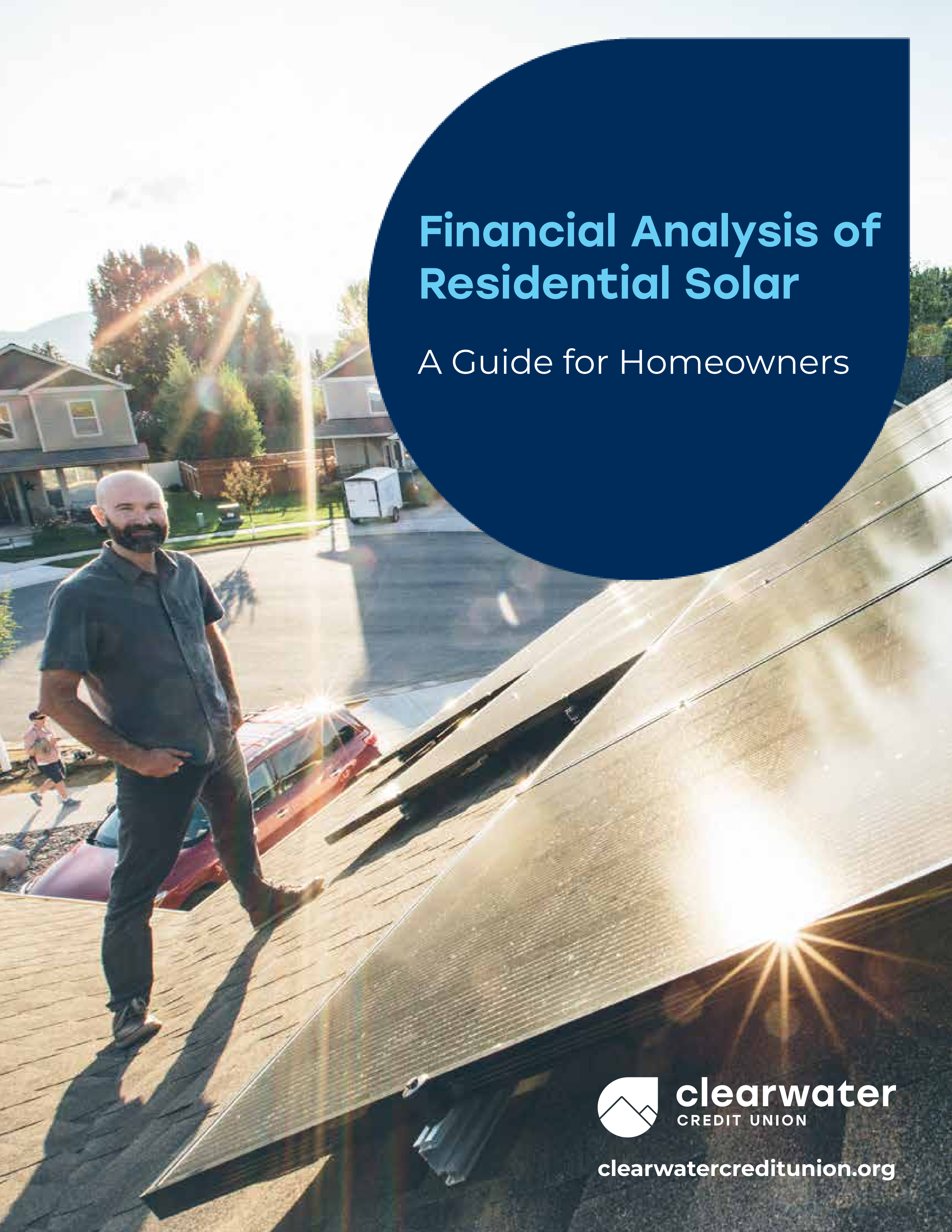


Financial Analysis of Residential Solar

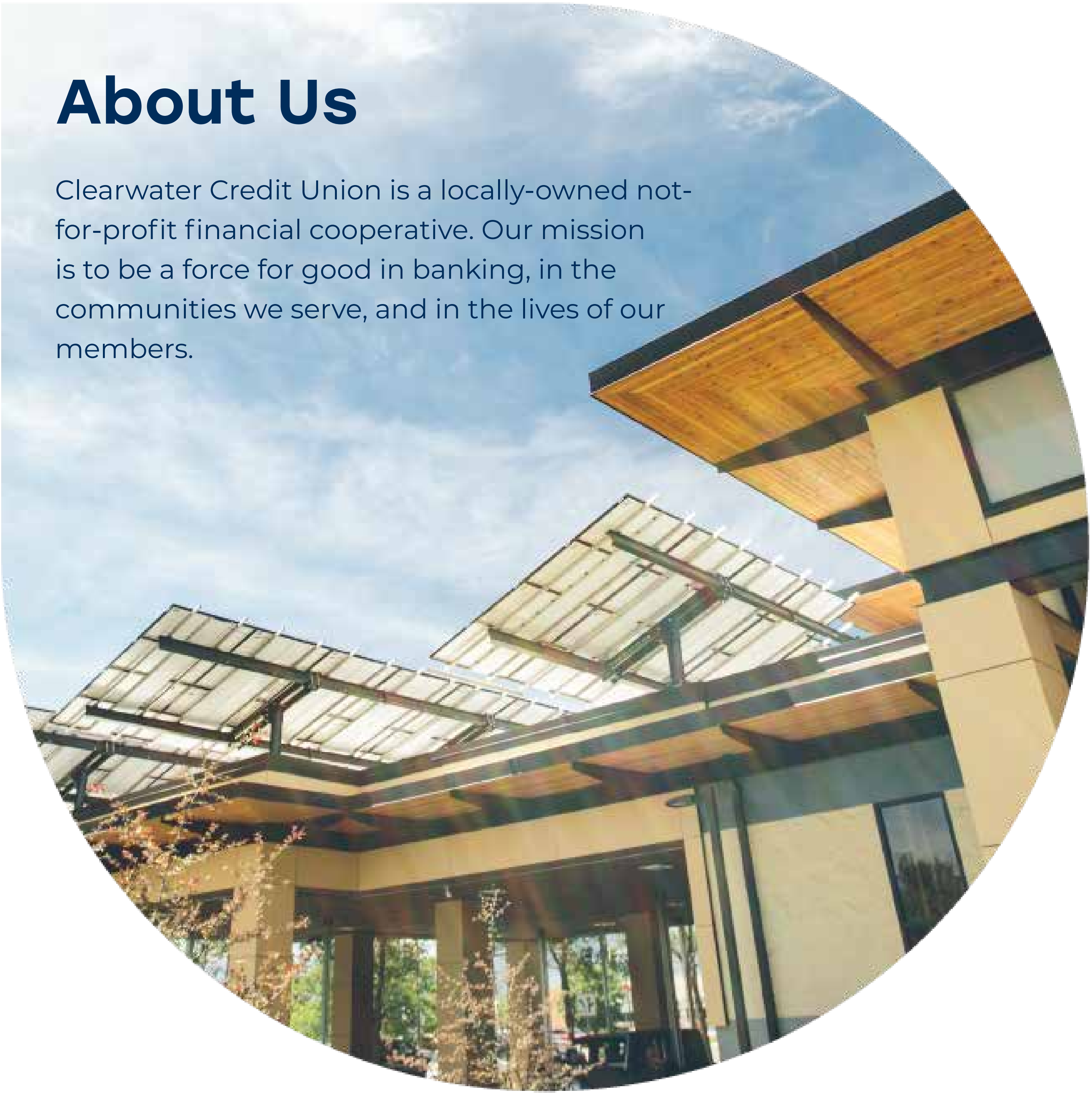
A Guide for Homeowners

Clearwater Credit Union

clearwatercreditunion.org

About Us

Clearwater Credit Union is a locally-owned not-for-profit financial cooperative. Our mission is to be a force for good in banking, in the communities we serve, and in the lives of our members.



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Introduction

There are many reasons you might want to add solar panels to your home: a desire for energy independence, a commitment to low-carbon energy sources, or as a financial investment. Whatever your motivation, at some point the question comes up, "does this make sense financially?" As it turns out, there is no single answer. The financial performance of home solar is generally favorable, but it depends on the specifics of the system, your financial situation, and assumptions about the future. The goal of this report is to provide a broad understanding of the economic performance of home solar and the factors affecting it, and to provide an assessment framework for homeowners interested in solar energy.

Because there is no single metric to assess financial performance, we frame our analysis with questions that a potential solar purchaser may have, such as: When will my system pay back? How much will I save on my utility bills? What is my return on investment? The answers are discussed in a general way and are illustrated using numbers from a hypothetical reference case. For those interested in the technical aspects of the analyses, more details are given in the end notes.

Clearwater Credit Union does not recommend whether our members should or should not make any particular investment, including purchasing solar energy systems. We also do not make recommendations about financing options for solar energy systems. The information presented here is for education only, and is intended to help anyone interested in home solar understand the financial aspects of their decision.

Background

The financial performance of a home solar energy system depends on the system details, utility electric rates, available incentives, and assumptions about the future. It is helpful to have some background understanding of these factors before addressing specific financial questions. Although solar energy can be used in many forms—solar electric generation, solar water heating, passive space heating—this report deals with electricity generation by solar photovoltaic systems.

Characteristics of Solar Photovoltaic Systems

For financial analysis, a residential solar photovoltaic (PV) system can be described by three characteristics:

- **Size:** The size of the system is usually given in kilowatts (kW) of direct current produced under specific reference conditions. This is also known as nameplate capacity or nameplate rating.
