



Solar & Electrification

Flexible Pathways for Energy Independent Homes in California

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Authors' Note

Every industry eventually confronts the natural forces of its life cycle. New technologies and business models are developed to fill customer needs. Early adopters validate and steer product concepts by selecting the best ideas. Growth accelerates as the market embraces innovation. Eventually, these industries reach maturity, stagnate, and start to decline—while the most innovative firms often find a way to reinvent themselves and meet the moment.

The residential solar industry is no exception. In California, customer interest in rooftop solar, the falling price of solar panels, and supportive policies like net metering have converged into a decade of rapid expansion and growth. However, in 2022, the CPUC voted to change its net metering policy, reducing the rate at which utilities credit solar power exported back to the grid, and in the process dramatically reshaping the value proposition of rooftop solar.

This disruption has resulted in acute growing pains for the solar industry, but we believe the macro-trends of a destabilizing grid, improving energy storage, and the home electrification movement are persistent and point to new opportunities.

To support the transition we have created the Agile Electrification project, a research collaboration housed at the Design Lab at UC San Diego. The project brings together researchers, designers, and industry to explore new approaches to rooftop solar that harness the electrification of home energy consumption as an accelerant to industry.

We are pleased to present this initial study, where we develop a simulation of 60-homes to illustrate four common investment scenarios across real-world solar and electrification upgrades. We aim for a level of detail that we believe is novel, sufficient, and necessary to support homeowners in their investment decision-making.

We hope that you'll find this work informative and actionable, and we look forward to engaging with you on opportunities to advance this effort.

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A Specials Thanks

We would like to thank the UC San Diego Design Lab—and in particular Dr. Eric Hekler—for their support of this initiative. As a world-class interdisciplinary research hub known for its pioneering work at the intersection of design, technology, and human experience, the Design Lab provides the ideal forum for an open, collaborative approach to developing new innovation models to support the next phase of the solar movement.

We would also like to thank the following people for their technical contributions to this project. We are honored to work with them.

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ENSTALL

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Introduction

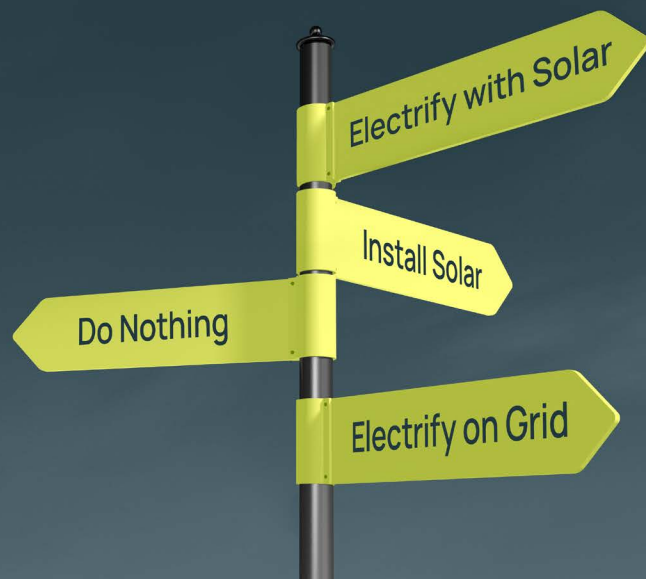
Today, California homeowners are confronted with important decisions about their home's energy usage. Faced with record-high and increasing electricity and natural gas bills, many are looking for ways to reduce and stabilize their energy costs. Others want to increase their resilience against power outages and natural disasters by minimizing dependence on imported energy. A growing number are also motivated by climate concerns and want to reduce their carbon emissions.

Most homes depend on grid-provided electricity and natural gas, with changes to cost and reliability largely outside the homeowner's control. However, there is a growing menu of options that cost-effectively enable energy independence. Rooftop solar panels can generate clean, low-cost electricity on-site. Electric heat pumps can eliminate natural gas use and heat more efficiently using electricity. Batteries can store excess electricity generated by solar for use as needed by the home. With this growing list of available upgrades, a new question emerges: what's the best approach for homeowners who are seeking energy independence?

To help address this question, the Agile Electrification Project, a research project associated with the UC San Diego Design Lab, partnered with Northern Pacific Power Systems to study 60 real homes in Northern California. The analysis simulated each home across a range of upgrade scenarios, taking into account real-world details like roof dimensions, existing equipment, and historical energy consumption. In the process, the study also sought to document any new data and modeling methods required to identify winning upgrade strategies. The outcomes support new ways of thinking about energy independence.

This ebook is the first installment in a series as we work together to develop a Contractor Playbook, highlighting actionable strategies for the industry to adapt to evolving market conditions and technological advancements.

We are at a fork in the road with a decision to make about your energy future. There are four competing strategies with varying degrees of grid dependence and lifetime costs. You can take action now or wait.



There is a natural tendency to wait until something breaks before taking action. In other words, Doing Nothing. The analysis that follows makes a case for proactively analyzing your current and future energy consumption. By doing so, you can leverage new tools to identify the best solutions that align with your budget and objectives. In this study we analyze 4 distinct strategic upgrades:

01

Do Nothing

Homeowners stick with grid electricity and natural gas and replace current appliances with the same technology when they break.

02

Install Solar

Homeowners install a solar system with one battery to offset some of their electricity consumption but forego any electrification upgrade.

03

Electrify on Grid

Homeowners convert their current gas appliances to electric equivalents but remain powered by the grid.

04

Electrify with Solar

Homeowners electrify their homes and install solar panels and batteries designed to offset their new electricity use.

Navigating the changes in the home energy landscape can be confusing. We hope this ebook will help simplify your journey and inform your decisions as you find the best option for your home or business.

