

Figure 17: IRR for PV in Oahu, HI
(Source: Author, 2009)

Consider that if electricity rates in Hawaii continue to escalate at the 5.27% per year rate of the last 16 years, a PV system with a 30 year life will generate a tax-free return of 10.2% (including the tax credit)! Most investors would consider this attractive. Homeowners on the other islands in Hawaii would receive a significantly better return due to their higher utility rates.

5. Cash-Flow Analysis of Solar Water Heating

5.1. SDHW in Michigan

There are numerous configurations for solar domestic hot water (SDHW) systems. Owing to the cold climate in Michigan, most systems rely on either a glycol-water solution as a working fluid, or a drain-back system to prevent collector freezing. The system used in this analysis is a drain-back system, which eliminates the maintenance cost of replacing the glycol every five years.

Typically the solar heated storage tank is plumbed in series between the water main or well, and the conventional tank-water heater. This has the effect of displacing the use of whatever fuel is used in the standard water heater –

natural gas, propane, or electricity. This analysis assumes that a conventional water heater is still used, so that the installation of a solar water heater does not reduce the system cost of the conventional water heater, but only the fuel cost. The cost savings of this preheating effect vary based on the fuel used to heat water, and the efficiency of the conventional tank water heater. Figure 18 illustrates a drain-back SDHW system, the same type priced in this study.

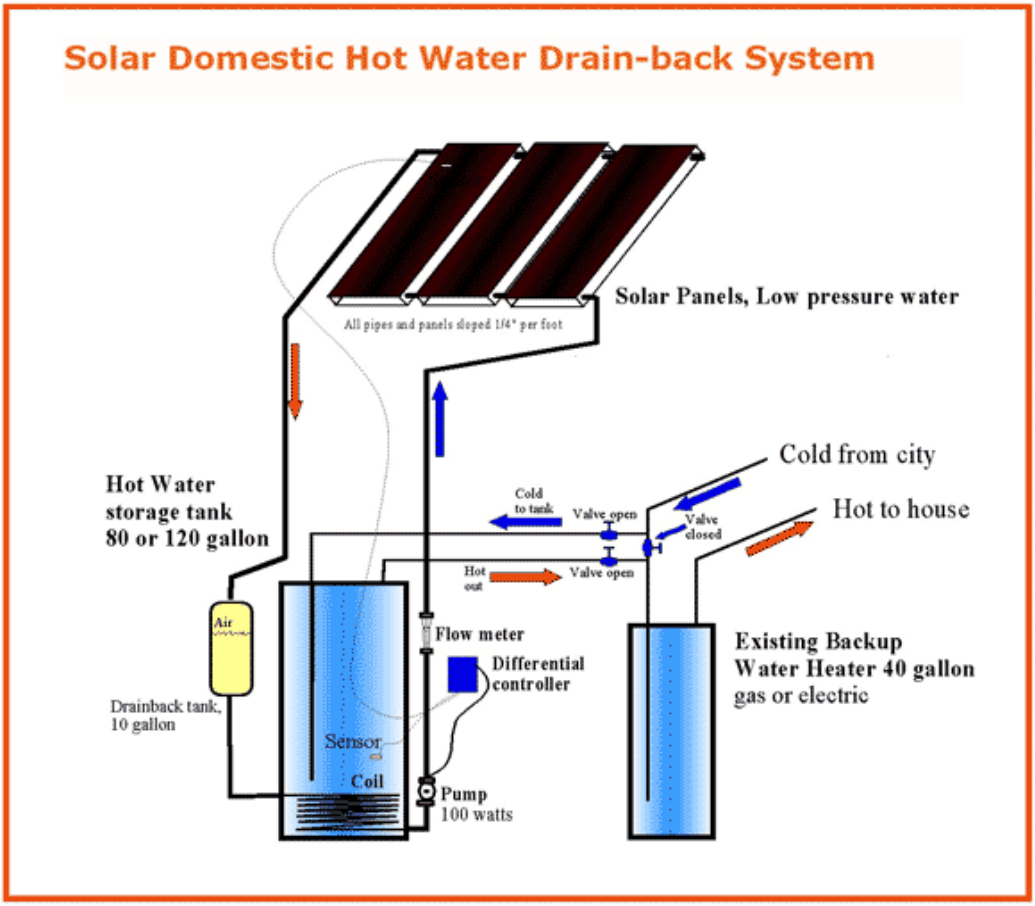

Figure 18: Schematic of a Drain-Back Solar Water Heater
[58]