- **Energy Production:** The amount of electricity actually produced depends on the details of the location and PV system. Energy production is often given in kilowatt-hours per year (kWh/year). This value can be easily estimated using online tools such as PVWatts[1], and should be provided by installers as part of their bid. Values in Montana for well-situated rooftop residential systems are in the range of 1,000 to 1,400 kilowatt-hours per year for each kilowatt of nameplate capacity (kWh/kW-year).
- **Price:** For analysis, the total system price should include everything needed from start to finish including design, permitting, installation, and grid interconnection. Most installers provide "turnkey" systems, which include all these costs. The system price is commonly given in dollars per watt of nameplate capacity ($/W). Prices for solar PV have declined substantially in recent years (Figure 1).

Price of Electricity

Most home PV systems are connected to the utility grid with a net metering agreement. Under net metering, when you are generating more energy than you are using electricity flows to the grid and you are credited for the amount. Because of mismatches in the timing of production and consumption most systems will frequently generate excess power, so the rate you are credited has a large impact on the financial performance of your system. Currently in Montana net metered systems are credited at the full retail rate of electricity, that is, you are credited for excess production at the same rate you are charged for what you purchase (¢/kWh). This simplifies analysis, but there are two important details to keep in mind:

- **Fixed vs. variable charges.** The price you pay for electricity includes two types of charges: a fixed charge for your service connection ($/month), and a variable charge based on how much electricity you use (¢/kWh). It is important to separate the two, as the variable rate is what you will be earning for the energy produced by your solar PV system. Rate structures vary between utilities: some use a low fixed charge and higher variable rate (more favorable for net metering), while others use a higher fixed charge and lower variable rate (less favorable). The fixed and variable charges should be listed on your bill[2].

  In some markets, electric rates may vary by the time of day or include charges based on peak demand. These rate structures complicate analysis somewhat, but are currently not implemented for homeowners in Montana.

- **Electricity price increases.** Because of the long lifetime of solar PV systems (25+ years), future electric rates have a large impact on the financial performance of the system. Assumptions about the increase in electricity prices are often buried in projections of financial performance, but they are a critical variable, as over 25 years the difference between seemingly similar growth rates (say 3% and 6% annual) are quite large. Over the last 25 years, electricity prices in Montana have grown at an average annual rate of 2.7% (nominal), or 0.4% when adjusted for inflation (real; Figure 2). Potential changes to this rate are discussed in the section on Risk.