Overview

Key Considerations When Determining the Best Long-Term Approach to Your Energy Needs

The Worsening Experience of Grid Dependency

California's electricity rates have more than doubled over the last decade and currently rank among the highest in the nation. As of January 1, 2025, PG&E's residential bundled average rate was 44.65 cents per kilowatt-hour (kWh), more than 2.5 times the average national rate of 17.01 cents per kilowatt-hour (PG&E, 2025; Ritchie, 2025).

According to the Legislative Analyst's Office (LAO), this trend is likely to continue, with rates expected to rise faster than inflation. A 2021 CPUC analysis confirmed this conclusion, forecasting that by the end of this decade, PG&E, SCE, and SDG&E customers would pay 12%, 10%, and 20% more respectively than they would have if rates had only grown at the rate of inflation (Sieren-Smith et al., 2021). The need to upgrade aging infrastructure to protect against wildfires, accommodate growing numbers of electric vehicles and electrified homes, and absorb power from distributed energy resources are all factors driving this growth (Petek, 2025; Hering, 2024).

Grid-dependent homeowners also face service interruptions, as extreme heat waves and wildfires continue to cause rolling blackouts (Rothleder, 2024). Taken together, these rising costs and decreasing reliability leave homeowners to adapt budgets, reduce energy use, or consider investing to produce and consume as much of their own energy as possible.

“Customers have this barrier—the high capital cost, but also the high operating cost. Why would you pay more ... to pay more? Have the customer put in solar, and suddenly their marginal price drops dramatically.”

Dr. Ahmad Faruqui
Economist-at-Large

The Challenges of Electrification on the Grid

In the last few years, the movement to replace fossil fuel-powered appliances with electric alternatives has accelerated. Today 88% of California households use natural gas for some or all of their home energy needs; but switching to heat pumps to power space and water heating is increasingly common as homeowners look to take advantage of government incentives and reduce their dependence on fossil fuels (Statista Research Department, 2024; Building Decarb Coalition, 2024). However, simply switching to electric appliances may not provide the financial relief homeowners seek. While heat pumps are cleaner and more energy efficient than gas equivalents, the current disparity between the marginal cost of natural gas and electricity means that many customers who switch to a heat pump may see their total energy costs rise. Widespread electrification will put upward pressure on natural gas prices as well, as a shrinking customer base forces gas utilities to raise rates for existing customers to cover infrastructure costs (Mi, 2022).

The Changing Economics of Rooftop Solar

Traditional grid-tied rooftop solar generated value in two ways. First, by utilizing solar-generated electricity as it was produced, homeowners saved money by avoiding electricity imports from the grid in a process known as “self-consumption”. Second, during time periods when panels produced more electricity than could be self-consumed, the excess power flowed back into the grid as exported energy, which generated a bill credit that was valued based on prevailing retail import rates. Over the course of one year, the net balance of imported and exported electricity was trued-up into one customer statement, which had an averaging effect over all time periods in that year. In general, customer systems could be designed to over-supply in summer, under-supply in winter, and balance out a customer bill on an annualized basis.

Net Metering Vs. Net Billing

In places like California, Net Metering has been baked into the economics of solar energy for decades. New Net Billing rules enacted in 2023 changed these economics significantly.

Net Metering: Under prior Net Metering rules, when solar panels produce excess power during the day, that energy flows into the grid and generates a financial credit. At night, or when the system is off, customers import power from the grid and generate a financial cost. The financial credits and costs acted as a sort of balance sheet that was trued up at the end of each year in a customer statement. Under most circumstances, customers were only incentivized to install solar systems large enough to meet 100% of their current annual electric load.

Net Billing Tariff: With Net Billing Tariff (NBT, sometimes called NEM 3.0), utilities pay for solar exports based on CPUC Avoided Cost Calculator (ACC) values rather than imported retail rates. The ACC includes wholesale power costs, avoided transmission and distribution costs, carbon benefits, and reliability. This rate is typically much lower than the retail import rate. Under NBT, customers are allowed to - and often incentivized to - install up to 150% of their annual load (California Public Utilities Commission, n.d.).

By reducing the economic value of exporting solar and allowing customers to install larger systems, NBT promotes battery storage and consuming as much of the energy you produce as possible. Under the new rules, customers can plan for future electrification loads to reduce grid dependency and overall costs substantially.

In 2022, the California Public Utilities Commission (CPUC) voted to stop valuing exported energy based on retail rates (California Storage and Solar Association, 2022). This meant that solar still had the benefit of self-consumed energy but no longer offered the same economic benefits for exported energy..

Under these new rules, the value equation for installing rooftop solar shifted from aiming at 100% annual energy offset to maximizing self-consumption. The appropriate response has been to incorporate battery storage into newly installed systems so that solar customers can save the excess energy they generate and self-consume it later. Batteries have the added advantage of acting as an emergency backup in the case of an outage.

The Opportunity to Combine Solar, Storage, and Electrification to Maximize Self-Consumption

For homeowners seeking energy independence, we see a more holistic approach: reduce total energy consumption and standardize on electricity via electrification and then permanently lower the marginal cost of electricity by shifting to solar power.

The truth is, navigating the solar and electrification landscape can be overwhelming for homeowners. Simulating the interactive effects of electrification, solar, and storage requires a new, more complex approach to modeling that is not common across contractors. The information required to run models can be difficult or impossible to access. And a wide range of possible scenarios may confuse rather than clarify which investment strategies are best for a given home.

“ What we’re doing at Agile Electrification is the seed of something that’s going to grow into the future of this industry... In the beginnings of residential solar, it was actually fairly straightforward. You had net metering. Now as we get into more complex rates, batteries have become an integral part of our systems to help manage the flow of electricity. ”

Carl Lenox

Product & Innovation Leader, Sunrun

Starting the upgrade cycle with solar and storage has several advantages:

- Adding solar reduces the consumption of the highest-cost imported energy (electricity) immediately.
- Coupled with storage, the system reduces peak loads, lowering consumption at the times when grid generation is the most expensive and dirtiest.
- If sized to meet future loads, solar + storage systems will absorb the costs of subsequent electrification: as customers use more of their own produced electricity, costs will go down instead of up.