Preheating the water before it enters the conventional water heater does not reduce the tanks stand-by losses, it only reduces the heat required to warm the incoming water. The amount of fuel to do so depends upon the *recovery efficiency* of the water heater. The recovery efficiency for an electric water heater is nearly 100%; i.e. all the energy of the electricity ends up as heat in the water. The recovery efficiency for gas (natural gas or propane) water heaters is less, since energy is lost up the flue. While the recover efficiency of a gas water heater may be as high as 94%, typical values are 76-78%.[59] This analysis uses 77%.

5.1.1. System Cost

The Michigan Energy Office funded a buyer-rebate program for SDHW systems in 2005. Data was collected on the system type, collector type, collector area, and system price for 61 professionally installed residential systems with flat-plate collectors. Collector sizes varied from 32 ft^2 to 128ft^2. System cost varied from $3,900 to $10,303, while the normalized price varied from $175.78/$ft^2$ down to $70.24/$ft^2$. [60]

While the normalized price varied considerably among installations, economies of scale were obvious from the data. Figure 19 shows the normalized price plotted against the collector area, and a least-squares regression analysis trend line.

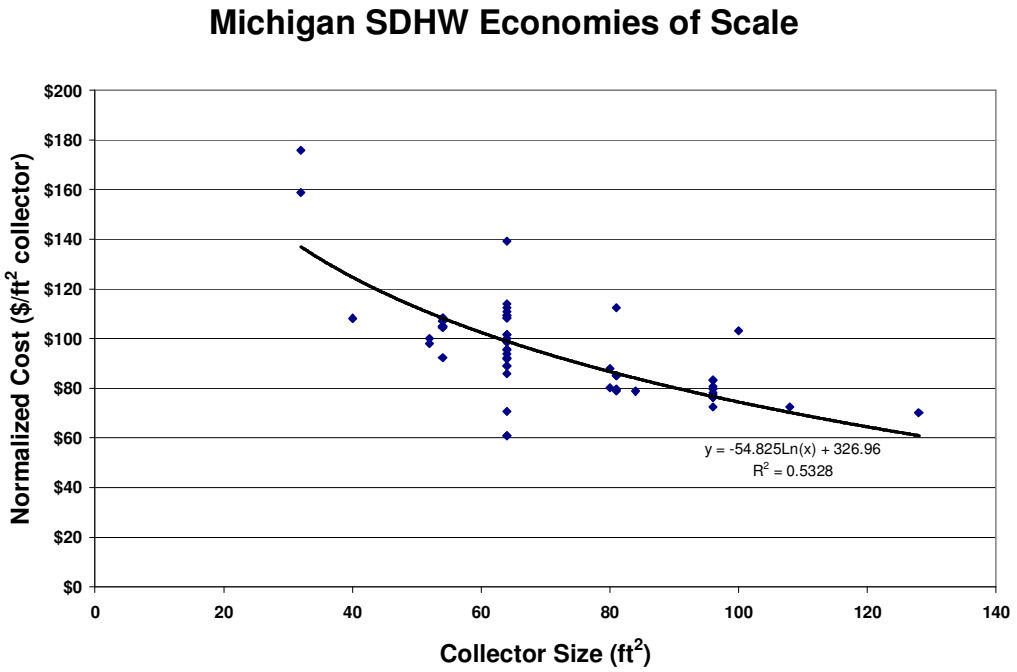

Figure 19: Solar Water Heater Economies of Scale
Source: Author, 2008 – based on data from [60]

The Michigan Energy Office also ran a solar water heating promotion program, with installers offering predefined systems as predefined prices. This analysis will use promotion #1, which was:

2 AET AE-32 (4'x8') collectors

80-gallon water storage tank (R17.3)

Installed price $5,960 + 6% sales tax = $6317.60

This system costs $99.53/$ft^2$. This is a typical normalized cost for a system of this size, but larger systems could be more financially advantageous if the demand was sufficient to make use of their output.