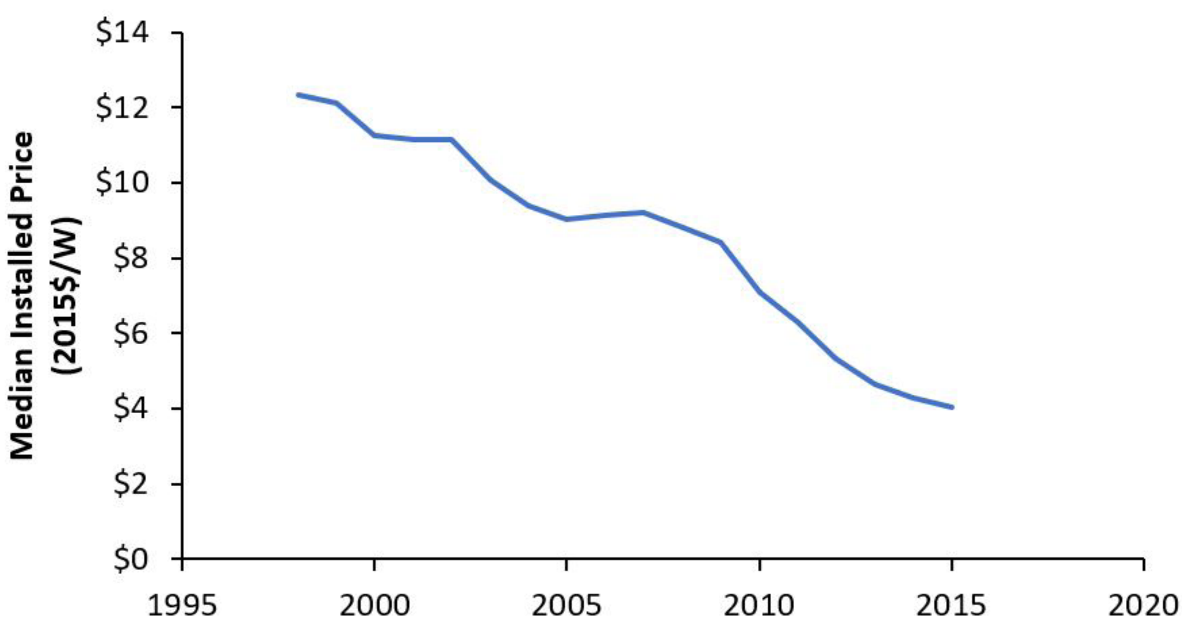


Figure 1. National median installed price of residential solar PV systems. Prices in Montana are not tracked, but tend to be below median. Data from *Tracking the Sun IX: The Installed Price of Residential and Non-Residential Photovoltaic Systems in the United States*, Lawrence Berkeley National Laboratory, 2016.

An additional, subtle factor is the annual billing period for net metering. The structure of most net metering agreements is that production and consumption are totaled monthly, and if production exceeds consumption the excess credit is carried forward to the following month. Once per year the account is "trued up" at which point any remaining credits are extinguished without compensation. Some utilities set the date of this true up, while others offer a choice of dates to the system owner. In either case, it is generally most advantageous to have an annual true up date in the spring, so that excess credits generated during the highly productive summer months can be used up over the less productive winter.

Incentives

As of 2017, there are two major incentives for residential solar PV systems in Montana: The federal Solar Investment Tax Credit, and the Montana Alternative Energy System Tax Credit. Both are tax credits, which reduce the total amount of money you owe, so you must have a large enough tax liability to make use of them (both can be spread out over several future tax years). In the past, utilities in Montana offered cash rebates to residential customers for solar PV systems, but these programs are no longer active for homeowners.

- **Solar Investment Tax Credit (ITC).** The federal ITC allows individual taxpayers to take a tax credit of up to 30% of the total cost of a solar energy system. The full 30% will apply to projects beginning construction through 2019, and is then reduced to 26% in 2020, 21% in 2021, and 0% thereafter. (Credits for commercial systems follow a similar timeline but with different percentages). The ITC was originally intended to expire at the end of 2007, but has been extended repeatedly. However, there is no guarantee that it will not expire on schedule this time, particularly in light of the dramatic decline in the cost of solar PV in recent years. This credit can be carried forward until the credit is used up (Internal Revenue Code 25D).
- **Alternative Energy Systems Tax Credit:** This Montana state tax credit allows taxpayers who install an alternative energy system to take an income tax credit of $500 for an individual, $1,000 for a couple. This credit can be carried forward for up to three additional years following installation of the system (Montana Code Annotated 15-32-201).

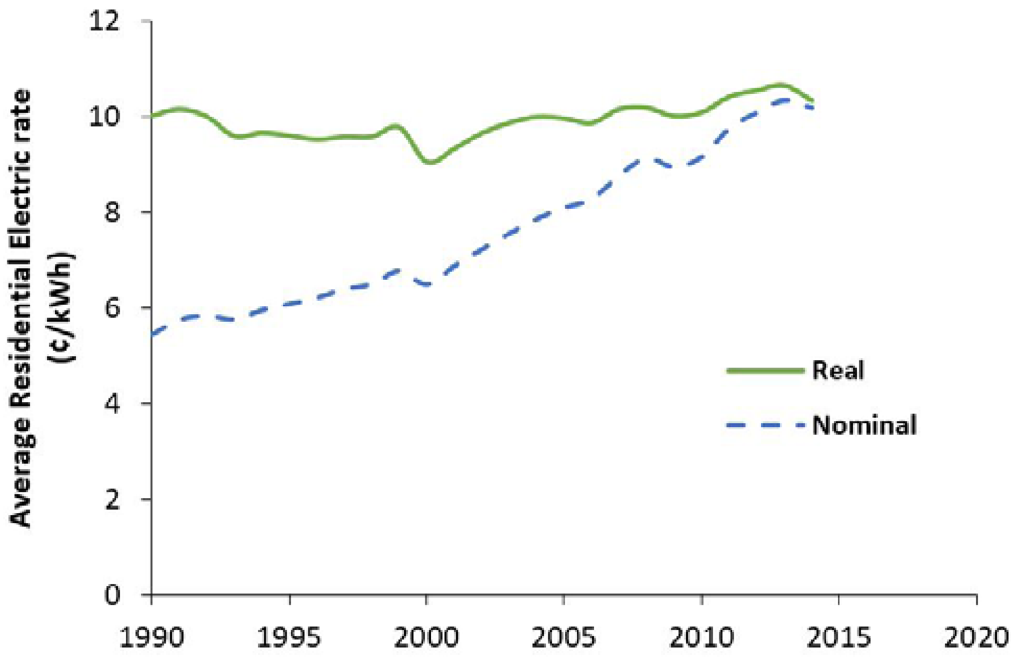


Figure 2. Average residential Montana electricity prices in real (2016) and nominal dollars. Price data from U.S. Energy Information Agency; deflation by national CPI-U.

Risk

In many regards the financial risk associated with solar PV systems is low, as system performance is generally under warranty and electricity prices are fairly stable. The two primary downside risks are:

- Changes to utility rate structure: Under current net metering arrangements in Montana you are credited for the electricity you produce at the full retail rate. While recent legislation provides some rate protections for net-metered customers, it does not preclude changes to rate structure such as raising fixed charges and lowering variable charge rates, which would lower the revenue your PV system generates .