To the extent it is properly sized for future loads, an approach that starts with solar might accelerate the proactive adoption of electrification by making these options the more economical choice.

Challenges of Electrifying with Solar

Higher Initial Investment

Although electrifying with solar typically delivers superior long-term value and higher net present value (NPV), it requires a larger upfront investment than solar alone. Access to attractive financing options may become crucial for widespread adoption. Solar loans and leases are well-established products, but lenders require confidence that systems will perform as predicted over the life of the loan. Incorporating future electrification into these forecasts adds complexity. Banks and other financial institutions need to see that modeling methodology is sound, and that predicted energy savings are bankable.

Increased Complexity

A comprehensive solar, battery, and electrification design requires more sophisticated modeling and analysis than partial solar or on-grid electrification. Each home has unique characteristics—from physical constraints like roof space and shading

Evaluating the Value of Home Energy Investments: Payback Time vs. Net Present Value (NPV)

When evaluating the financial implications of different home energy options, it's useful to keep a few concepts in mind.

Simple payback time is a commonly promoted investment metric that estimates how long it takes to recover an initial investment through accumulated savings. While it's easy to understand, payback time doesn't account for the time value of money or what happens after the project breaks even, only how long it takes to achieve break even. For this reason, simple payback is not always the best indicator of the total value of a proposed energy upgrade.

Net Present Value (NPV) compares upfront costs with the total value of future cash flows from the savings of the project expressed in present terms. For long term energy upgrades NPV is a superior metric as it captures the expected savings for the duration of the equipment's useful life.

In many cases, calculating the value of a solar investment based on simple payback time may be misleading or fail to take into account important factors. For example, a small system with a 5-year payback might seem better than a larger one with a 7-year payback, but the second project could deliver more savings in the long run. For this reason, we have chosen to use NPV to evaluate the alternatives in this study.

“Solar-led electrification is the starting point for home electrification. It’s complicated, and not for every solar contractor. Using the right tools, Solar-led electrification provides the best long term savings for homeowners.

As Wayne Gretzky said: “Skate to where the puck is going to be, not where it has been.” SLED is where the greatest home electrification opportunities will be. ”

Barry Cinnamon

CEO, Cinnamon Solar Energy

to occupant behavior and equipment preferences—that drive both current energy needs and influence the potential impact of electrification upgrades. Considering the various solar system sizes, battery options, and equipment combinations available, homeowners can have thousands of possible configurations. In addition, the sizing of the solar and battery system must account for changes to the size and shape of hourly consumption profiles due to electrification. This is a significant departure from the capabilities of most contractors today and requires fundamental advances in the knowledge and tools available to the industry.

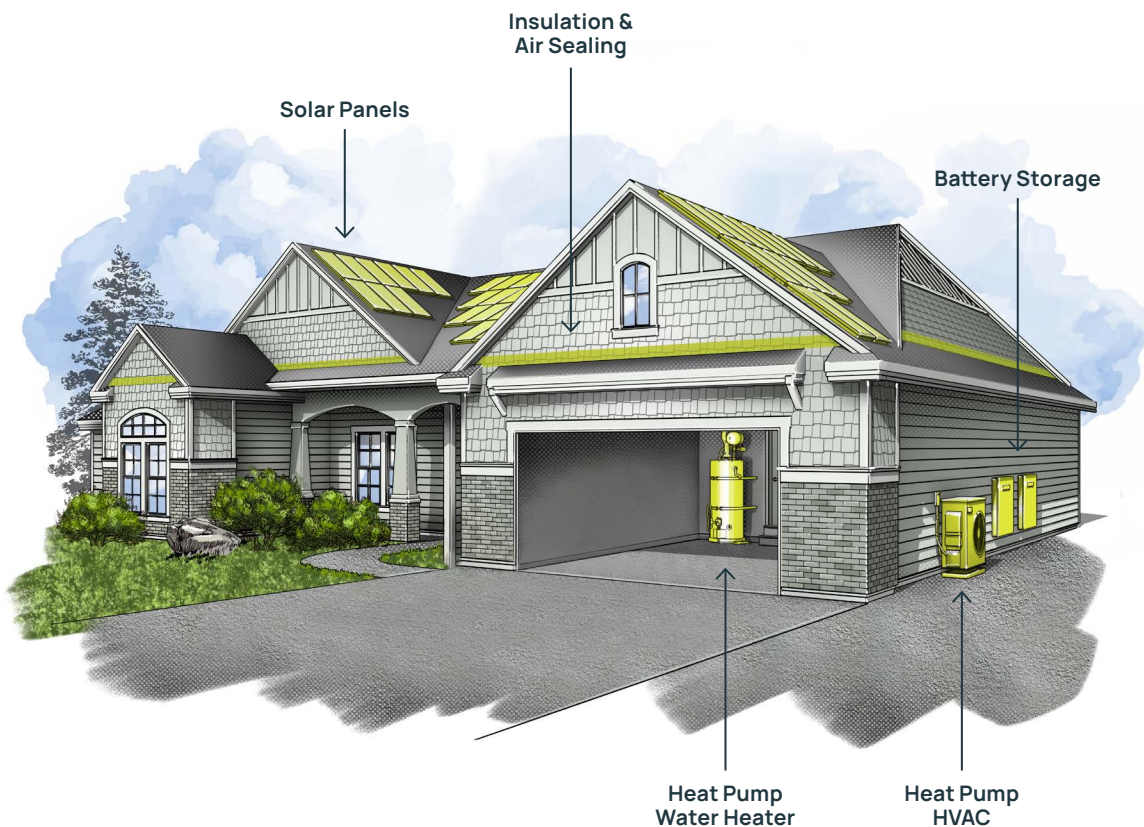
To help address these challenges, Agile Electrification is developing a Contractor Playbook based on real-world research, including the 60-home study described in this ebook. This is the first in a series that will be published to share insights from the research and pilots underway. Live events will also be held to bring stakeholders together to challenge assumptions and define the best approach to implementing new solutions. The playbook is centered on a review of new methods and tools to help contractors adapt their business to meet new needs including specific pointers around:

- Modeling and sizing solar for electrified homes
- Communicating customer benefits across all upgrade scenarios
- Phasing investments and harnessing incentives
- Monitoring and verifying system performance

In the next section, we present the results of an Agile Electrification study that modeled the energy and bill impacts of four home energy pathways on 60 California homes. The study quantifies the financial forecast of each pathway and lays out the modeling and data requirements necessary for this approach.