5.1.2. Discount Rate

For the solar water heating system, a typical system and financial situation may be more attractive than even the best-case for a PV system. Consider a middle-income household which is deciding to either buy a 20-year treasury bill, paying 4.5%[61], or invest the funds in the SDHW system described above. Interest on the bonds is taxable. The median Michigan household income is ~$46,000[62], placing them squarely in the 15% federal tax bracket. Adding the Michigan tax rate of 4.35%, the after-tax yield is (4.5%)(1-.15-.0435) = 3.63%.

5.1.3. System Output

System output was computed using Michigan average monthly solar insolation and temperature data from the Lansing data station (in the center of the state).[63] An "f-chart" spreadsheet computed the system output by month. This was roughly confirmed by running the same system through F-chart software (using "upper Midwest US" weather data), and by using RET-Screen software. Heat loss from the water storage tank was computed using dimensions and R-values from AET. The following assumptions about system demand and operations:

Water Demand:	250 L/day
Mains water temp:	15℃ (59 ℉)
Water heater set point:	50℃ (122 ℉)
SDHW system annual output:	9.86 MJ (2738 kWh)

Coincidently, the annual output (thermal) of this solar water heating system is about the same as the annual output (electrical) of the PV system, but at one-third the installed cost.

5.1.4. Michigan Typical SDHW System Financials

The financial metrics analysis in Figure 20 considers a SDHW system displacing energy provided by natural gas, propane, or electricity. Note that using propane heating is more expensive than electricity; this is a recent development, following the rise in the price of oil. It's clear from all four financial metrics (payback period, NPV, IRR, and COE) that solar heating make much more sense for those heating water with propane than electricity or natural gas. Also note that all of the metrics for this typical SDHW system are more attractive than the best-case metrics for a PV system. But this simple analysis assumes the price of these fuels is fixed.

	Natural Gas	Propane	Electricity
Unit being priced	1000 cubic feet	1 gallon	1 kWh
Fuel cost per unit	$10.76	$2.45	$ 0.1114
kWh/unit	292.91	26.83	1.00
Fuel cost per kWh	$0.037	$0.091	$0.111
Water heater efficiency	77%	77%	100%
Fuel cost per kWh (thermal) delivered	$0.048	$0.119	$0.111
Value of output (USD / yr)	$130.62	$324.70	$305.03
Present value of fuel savings over lifetime ($)	$1,834.81	$4,560.90	$4,284.65
SDHW System Financial Metrics (no incentives)			
Cost of SDHW system	($6,317.60)	($6,317.60)	($6,317.60)
Payback period (years)	48	19	21
Net Present Value of project (NPV) ($)	($4,482.79)	($1,756.70)	($2,032.95)
Internal Rate of Return (IRR) (%)	-7.3%	0.3%	-0.3%
Cost of energy ($/kWh-thermal)	$0.16	$0.16	$0.16
SDHW System Financial Metrics (w/30% Fed Tax Credit)			
Cost of SDHW system	($4,422.32)	($4,422.32)	($4,422.32)
Payback period (years)	34	14	14
Net Present Value of project (NPV) ($)	($2,587.51)	$138.58	($137.67)
Internal Rate of Return (IRR) (%)	-4.6%	4.0%	3.3%
Cost of energy ($/kWh-thermal)	$0.11	$0.11	$0.11

Figure 20: NPV for a Solar Water Heater in Michigan

(Source: Author, 2009)

Based on this static-price model and before the tax credit, a solar water heating system is a poor investment for a Michigan home owner. Regardless of the heating being replaced, the NPV is negative and the IRR negative or near-zero. The tax credit improves the result, and a Michigan homeowner with a low discount rate may find a solar water heating system an acceptable investment. But as we saw with the PV examples, including future utility / fuel price increases can improve the return.