  A recent controversy in Nevada offers an example of this risk. In 2015, Nevada utility regulators created a separate rate class for net metered customers, reducing the rate credited for excess production by roughly 70%. After political push back, regulators have recently restored the excess production credit to 95% of the retail rate (stepping down to 75% as the number of net metered systems grows).

  The effect of potential future rate changes is illustrated in Figure 3, which shows the internal rate of return for a hypothetical PV system when the credited rate is reduced by 25% or 50% at some point during the life of the project (both the IRR and the hypothetical reference PV system are described in the Results section). The IRR of the reference case with a full retail rate credit is 6.5%. Even with a 25% rate reduction in the first year of the project, the IRR is still 3.9%[4].

- Unanticipated costs: The financial performance of your solar PV system will be decreased by additional future costs, such as inverter replacement (~$1,000-$2,000), or the need to have your solar panels removed and reinstalled during roof replacement (~$500—$1,000).

Owning a solar PV system also has upside risk, in particular the possibility that electricity prices will rise faster than in the past. Electricity prices have increased at a steady, low rate over the past 25 years (figure 2), but continued growth at the same rate for the life of a PV system is not assured, particularly in the context of growing global energy demand and the need for sharp reductions in greenhouse gas emissions in order to meet climate change temperature targets[5].

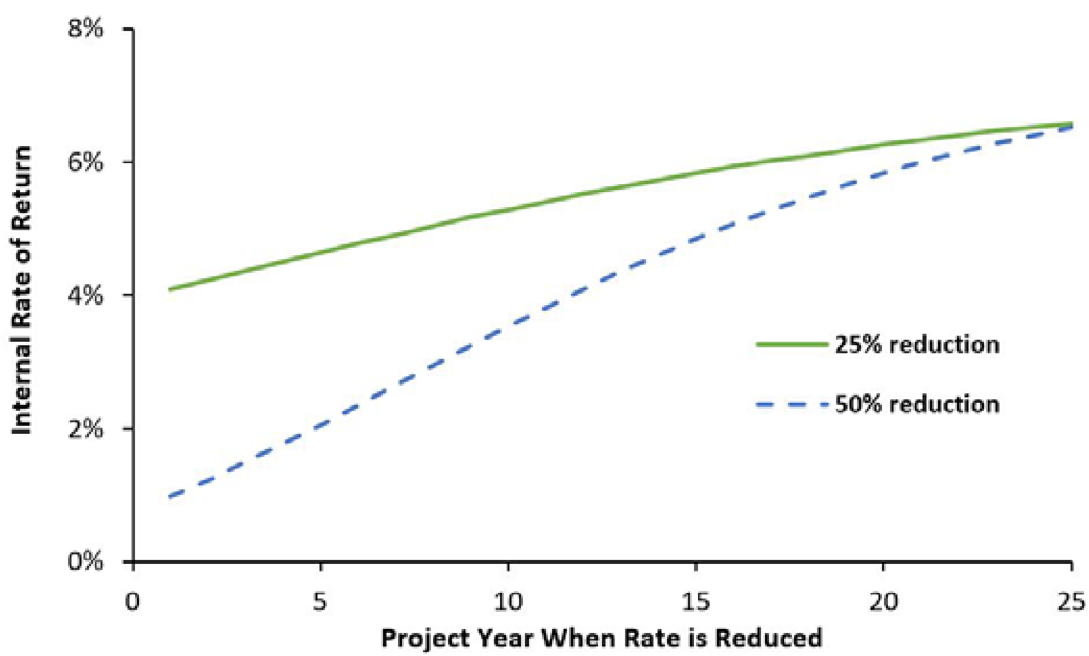


Figure 3. The effect of potential rate changes on system financial performance. The internal rate of return is for the entire 25-year project lifetime. The two data series show a reduction of 25% and 50% of the rate credited for excess production[3].

Results

The question "does solar make sense financially?" turns out to have many variations. Does it refer to the return on investment? Monthly savings? Time until the system pays for itself? Instead of a single answer, we discuss a number of questions that may come up for a homeowner interested in solar PV.

Reference case

To illustrate the following discussion, we will present the results for a hypothetical home PV system of 5 kW, an installed cost of $3.0/W, and energy production of 1,200 kWh/kW-year. This would cover around 60% of the annual electric use for an average home. For the cost of electricity, we used a variable rate of 11.3 ¢/kWh, growing at a rate of 2.6%/year (nominal).

This is an example case, intended to illustrate the concepts using numbers estimates from the time of writing. The financial performance of a specific project will depend on the owner's financial situation (electric rate and ability to take tax credits; loan details and income tax rates if appropriate), system specifics (price, annual production), and assumptions about the future (electric rate escalation and changes to the rate structure). Many of these parameters are changing rapidly as the solar landscape evolves. Homeowners interested in analysis of their own systems are referred to the section "Putting It All Together," pg. 14.

Table 1. Reference case parameters.

System Size	**(kW)**	5.0
Price	**($/W)**	3.00
Production	**(kWh/kW-year)**	1,200
Federal Tax Credit	**(%)**	30
State Tax Credit	**($)**	1,000
Electric Rate	**(c/kWh)**	11.3
Electric Rate Escalation	**(%/year, nominal)**	2.6
Federal Tax Rate	**(%)**	25
State Tax Rate	**(%)**	6.9

How large should my system be?

Most of the factors affecting the financial performance of home solar scale with the size of the system. That is to say, the percentage return on a 3 kW system is the same as a 10 kW system, although the total dollar amount will be larger for the larger system. There are two mild exceptions to this: First, the Montana Alternative Energy Tax Credit is for a fixed amount, regardless of the size of the system ($500/$1,000 for single/joint filers), meaning that smaller systems will receive a larger discount as a percentage of the total cost. Second, there is some economy of scale as the system size increases, so larger systems tend to be cheaper on a per-watt basis.

The effect of these two factors is small however, and system size is best determined by other considerations, such as how much you can afford, or how much of your electricity use you would like to offset. It's also important to note that under most net metering agreements you cannot offset more electricity than you use in a year, so you will not receive any financial benefit for generation in excess of your annual consumption. Electricity use varies widely between homes, so it is important to know how much yours uses annually.

How long until the system pays itself off?

The simple payback of a system is the point at which the savings generated by the system exceed the system cost (the term simple here refers to the fact that the future savings are not discounted, that is adjusted for the assumption that money received in the future is worth less than money received today)[6].

The simple payback for our reference system is 12.4 years. The payback is sensitive to the system price and electric rate[7]. For example, an electricity rate with a higher fixed charge and lower variable charge rate of 7.5 ¢/kWh has a payback of 17.7 years. Any increase in rates above the assumed 2.6% annual (nominal) would decrease the payback time.