The Agile Electrification Study

The Agile Electrification study was designed to evaluate different paths California homeowners might take to upgrade their home energy systems and to develop a comprehensive process that contractors can use to show customers how different choices affect their energy use. We hope that this process will help homeowners make more informed decisions about their energy futures.



Which upgrades should homeowners choose?

The study simulated four distinct options for 60 real homes in Northern California to understand the range of outcomes and rank the relative benefits of each scenario. The integrated methodology incorporates solar potential, home energy modeling, and financial forecasting. Data inputs included energy bills, hourly electricity and daily gas meter readings, tilt and orientation of the roof, shade, building characteristics, and PG&E rates. A single electrification package was modeled to include a heat pump water heater, heat pump HVAC, and air sealing and insulation. The financial analysis assumed that homeowners paid cash for upgrades; no financing costs were included.

01

Do Nothing

What energy bill trends would be if the homeowners installed no electrification or solar upgrades. This scenario assumes that when a gas appliance breaks, the homeowner replaces it with a similar model.



02

Install Solar

In this scenario, the homeowner adds one battery and solar to offset some of the electric load. This scenario follows conventional solar practice and assumes that the solar system is sized to meet 100% of the current yearly electric load.



03

Electrify on Grid

In this scenario, the building envelope is improved through insulation and air sealing, and the furnace and water heater are replaced with efficient electric heat pumps. No solar is added.



04

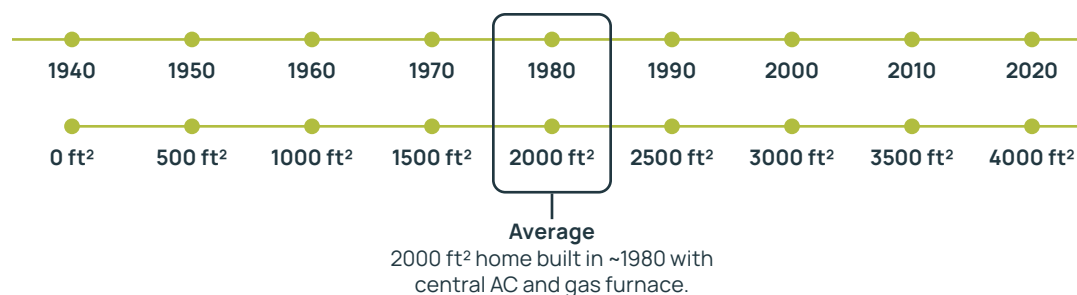
Electrify with Solar

This scenario combines solar and electrification with one battery for storage. The solar system is sized to 150% of the electrified load to accommodate electrification, hourly load and solar production profiles, and potential added loads (i.e. EV).

Each home was unique, with many variables affecting their upgrade potential. The data inputs were used to create physics-based models of each home's energy usage, calibrate those models using actual consumption patterns, and then analyze the model predictions of four scenarios.

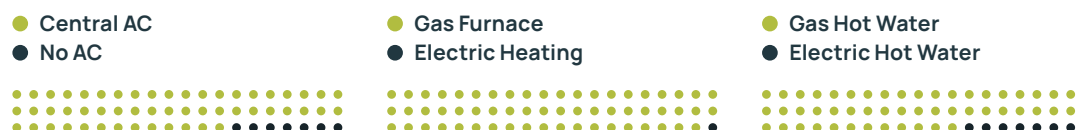
Vintage & Area Distribution

The study sample included a wide range of homes, built across various eras, from 1910 to the 2010s. The size of homes ranged from 1000 to 4000 square feet. The average was a 1977, 2000 square foot home.



Equipment

Most homes were heated with natural gas furnaces and hot water heating systems. Eight used electric water heaters and one used an electric resistance heater for heating. Seven homes did not have central air conditioning. None of the homes had an existing solar system.



Data Requirements & Modeling Methods

While solar contractors today collect basic usage data and roof details to size systems, modeling that incorporates both solar and electrification scenarios requires a more comprehensive approach.

Inputs Required for the 4 pathways



All scenarios required meter readings (the home's energy consumption as measured by the utility meter), and rate plans (the price a customer will pay for their consumption in \$/kWh or \$/therm). Hourly electricity and daily natural gas measurements were used to capture the impact of electrification or solar on peak energy use (the degree to which a battery system can effectively shift energy use from low-value to high-value hours).

Home Energy Modeling

The first step in home energy modeling is to generate a set of starting assumptions for the building characteristics of the home. The starting assumptions are determined using publicly available data such as permit records and MLS data and includes hundreds of characteristics including vintage, square footage, number of rooms, insulation, and equipment. This information is then input into EnergyPlus, an industry-standard program developed by the National Renewable Energy Laboratory (NREL) that enables detailed modeling of energy consumption and flows within buildings in order to generate usage profiles based on the assumed building characteristics.

EnergyPlus generates an uncalibrated model which is calibrated to minimize the error between the predicted usage profile and the actual usage. Results were calibrated by running hundreds of simulations varying the building characteristics and selecting the set that most closely matched the actual usage as measured by the meter. Future research will focus on validating initial assumptions through customer feedback and further reducing modeling errors.