The graph in Figure 21 shows the IRR for each of the three fuels, varied depending on the assumed rate in price escalation of those fuels.

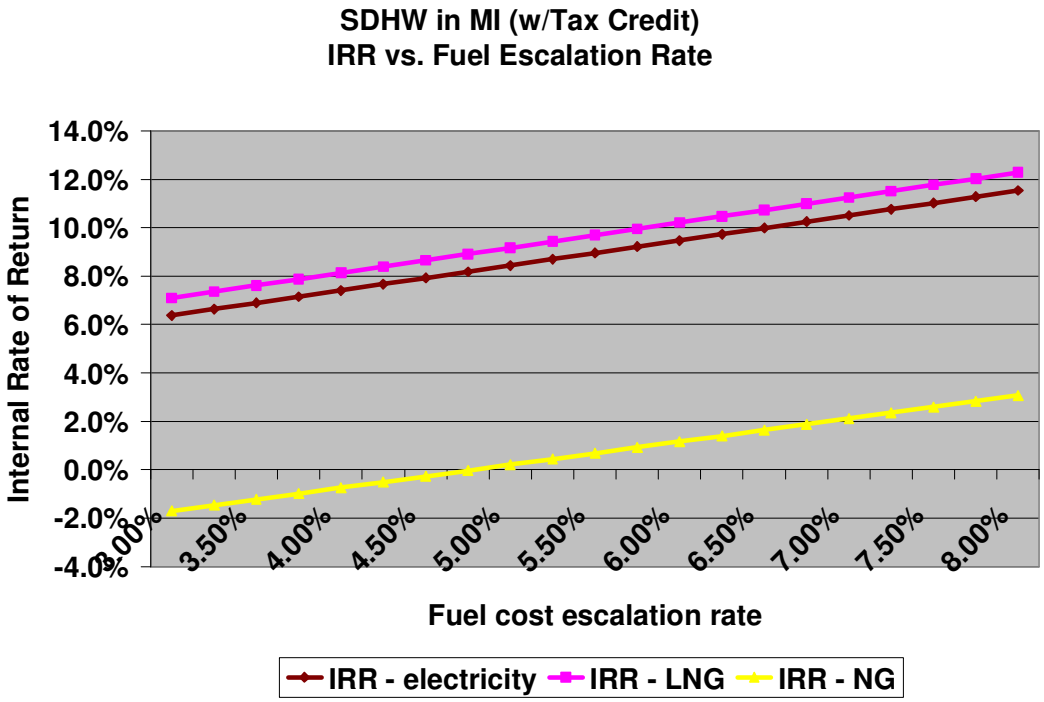

Figure 21 IRR of a Solar Water Heater in Michigan (Source: Author, 2008)

A prospective investor in a solar system may consider the IRR based on historical price escalations in Michigan. Figure 22 shows the rate of price increases as a compound annual growth rate (CAGR) over 9 years.

	Price in 1997	Price in 2006	CAGR
Natural Gas ($/000 ft^3)	5.2	11.97	9.7%
Propane ($/gallon)	$1.04	$1.92	7.0%
Electricity (cents/kWh)	8.57	9.77	1.5%

Figure 22: Michigan Historical Price Escalations from 1997 – 2006
Data Sources: [20], [34], [35]

It is clear that a SDHW system is a poor investment for a Michigan home owner with a natural gas water heater – unless natural gas prices skyrocket in the near future. A SDHW system is a reasonable investment for most Michigan home owners heating their water with propane, if past trends in propane pricing continue. Michigan home owners heating their water with electricity may consider a SDHW system a strong or weak investment, depending on their personal discount rate and the rate at which they predict electricity prices rise in the future.

5.2. SDHW in Hawaii

Oahu's "natural" gas is a synthetic gas (SNG) made in a plant and distributed by pipeline. The price of natural gas, propane, and electricity on Oahu are all much higher than in Michigan. These higher prices, combined with the higher level of solar insolation and system output makes a solar water heating system there a very attractive investment.