Is solar PV a good investment?

One way to look at a solar PV system is purely as an investment, just like buying a bond or investing in a mutual fund. How does solar PV compare? To answer this, we use the internal rate of return (IRR). Essentially, the IRR is the rate of return your money earns while it is invested[8].

It is important to note that the return on a solar PV system is after tax, because you are avoiding purchasing electricity with your after-tax dollars. So, when comparing solar PV to other investments they should be adjusted for the effect of taxes[9].

Figure 4 shows the tax-adjusted return for solar PV, a 20-year treasury bond and the 25-year return of the stock market. The reference case has an IRR of 6.7%, compared to 1.9%—2.1% for a 20-year treasury (after tax) and

7.2%—8.6% for the total stock market (after tax). Downward adjustment of the electric rate by 25%, representing the risk of changes to the electric rate structure, reduces the IRR to 4.1%, still well above the 20-year Treasury yield. The IRR is sensitive to the system price and the electric rate[10], so it's important to use accurate values for your analysis.

In terms of risk, a solar PV system is somewhere between a Treasury bond and a total stock market index fund. Performance of a solar PV system is generally under warranty, and electricity prices are unlikely to decline significantly. As described in the *Risk* section, the principal component of risk is changes to the variable rate component of the electric tariff, which can substantially decrease the financial performance of the system. Of course, above-expected increases in the electric rate can substantially increase the return.

How much money will I save on my electric bill?

Your monthly savings depend on how much

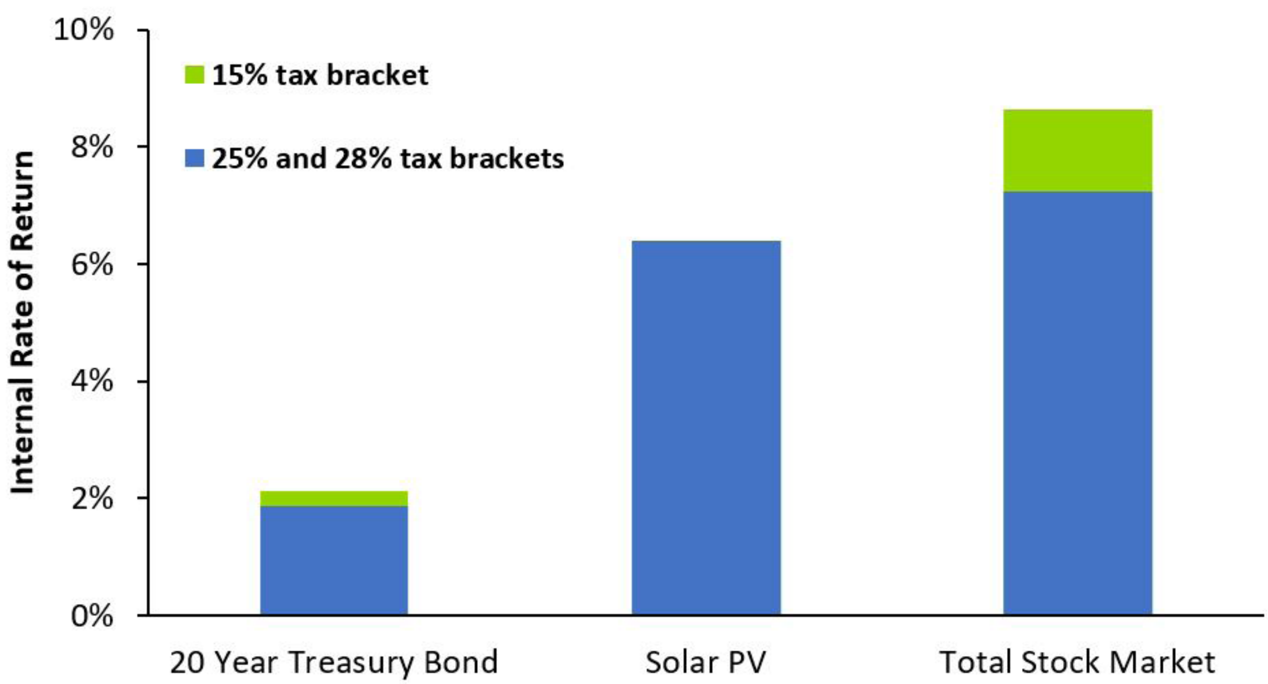


Figure 4. Tax-adjusted investment returns. The 25 and 28% brackets are combined here as the relevant tax rate (long term capital gains) is the same for both. Treasury yield as of July 2017. Total stock market from Wilshire 5000 1992-2017.

electricity the system produces and your electric rate. Solar PV systems produce much more energy during the summer (about 6 times as much), so we average the savings across the year to give the annualized monthly bill savings (MBS[11]). In the case that you have financed the system with a loan, you can subtract your monthly loan payment from the MBS to get your monthly cash flow.

Our test case produces $57/month of electricity on average. Depending on the specifics of the loan, the loan payment would be between $100 and $140 per month, so you would save less money than it costs to pay the loan until the loan is paid off, at which point the cash flow is positive for the rest of the project lifetime (Figure 5).

Should I take a loan or pay cash?

The answer to this question depends on the answer to another: what else would you do with the money? Instead of paying cash for a solar PV system, would you invest it in a mutual fund? Pay cash for a car you would otherwise take a loan for? Take a vacation? The return you would get from this other use is your personal discount rate, and it is the key to deciding between paying cash and getting a loan.

If your personal discount rate is higher than the interest rate on the solar loan, it is preferable to finance the system. This makes intuitive sense: if you finance a PV system and instead invest your money somewhere with a higher rate of return, it will earn money faster than the interest accumulates on the loan. If your personal discount rate is lower than the interest rate on the loan, it is preferable to pay cash for the PV system. The closer the rates are to each other the less impactful the decision.

A few examples should help to make this clear. Let's say that you have decided to purchase a $15,000 solar PV system and you are trying to decide if you should pay cash or take out a loan.

- You will either pay cash for the solar PV system, or you will finance the system with a loan at 5% and put the cash into a mutual fund you expect to earn 7%. In this case your alternative rate or return (7%) is greater than the loan interest rate (5%), so it is better to finance the system.
- You will either pay cash for the solar PV system and finance a new car at 3.5%; or you will pay cash for the car and finance the solar PV system at 5%. In this case your alternative rate of return (3.5%) is lower than the solar loan interest rate (5%), so it is better to pay cash for the solar PV system.
- You have a strong preference for using the money for something besides a solar energy system, say a needed home repair, or a vacation you've been waiting for. In this case your return on that vacation may be hard to put a number on, but you do know that it's larger than the 5% interest rate on the solar loan, so it makes sense to finance the solar PV system.