Solar Production Modeling

To determine the hourly solar potential of the home, extensive roof details using the best-in-class tools available to contractors today were used. This process leverages LIDAR (Light Detection and Ranging) technology to measure distances and create high-resolution 3D maps of each home. These maps provide detailed data on factors influencing solar potential, including available roof area (accounting for setbacks and obstructions), roof angles and orientation, and shading patterns from nearby structures and vegetation.

Financial Modeling

The financial modeling calculated the bills and savings for all scenarios by combining utility rate structures and incentives—including rebate and tax credit incentives, net billing export rules, monthly true-up provisions, time-of-use rates—with the home usage profiles and predicted solar production and storage. During this step the hourly usage profile is analyzed against the solar production profile to assess how battery storage could maximize savings by storing excess production during the day for use during peak rate hours.

Key Findings

All results presented in this section represent the average across the set of homes that were studied.

Annual Fuel Mix

Most homes run on multiple fuels, with natural gas used as a source of heat. Analysis of energy use across homes showed that on average in a Do Nothing scenario, natural gas accounted for 63% of a home's total energy use, but only 22% of customer energy bills. This disparity highlights a challenge of electrification: all other factors being equal, switching the majority of a home's energy use from a cheaper fuel (gas) to a more expensive one (electricity) may not yield significant bill savings, even with much more efficient technology.

Figure 1
Do Nothing
Energy Usage

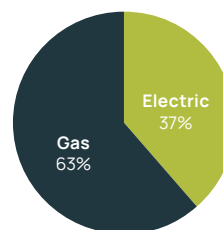
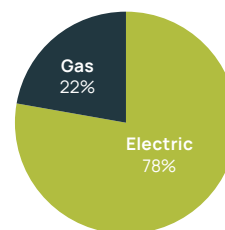


Figure 2
Do Nothing
Energy Cost

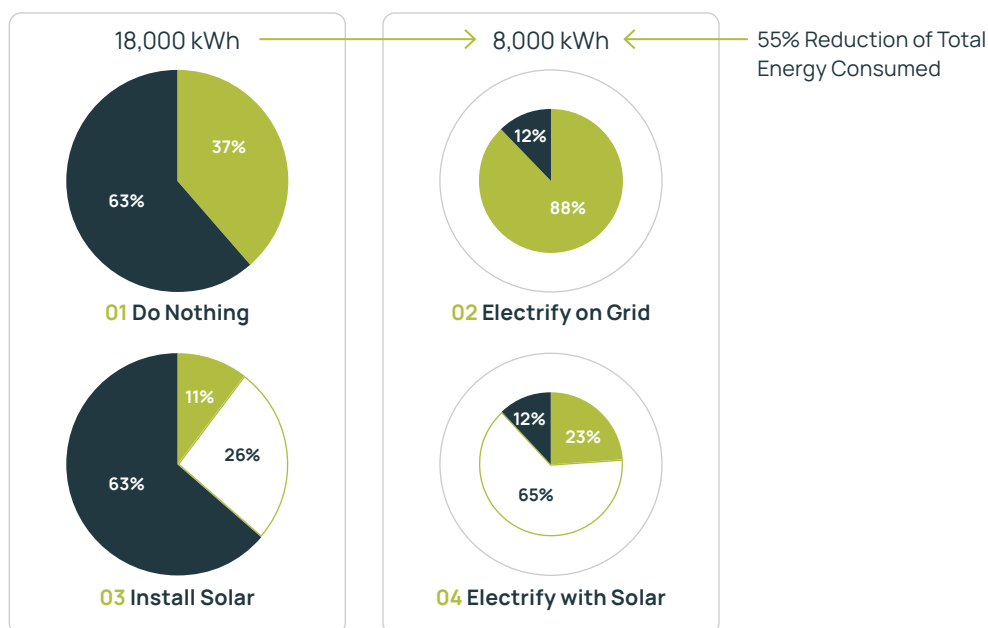


Imported Fuel Use Mix

Estimating how much energy will be imported is important to understand the degree of energy independence each pathway provides. The greater a home's ongoing dependence on grid electricity and imported gas, the more subject it is to market volatility and unpredictable rate hikes. Solar and electrification provide different but complementary approaches to reducing dependence on grid energy, with electrification reducing the total energy required to operate the home and solar replacing imported energy with energy produced on-site.

Figure 3
Impact of
Electrifying
with Solar

- Gas Import
- Electric Import
- Solar



The average home imports around 18,000 kWh of energy, around 60% of which is gas. (For easy comparison, natural gas units have been converted from therms to their kWh equivalent). Note that solar only generates electricity and therefore can only address electrical loads. Without electrification, solar homes are still dependent on natural gas for 60 percent or more of their total energy consumption.

For the average home, electrification reduced overall energy consumption by 55%, from nearly 18,000 kWh to 8,000 kWh, because heat pump HVAC and water heaters are more efficient than their natural gas equivalents. Air sealing and insulation also improve efficiency by reducing losses through the exterior of the building. Switching does not necessarily yield commensurate bill savings. Electrification will provide net savings for the average home with air conditioning, but also more exposure to increasing grid electricity costs. Homes that do not currently have air conditioning were likely to see their bills go up when switching to a heat pump. This is because heat pumps double as air conditioners, adding a cooling load where there wasn't one before.

With the Install Solar scenario, the average home reduced imported electricity by 26%. In contrast, the Electrify with Solar scenario reduced total energy imports by an average of 65%. This suggests that homes electrifying with solar can reduce energy imports 2.6 times more than those with solar alone. We assume that homes will continue to use a small amount of natural gas for cooking in all cases. Homeowners who wish to eliminate gas use entirely could replace gas cooking appliances with efficient electric alternatives such as electric ovens and induction ranges.