F-Chart was rerun using the average monthly solar insolation and temperature data from the weather station in Honolulu, HI. [63] All the system and financial parameters are the same as the Michigan system. Due to the higher level of solar insolation in Hawaii, this system may be larger than optimum for the assumed hot water demand of 250 L/day. As shown in Figure 23, the solar system would supply 100% of the hot water demand for nine months a year. A smaller, less expensive system may be more suitable for the Hawaiian climate. Also, freeze protection may not be necessary, which may allow a lower-cost system configuration.

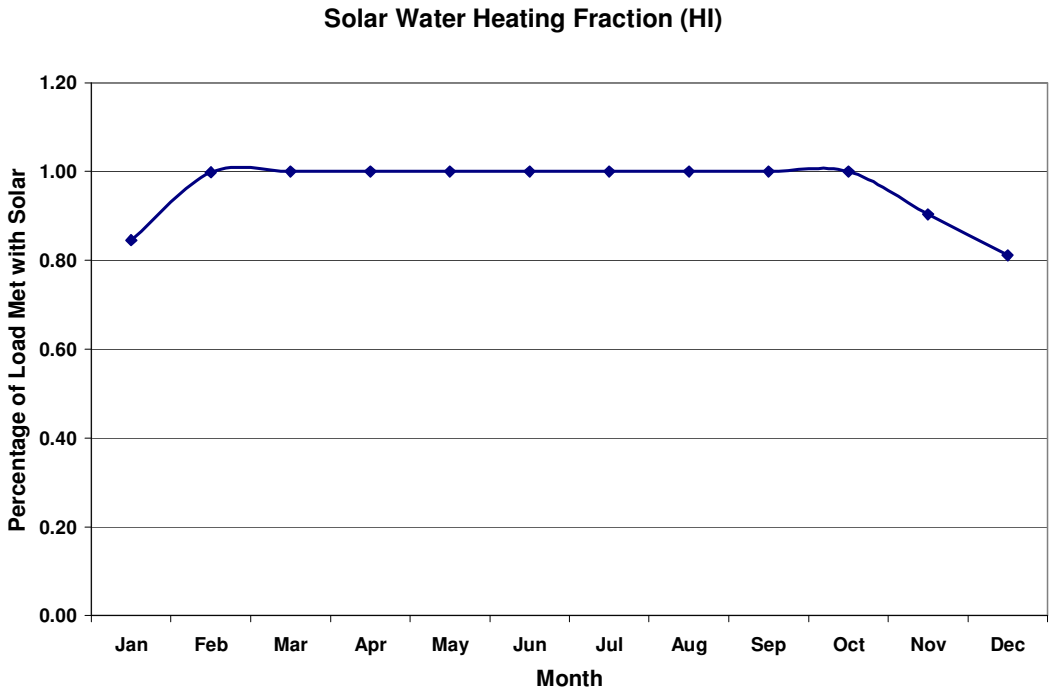

Figure 23: Fraction of Hot Water Demand Met by Solar in HI
(Source: Author, 2008)
SDHW system annual output: 13.78 MJ (3828 kWh)
(40% higher than the same system in MI)

The table in Figure 24 is a static-price model financial analysis of a SDHW system in Oahu, HI. Unlike Michigan, the cost of heating water is approximately the same, regardless of the fuel used.