Quantitatively, assessing various financing options

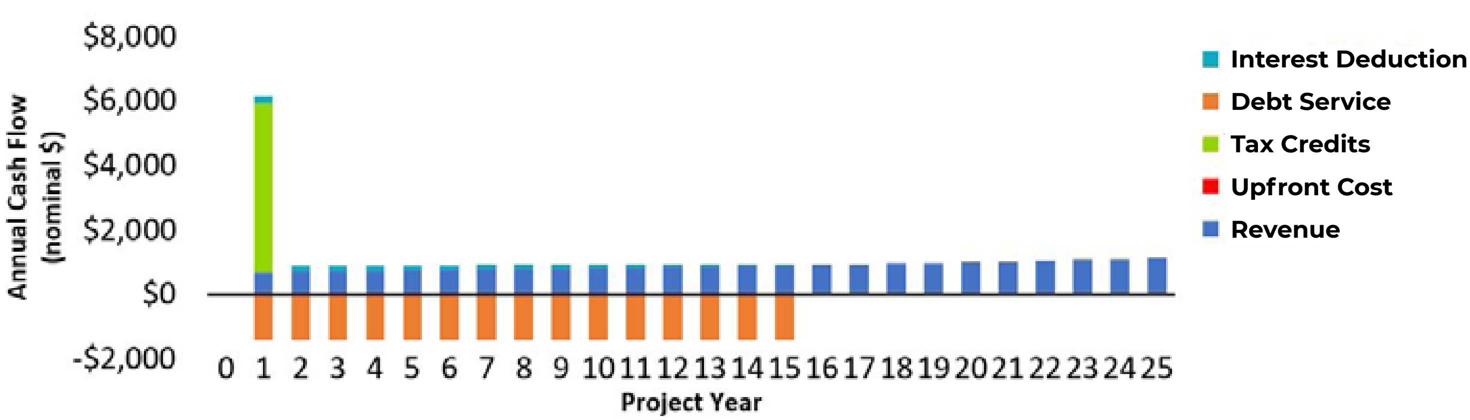


Figure 5. Cash flow for a 100% financed, 5% APR, 15-year term, home equity loan with interest deduction.

is done using the net present value (NPV)[12]. The NPV sums all the cash flows (positive and negative) over the life of the project. These cash flows are reduced at a discount rate to reflect the idea that money spent or received in the future is considered less valuable than money today. In this case, you would calculate the NPV of the various scenarios using your personal discount rate and select the one with the highest NPV.

What type of loan is best?

Standard personal finance advice is to minimize your (weighted) average interest rate, so you should take loans with the lowest rate possible, even if that means taking a longer term and/or higher total interest payments. In the case of solar energy systems, two additional points warrant consideration: loan availability and features, and the tax implications of home equity loans.

- A variety of loans can be used for solar energy systems, both secured and unsecured. Secured loans generally offer lower interest rates but require pledging collateral for the loan, such as a lien on your home or the solar energy system itself. Unsecured loans do not require collateral and therefore require less administration. Solar-specific loans are becoming more common, both from local providers and national financial institutions, and many provide solar-friendly features, such as the ability to re-amortize the loan after receiving tax credit incentives. Some state and local governments may also offer solar loans. Traditional unsecured and home equity loans can also be used for home solar energy systems.
- An important feature of home equity loans is that the interest portion of your payment is deductible from your federal and Montana state income taxes, if you itemize deductions (as opposed to taking the standard deduction). This seemingly small detail can significantly increase the financial performance of your system. (Table 2).

Should I buy now, or wait for prices to get lower?

The price of solar PV systems has declined more than 70% over the last 7 years (Figure 1), and prices are expected to continue to decline into the future, albeit at a slower rate. With this in mind, does it make sense to wait for prices to come down before buying a system? The answer to this question hinges on three points:

- First, how much will prices come down? The price decline in the PV modules themselves appears to be slowing, but there is still substantial opportunity for declines in the so-called balance of system costs (permitting, installation, and non-module system components). We use an 8% annual decline as a midpoint estimate.
- Second, if you're paying cash, what will you do with the money in the meantime? Standard personal finance advice is that money you plan to use in the near future should be in safe investments, such as certificates of deposit (CDs), which are currently generating very low returns.
- Finally, while you wait you will be paying for your full electricity use.

Putting these together, the total price of future scenarios doesn't decline much even with

Table 2. The effect of interest deduction on financial performance. The system details are given in Table 1.

Term (years)	Rate (%)	Loan Type	Interest Deductible?	Monthly Bill Savings	NPV[9] (5% discount)
15	**5.0**	Unsecured	N	$57	$1,981
15	**5.0**	Home Equity	Y	$74	$3,362

sustained declines in the price of the solar PV system itself (Table 3). Increasing interest rates, and the reinvestment opportunity of avoided electricity purchases decrease the price difference even more[13].

What's the effect on the value of my home?

The short answer is: it all depends on the local market. Solar PV increases the value of your home to the extent that it will sell at a higher price, and this depends entirely on what consumers are willing to pay. A recent study showed that a solar PV system increases the price of the home by roughly the replacement cost of the system. This study was limited to seven eastern states plus California[14]; there is not sufficient data available from the Montana market to show an effect of solar PV on home prices.

Our analysis does not include increased home price in the financial return. If you are thinking of selling your home in the future, a reasonable assumption is that you will be able to recoup the replacement cost of the PV system. Note that if solar prices continue to decline, the replacement cost, and hence price premium, will decline along with them. (Of course, as time goes on you will have recouped more of your initial investment through avoided electrical purchases).

The effect of home solar on property taxes has not yet been codified in Montana. As discussed above, there are not sufficient comparable sales of homes with solar PV systems to incorporate them into valuation. In addition, Montana State code exempts residential solar PV systems from property tax for up to 10 years and $20,000 (MCA 15-6-224). The assumption is that at the present time a home solar PV system will not affect your property tax bill, but this may change in the future.

Roof-mounted solar PV systems generally are covered under homeowners insurance, but ground-mounted systems generally are not. Note that this means that the system will be covered for losses from the same perils as covered for the home, but the insurance will not cover malfunction or degradation (which should be covered under the warranty). In all cases, coverage will depend on the specifics of your policy, so it is best to consult with your insurance agent for a definitive answer.