These results point to the complementary role of electrification and solar. Electrifying a home improves efficiency and reduces dependence on the largest source of imported energy (gas). Adding solar and batteries improves resilience and reduces dependence on the costliest energy source (electricity).

The Heat Pump Paradox: When Higher Efficiency Doesn't Equal Lower Bills

Natural gas furnaces and water heaters convert fuel to heat directly through combustion. The efficiency of modern gas furnaces ranges from 80-95%. This means that one unit of gas energy input produces 0.8-0.95 units of heat output.

In contrast, heat pumps use electricity to move heat rather than generate it directly. In cold weather, heat pumps can extract heat from outside air and move it indoors. In summer, they reverse the process.

Heat pump performance is measured by the Coefficient of Performance (COP). Since heat pumps move existing heat rather than converting energy from one form to another, the COP can be greater than 1. Modern heat pumps can achieve a COP of 2-4. In other words, heat pumps can use one-half to one-fourth the energy of natural gas furnaces to deliver the same amount of heating.

However, because the price of natural gas is so much lower than that of grid electricity, this difference doesn't always translate into large savings on heating bills. Natural gas prices are driven by regional and national supply and demand. Production costs, storage volumes, weather patterns, economic growth, and competition from other energy sources all play a role in setting prices. Electricity rates are heavily influenced by local grid conditions, peak demand periods, regional generation mix, and utility rate structures set by public utility commissions. This means that while your heat pump may be using far less energy, the higher per-unit price of grid electricity limits bill savings.

Rooftop solar systems lock in electricity at a much lower cost over the life of the system. Electrifying with solar takes advantage of both lower rates and the greater efficiency of heat pumps.

Figure 4
Five-Year Escalation of
Electric & Gas Rates

- Electric (TOU-D)
- CAGR: Electric
- Gas (G-1)
- CAGR: Gas
- LCOE - PV and Battery

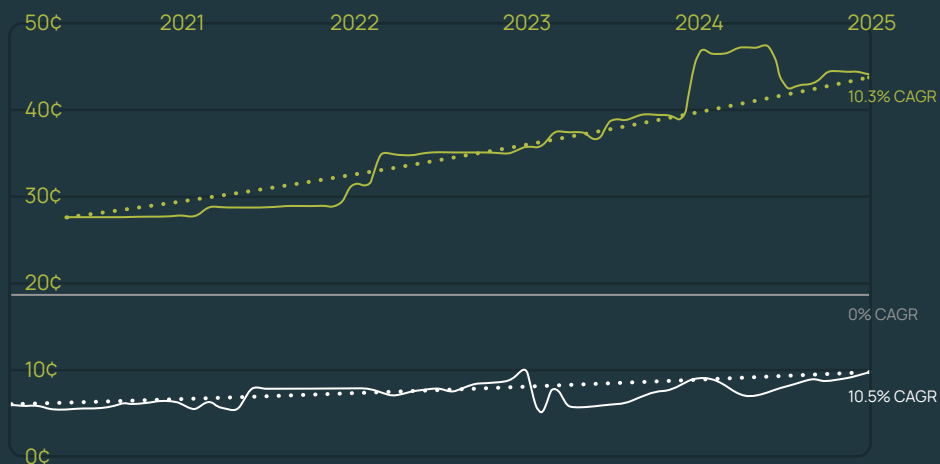


Figure 5
Lifetime Bills Escalations

- Do Nothing
- Electrify on Grid
- Install Solar
- Electrify on Solar

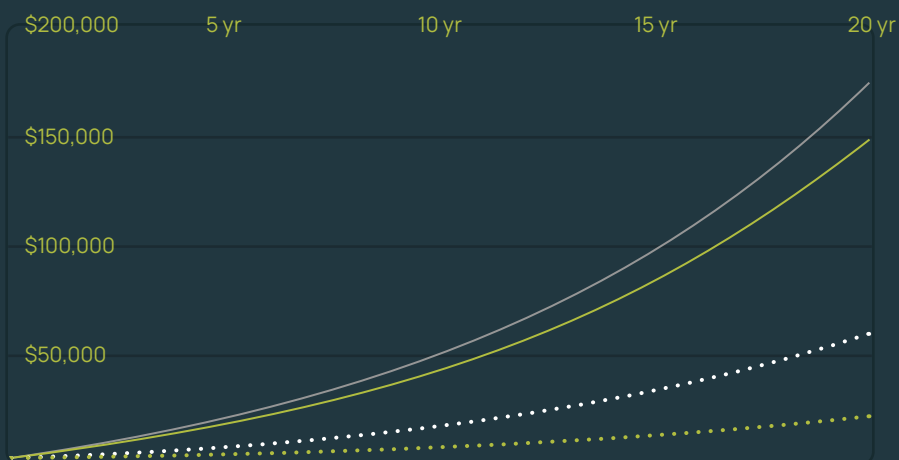
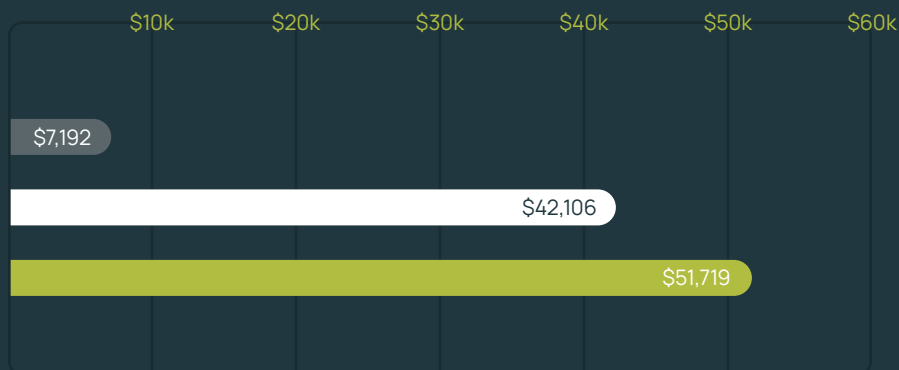


Figure 6
NPV of the 3 Upgrade
Scenarios when Compared
to Doing Nothing

- Electrify on Grid
- Install Solar
- Electrify with Solar



Implications for Fuel Costs Over Time

Growth in fuel costs over the last 5 years was used to analyze each scenario.