	Synthetic Natural Gas	Propane	Electricity
Unit being priced	**therm**	**1 gallon**	**1 kWh**
Fuel cost per unit	**$5.40**	**$4.38**	**$ 0.2710**
kWh/unit	**29.29**	**26.83**	**1.00**
Fuel cost per kWh	**$0.184**	**$0.163**	**$0.271**
Water heater efficiency	**77%**	**77%**	**100%**
Fuel cost per kWh (thermal) delivered	**$0.239**	**$0.212**	**$0.271**
Value of output (USD / yr)	**$916.51**	**$811.57**	**$1,037.39**
Present value of fuel savings over lifetime ($)	**$12,873.95**	**$11,399.78**	**$14,571.84**
SDHW System Financial Metrics (no incentives)			
Cost of SDHW system	**($6,317.60)**	**($6,317.60)**	**($6,317.60)**
Payback period (years)	**7**	**8**	**6**
Net Present Value of project (NPV) ($)	**$6,556.35**	**$5,082.18**	**$8,254.24**
Internal Rate of Return (IRR) (%)	**13.3%**	**11.3%**	**15.5%**
Cost of energy ($/kWh-thermal)	**$0.12**	**$0.12**	**$0.12**
SDHW System Financial Metrics (w/ 30% Fed Tax Credit)			
Cost of SDHW system	**($4,422.32)**	**($4,422.32)**	**($4,422.32)**
Payback period (years)	**5**	**5**	**4**
Net Present Value of project (NPV) ($)	**$8,451.63**	**$6,977.46**	**$10,149.52**
Internal Rate of Return (IRR) (%)	**20.2%**	**17.6%**	**23.1%**
Cost of energy ($/kWh-thermal)	**$0.08**	**$0.08**	**$0.08**

Figure 24: NVP of a Solar Water Heater in HI

(Source: Author, 2009)

Note that the NPV is strongly positive for all three displaced fuels, and the IRRs are all above 10% without the tax credit, and above 17% with it. This illustrates a very attractive investment, even if fuel prices don't change for the next 20 years! When future fuel price escalations are included, a SDHW system in Hawaii looks even better.

Figure 25 shows the compelling tax-free returns such a system will generate, depending on the rate of future increases in the price of fuels and electricity.

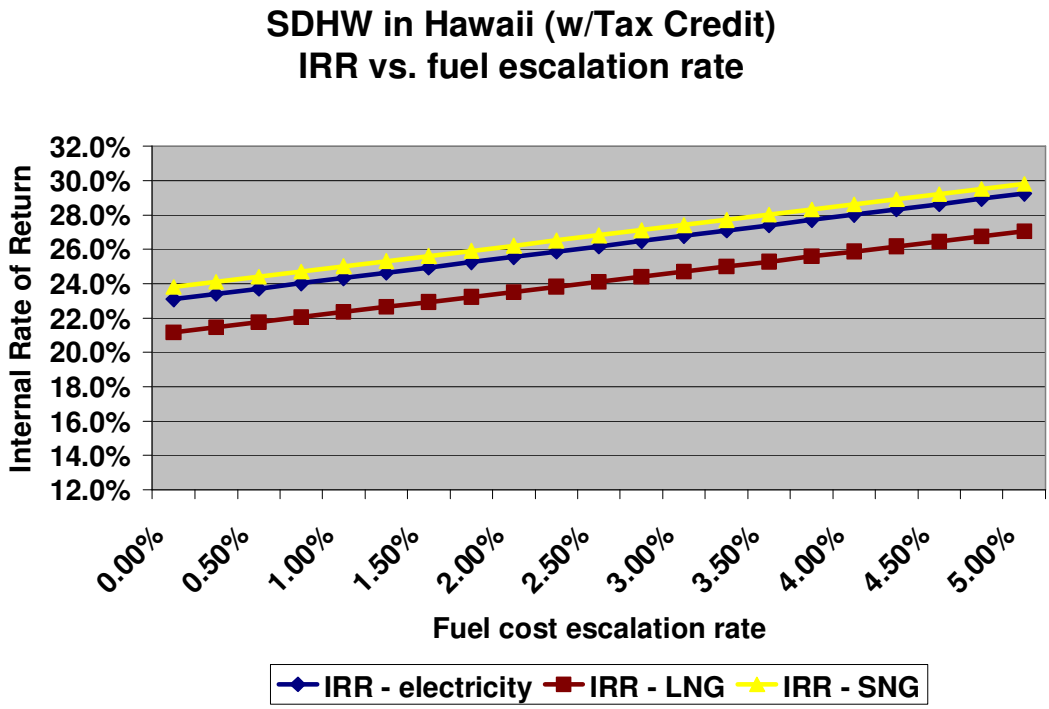

Figure 25: IRR of a Solar Water Heater in HI
(Source: Author, 2009)