Table 3. Estimates of future costs of solar PV systems. Parentheses denote negative values.

	2017	2018	2019	2020
Price ($/W)	3.00	2.76	2.54	2.34
Alternative Rate of Return (%/yr)	n/a	1.25%	1.25%	1.5%
Gross Cost ($)	15,000	13,800	12,696	11,680
State Tax Credit ($)	(1,000)	(1,000)	(1,000)	(1,000)
Federal Tax Credit ($)	(4,500)	(4,140)	(3,809)	(3,037)
Additional Electric Cost ($)	n/a	678	1,374	2,087
Interim Interest Earned ($)	n/a	(188)	(377)	(685)
Total Cost ($)	**9,500**	**9,151**	**8,883**	**9,046**

Putting It All Together

The financial performance of a proposed system depends on the specifics of the system, your finances, and assumptions about the future. A variety of financial modeling tools are available, from the very simple (e.g. PVWatts) to the very complex (e.g. System Advisor Module); Clearwater Credit Union has published a spreadsheet model to accompany this report, available at clearwatercreditunion.org/environment. Using one of these tools, a financial analysis of a proposed solar energy system can be approached with the following steps:

1. **Identify your questions.** Are you deciding between paying cash or taking a loan? Wondering if solar is a good investment? Before beginning, ask yourself what aspect(s) of financial performance interest you:
    - Do you want to know when your system will pay off? (Simple payback).
    - Do you want to know how much you'll save on your electric bill? (Monthly bill savings and monthly cash flow).
    - Are you interested in how your system performs as an investment? (IRR).
    - Are you deciding between taking a loan and paying cash? (NPV).
    - Are you deciding between various types of loans? (NPV).
2. **Collect data.** Many of the parameters can be estimated for a "back of the envelope" estimate, or you can collect bids from contractors for a more precise analysis. The basic parameters for analysis are:
    - System size (kW)
    - Price ($/W)
    - Energy production. This can be estimated with PVWatts, but will require an on-site shade assessment for best accuracy. (kWh/kW-year)
    - Variable charge rate for electricity. (¢/kWh)

If you are taking a loan, you will want to know the loan rate and term (length). If the loan interest is deductible and you itemize deductions you will want to know your state and federal income tax rate. You may wish to know your personal discount rate for NPV analysis. Some models allow you to vary your assumptions about future electric rate growth and future costs (such as inverter replacement or removal for roof work).

3. **Run a focused set of scenarios to answer your questions in (1).** The available variables can be overwhelming, so a clear set of scenarios and decision metrics can help you decide between your options.

Conclusion

Recent declines in the price of solar photovoltaic systems have made them an increasingly attractive purchase for homeowners. However, financial performance of a proposed system depends on the specifics of the system itself, the purchaser's finances, and assumptions about future electricity rates, preventing blanket assessments. *The information in this report is intended to give someone interested in solar a broad understanding of the financial performance of home solar and the factors affecting it, and help prepare them for a more detailed analysis of their particular situation.*

Technical Notes

[1]PVWatts, a product of the Department of Energy's National Renewable Energy Laboratory, is both easy to use and powerful. All that is needed for an estimate of production is the location (zip code is sufficient), the system size, and the array orientation (azimuth, the compass direction the array faces, and tilt, the angle of the panels from horizontal). Energy production is often expressed in kWh/kW-year, which can be determined by running the model for a 1 kW system. Many other solar energy estimators are available (Google's Project Sunroof, for example), but most offer easier use at the cost of detail and transparency.

[2]Depending on your utility, it may be difficult to determine the total variable charge rate, as your bill may include supply and delivery charges as well as a variety of taxes and other fees. For solar PV analysis, you can determine your total variable rate by subtracting all the fixed charges from your monthly bill total, then dividing by your monthly use. (Or you can call your utility and ask.)

[3]Specifically, HB219 (1) requires public utilities to conduct a cost-benefit analysis of net metering ("customer-generators") by April 2018; (2) allows a public utility to create a separate rate class for customer-generators, as part of a general rate case and based on the results of this study; (3) requires that customer-generators be allowed to remain in the rate class they begin generation in. Essentially, a customer-generator cannot be moved into a new rate class unless they opt in. However, this does not preclude changes to the tariff for the existing rate class, such as raising the fixed charge and lowering the variable charge rate.

[4]The IRR shown in Figure 3 assumes that all production is credited at the excess production rate. In fact, some percentage of production will occur at times when the power production is less than on-site consumption, in which case it will displace electricity that would otherwise be purchased at the (higher) retail rate. As such, Figure 3 shows the low limiting case, essentially as bad as things could get. The true value would be somewhere between the curve shown and the IRR of the
un-modified case (6.5%).

[5]For more detail see, e.g.:

- How much carbon dioxide can we emit? Peters, G. (2017). Center for International Climate Research [Blog post]. Retrieved from http://cicero.uio.no/en/posts/climate/how-much-carbon-dioxide-can-we-emit
- What would it take to achieve the Paris temperature targets? Sanderson, B. M., O'Neill, B. C., & Tebaldi, C. (2016). Geophysical Research Letters, 43(13), 7133-7142

[6]Multiple definitions of payback exist, ranging from the quite simple to fairly complex, depending on the treatment of future cash flows and financing options. We define here the simple payback to be the first point in time where:

$$\sum_n C_n > I$$

Where:

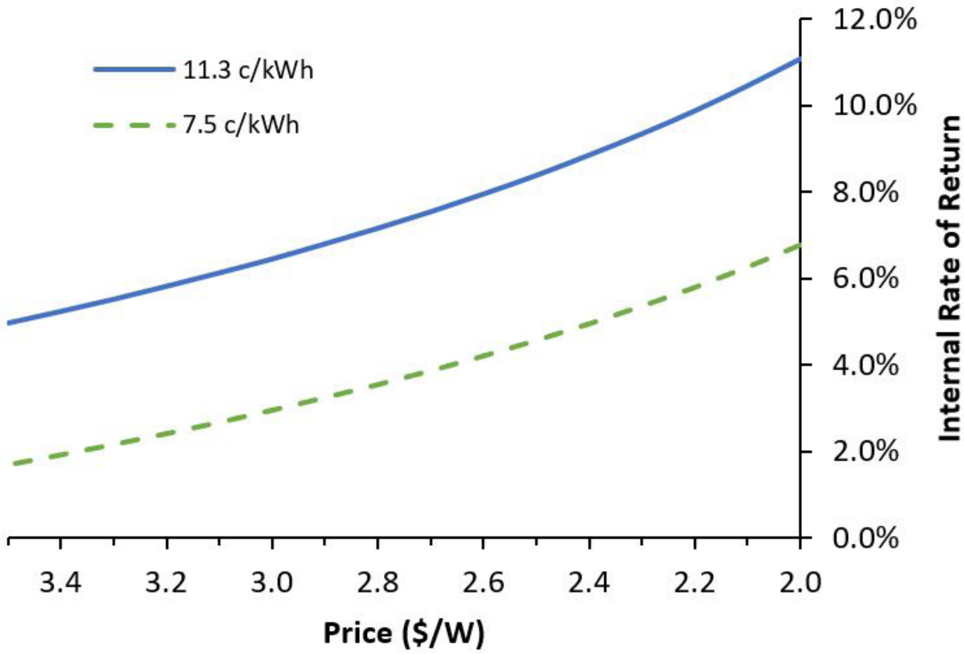
C = annual income (avoided electricity costs + state and federal tax credits)