- As seen in Figure 4, electricity and gas rates for PG&E customers have risen more than 10% year-over-year over the past five years. A homeowner who installed a solar and battery system in 2020 would have locked in lower rates (i.e. their levelized cost of energy) and avoided this increase. Figure 5 estimates the cumulative lifetime energy costs over 20 years, assuming current trends continue. While it isn't possible to predict how rates will change, it is likely energy costs continue to increase.
- Electrification on Grid provides some bill savings for the average home, though results varied depending on the current state of the home.
- Adding solar without electrifying results in a lower lifetime cost compared to staying on the grid by locking in lower rates for solar generation. This suggests that homeowners would benefit from prioritizing solar for immediate and sustained savings.
- A combined approach of electrifying on solar represents the lowest lifetime cost solution for most customers.

Figure 6 displays the net present value (NPV) for each upgrade case relative to a Do Nothing baseline. In the baseline scenario, it is assumed that the homeowner would eventually need to replace a failing gas heating and domestic hot water (DHW) system.

The NPV was based on projected annual cash flows over 20 years (the expected lifetime of the solar and electrification upgrades) and accounted for capital expenses, operating expenses, and avoided costs associated with each scenario. Among the upgrade scenarios:

02

Install Solar resulted in a significantly higher NPV of approximately \$42,000, with a positive return across all homes.

03

Electrify on Grid had the lowest average NPV at approximately \$7,000. While this is a positive value which indicates a profitable investment, several homes within the study set experienced a negative NPV, particularly those that did not have air conditioning in their current state.

04

Electrify with Solar yielded the highest NPV across all homes, indicating the most favorable financial outcome. This scenario also had the lowest amount of grid-consumed energy, which equates to the most protective hedge against any grid volatility.

With all imported energy costs increasing, each additional unit of energy consumed from the grid will cost more in future years. In contrast, the levelized cost of solar is flat. This means that the more of a home's energy use that can be met with on-site solar, the less vulnerable the homeowner is to rising energy costs over time.

Buyer Beware

Sizing to 100% of Your Current Annual Load May Not Be Enough.

Implications of Net Billing Changes on System Sizing

Traditionally, solar installers have sized systems to offset 100% of a home's current electrical load. This approach made sense under previous net metering policies, where excess solar production was credited at a rate indexed to grid imports.

Under new net billing rules, utilities pay much less for electricity exported to the grid. This makes consuming the energy you produce much more important.

Because solar production varies by weather, time of day, and time of year, systems sized to current annual consumption will likely not generate enough energy to meet demand during cloudy periods or winter months when there is less sun. This leaves the homeowner exposed to higher retail grid rates during these periods. In addition, homeowners who are planning to electrify heating and hot water will be adding electrical load. The Agile Electrification study found homes should oversize their solar system by more than 50% on average to meet these additional needs.

Understanding oversizing is especially important when installing a new system. While it may be possible to expand an undersized system later, it is almost always easier and more cost-effective to install a larger system upfront, when the incremental cost of additional panels is low relative to the cost of the project overall. In addition to maximizing self-consumption immediately, oversizing upfront gives homeowners breathing room to add additional loads from the electrification of appliances or the addition of an electric vehicle.

Case Studies

Selected Home Profiles from the Study

While averages and overall trends are useful, looking at individual homes reveals the importance of customized analysis to optimize energy and bill savings. The results presented in the previous section were based on one composite home—the average of 60 real homes. In practice, each home has a specific upgrade profile, and some homes fare better than others.

The following examples illustrate how factors like vintage, size, current energy use patterns, and upgrade potential create unique opportunities and challenges for each home. By looking at specific cases, we can better understand how various factors influence the potential benefits of solar and electrification upgrades. Here we present a comparison between the Do Nothing scenario and the Electrify with Solar scenario to show the range of investment outcomes for different houses.

Dominant Strategy: Solar-Led Electrification

Overall, we found that pairing solar with electrification was the dominant strategy for maximizing customer savings and energy independence. In theory, starting with solar to take advantage of immediate electricity cost savings and then electrifying appliances is the most cost effective order of investments.

We call this strategy solar-led electrification. While this approach is more complicated than installing solar or electrifying alone, it's also more rewarding, providing homeowners with maximum independence and the largest return on their clean energy investments.

Example 1

High Gas User

Size: 3,410 square feet
Year built: 2001
Starting equipment: natural gas furnace and water heater.

Current annual energy usage:

Electric: 12,647 kWh
Gas: 22,442 kWh equivalent

Return on Investment (NPV):

\$132,961

Built in 2001, this 3,400 square foot home was projected to achieve a return on investment of approximately \$132,961 over 20 years from electrifying on solar versus doing nothing—the largest savings out of all 60 homes. This home was notable for its high gas consumption—nearly double the average. The home's electric usage (12,647 kWh) was significantly higher than the average (6,592 kWh) as well.

The fact that a high overall energy user would save more isn't surprising; in general, the more energy a home uses, the greater the potential savings from electrifying with solar.

Example 2

High Electric User

Size: 3093 square feet
Year Built: 1990
Starting equipment: electric resistance heating and electric water heating.