Even if future fuel or electricity costs rise at only 3% per year, a SDHW system will generate an IRR of 20% or more! This is a stunning tax-free return for such a low-risk investment. With such excellent returns (and a $1000 utility rebate not included in this analysis), its surprising that the residential SDHW system penetration in Hawaii is "only" 25% (1 in 4 houses have one). [64] Hawaii recently passed a new state law mandating SDHW systems on all new homes starting in 2010. [65]

6. Recommendations for Further Study

This study has used available pricing data for solar systems added to existing homes. But a study of more than eighteen thousand PV systems installed in California showed a substantially lower cost ($1.20 / W_{AC} less) in systems installed during construction of large housing developments.[66] The opportunity for expanding the market niche for financially viable grid-connected PV systems could clearly be expanded by considering new construction vs. retrofit systems. Logically this should be true for SDHW system as well and perhaps to an even greater extent, considering the difficulty of adding plumbing runs to an existing structure.

This study has focused on residential installations, which are the most common in Michigan. Solar systems installed on businesses should have somewhat better economics for several reasons:

- Commercial enterprises pay higher effective rates for electricity than residential customers.
- Commercial tariffs include a significant capacity charge. For many businesses, peak usage occurs during hot summer days due to air-conditioning load. This peak usage could be cut significantly by solar, since insolation is well correlated with this load.
- Businesses can deduct depreciation of the system from their income tax. While they can also deduct utility charges, depreciation schedules are generally shorter than system lifetimes, making this tax affect a net benefit.
- Commercial or industrial solar systems are larger, gaining economies of scale on the cost of initial installation.

This study has assumed a fixed position collector. Many PV systems are installed on trackers, which increases the solar energy captured, but also the initial capital cost. Trackers particularly increase energy capture during the early morning and late evening hours in the summer, and this effect should be studied under a season rate tariff.

7. Conclusions

The claim that unsubsidized solar systems have reached grid parity in the U.S. is generally false, but true for specific locations within the country – locations with high utility rates and abundant solar insolation. Grid parity is a local matter, depending on local insolation and cost factors. While the term is most commonly used in relation with PV systems, grid parity, or "utility parity" may be more readily achieved with solar water heating systems – especially where natural gas is not available. The study found that:

1) Unsubsidized residential PV systems are not an attractive investment option in Michigan, under any reasonable set of assumptions. But a system qualifying for the Consumer's Energy feed-in tariff is a good investment. The federal tax credit makes a SDHW system in Michigan marginally attractive to homeowners heating their water with electricity or propane. It is not competitive with natural gas. If prices of fuels and electricity continue to rise faster than system costs, this will eventually change.
2) With the federal tax credit, a residential PV system on Oahu is a reasonable investment even if future electrical rate increases are not considered. But assuming utility rates for electricity and gas follow past trends upwards, a PV system on Oahu is quite attractive. A SDHW system in Hawaii is such a compelling investment it is surprising that every unshaded rooftop does not have one.
3) An NPV that assumes fixed utility prices in the future shows a negative value for either a SDHW in Michigan, or an unsubsidized PV system in Oahu. When a reasonable value for the future rate of utility price

escalation is considered, however, the IRRs for these systems become attractive. Any financial analysis of a solar energy system that assumes flat utility rates in the future is misleading, and does a disservice to its readers - and the solar industry.

4) In both locations studied, the SDHW system provides a much better return than the PV system. This is hardly surprising, since the output of the two systems considered is approximately equal, and the PV system costs about three times as much as the solar water heater. This higher initial cost overwhelms the fact that electrical energy may be more valuable than thermal energy.

Both the PV and SDHW industries are growing at enviable rates. For now, sales continue to be stimulated by favorable government policies, a trend which is still accelerating. The price of fossil fuels and utility electricity are both likely to continue to climb in the future. In the long run, this the most powerful force in favor of the growth of solar industries. Explicitly including the escalating cost of conventional energy in any financial analysis of a solar system greatly enhances the system's attractiveness to the would-be owner. Solar energy remains a "ward of the State", but the trends are all in its favor.

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