I = upfront cost of solar PV system (prior to state and federal investment tax credits)

n = years

A related, and common, formulation of simple payback is calculated by dividing the system cost (after incentives) by the annual income, but this does not allow for increasing electric rates. Neither of these definitions account for the effects of financing, although there are payback formulas that do. In our opinion, simple payback is best used to provide a rough sketch of the financial performance; scenarios including financing and discounted cash flows are better handled using net present value[11].

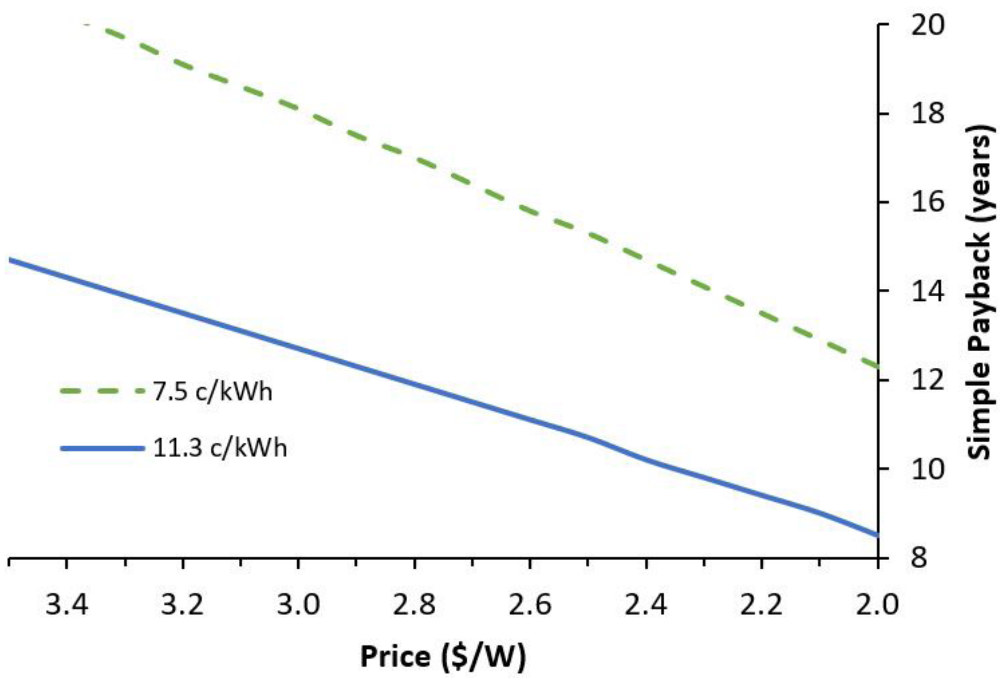
[7] **Figure A1.** The effect of installed price and electric rate on the simple payback. All other parameters are from the reference case.



[8]Technically, IRR is the discount rate at which the net present value (NPV, see endnote 9) of the project is zero. There are a number of well-known problems with the IRR and its use for complex projects is discouraged (see e.g. *Internal rate of return: a cautionary tale*, McKinsey & Co., 2004). This particular application – a simple series of cash flows, and compared to alternative investments that assume reinvestment of interim cash flows - is a limited case where the intuitive interpretation of IRR is essentially correct.

[9]To calculate the after-tax return of an investment, multiply the return by (1 – tax rate), where tax rate is appropriate to the investment (e.g. long-term capital gains for a mutual fund held longer than one year) and is expressed as a ratio (e.g. 0.15 for a 15% rate).

Figure A2. The effect of installed price and electric rate on the internal rate of return. All other parameters are from the reference case.



[11]There are two approaches to Monthly Bill Savings (MBS). The more complex of the two is based on the levelized cost of energy (LCOE) of the system (essentially the sum of the discounted costs divided by the lifetime electricity production of the system). This method is relatively complex, and depends on the discount

$$MBS = \frac{P}{12} * R + i$$

rate used. Instead, we use a simpler method to estimate the first-year annualized MBS as

Where:

MBS = annualized monthly bill savings ($/month)

P = annual energy production (kWh)

R = first-year variable electric rate ($/kWh; note that electric rates are given elsewhere in ¢/kWh)

i = income from tax deduction of interest payments ($/month)

$$\mathrm{NPV} = \sum_{n=0}^{N} \frac{C_n}{(1+d)^n}$$

[12]The net present value of a series of cash flows is given by:

Where:

NPV = net present value ($)

C_n = net after-tax cash flow in year n

N = length of analysis period (years)

d = annual discount rate, expressed as a ratio (between 0 and 1)

The analysis hinges on the value of the discount rate d, particularly over long project lifetimes. For commercial projects the discount rate is usually clearly defined, often the weighted average cost of capital. For consumer finance, the appropriate discount is not so clear. For our analysis here, we select a discount rate that corresponds to the alternative use of the money, either the rate of return of an alternate investment, or the interest rate of an alternative loan.

[13]We have chosen the analysis used to demonstrate the up front costs, which is most likely the relevant metric for those interested in the question. This analysis does not account for the full lifetime benefits of the system, which would need to account for the fact that a system installed one year later will be producing electricity for an additional year at the end of its lifetime. Furthermore, any analysis that hinges on a cash flow 25 years in the future will necessarily be highly dependent on the discount rate, in this case to the extent that it will dominate the results.

[14]*Selling Into the Sun: Price Premium Analysis of a Multi-State Dataset of Solar Homes,* Lawrence Berkeley National Laboratory, (2015).

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