Current Annual Energy Usage:

Electric: 13,742 kWh
Gas: 947 kWh equivalent

Return on Investment (NPV):

\$115,183

As the only house with an electric resistance heating system, this 1990 house was an outlier. Because electric resistance heating is less cost efficient than either natural gas furnaces or electric heat pumps, this house is particularly well suited for both solar (to reduce overall dependence on high-cost grid electricity) and replacing inefficient electric heating and hot water heating with an efficient electric heat pump and heat pump water heater, respectively. With a projected return on investment of \$115,000, this house was the third largest savings of the 60 homes.

Example 3

Second Highest Electric User

Size: 4,114 square feet
Year Built: 1983
Starting equipment: natural gas furnace and water heater.

Current Annual Energy Usage

Electric: 12,951 kWh
Gas: 17,388.1 kWh equivalent

Return on Investment (NPV):

\$127,751

This 4,114 square-foot home was the largest in the set. It had the second highest electric use, just behind the home with electric resistance heating. With a projected return of nearly \$127,751, this home showed the second highest potential savings from electrifying with solar. As with the high gas consumption house, this home reinforces the point that homes with high energy consumption are most likely to see large savings.

Example 4

Smaller Home With No AC

Size: 1,377 square feet
 Year Built: 1910
 Starting equipment: natural gas furnace and electric water heater.

Current Annual Energy Usage:

Electric: 5,859 kWh
 Gas: 3,580 kWh equivalent

Return on Investment (NPV):

\$32,112

This relatively modest 1910 home is the oldest in the study set. It showed modest but positive savings by electrifying with solar. Unlike most homes in the study, adding solar alone saved more than electrifying with solar. This is likely because the home currently doesn't have air conditioning; adding a heat pump would add a summer cooling load where none existed before.

This home highlights the importance of discussing needs and goals with the homeowner when planning a solar or electrification strategy. In this case, if the homeowner was not intending to add air conditioning, it would be more financially beneficial to simply add solar without electrifying. However, if the homeowner intends to add air conditioning at some point, an efficient heat pump could provide the desired summer cooling and also replace the natural gas heating. Sizing the solar system to accommodate this and other potential future loads such as an EV is an important consideration as well.

Results from this home reflect those of seven other homes that did not have air conditioning. In all cases, homes without air conditioning did not save money by electrifying on grid (without solar).

Example 5

Two Similar Homes With Different Energy Profiles

Home 1

Size: 1,930 square feet
 Year Built: 1971

Current Annual Energy Usage:

Electric: 5,933 kWh
 Gas: 15,867 kWh equivalent

Return on Investment (NPV):

\$52,311

Home 2

Size: 1,726 square feet
 Year Built: 1971

Current Annual Energy Bills:

Electric: 5,367 kWh
 Gas: 10,225 kWh equivalent

Return on Investment (NPV):

\$34,788

The final example looks at two homes with identical vintages and very similar square footage. Both homes are medium-sized, built in 1971 with a gas furnace for heating, and gas hot water heaters. Both homes have central air conditioning. However, the homes have different energy consumption patterns. The first home uses almost 50% more gas than the second home. As a result, the projected return from electrifying with solar for the first home is nearly \$18,000 more than the second home.

The diversity of homes and energy use patterns highlight the importance of individual modeling to identify the optimal approach for each homeowner. In addition, it is important to understand each homeowner's goals, plans, and resources.

In most cases, electrifying with solar is the optimal approach, but the timing and sequencing of upgrades should be customized based on each home's unique characteristics, the homeowner's financial situation, and the current state of their existing equipment.

Making Solar-Led Electrification Work for You

Solar-led electrification is a compelling strategy but can be complex. Following a standard of practice can offer both contractors and homeowners clarity and confidence as they take the next step. While customers begin their home upgrade journey with a variety of goals, our study shows that most successful projects would follow a similar progression. Here's how that journey would unfold in a theoretical upgrade based on our findings.

Phase 1: Initial Assessment & Planning

During this phase, your solar contractor will gather the information needed to design an optimal system, including:

- Historical energy usage (both gas and electric)
- Building characteristics and vintage
- Existing HVAC and water heating equipment
- Roof specifications and solar potential
- Current and projected utility rates
- Available incentives and financing options

The contractor will also discuss short and long-term goals for electrifying your energy use, including your plans for electrifying space heating, water heating, cooking, and if you have or plan to purchase electric vehicles.

Takeaways from the Study

Analysis of the 60 homes revealed that comprehensive data collection at this stage is essential for accurate system sizing. Homes with similar characteristics often showed

surprisingly different energy usage patterns, highlighting the importance of using actual utility data instead of relying on general assumptions.

Phase 2: Integrated System Design

With baseline data collected, this phase focuses on designing an integrated home energy system that meets your current needs while preparing for future electrification.

Key activities in this phase include:

- Solar system sizing (accounting for future loads)
- Optimizing battery capacity
- Electrification upgrade potential and recommendations
- Financial modeling and incentive analysis

Takeaways from the Study

Under California's new net billing rules, systems typically need to be 60% larger to accommodate future electrification compared to traditional solar-only designs. This finding drives key decisions about initial system size and timing of upgrades.

Phase 3: Implementation

Once the solar + storage system is installed, you can begin to layer in electrification options on a timeline appropriate to your situation.

Takeaways from the Study

Households without solar power who switch from gas furnaces and water heaters to electric heat pumps may not see immediate savings on their utility bills, and some could face higher costs. For these customers, the most cost-effective approach may be waiting until their existing gas appliances reach the end of their life before replacing them, avoiding premature capital expenses.

In contrast, households that have already installed adequately sized solar panels and battery storage typically see substantial reductions in operating costs when converting to all-electric appliances. These homeowners may benefit financially from accelerating their transition away from gas appliances, even before the existing units fail.

In simple terms, customers who do not have broken appliances might consider investing their next dollar in solar to build financial savings capacity. Customers who upgrade broken appliances to their electrification equivalent should consider budgeting for solar.

Conclusions for Contractors & Homeowners

The Agile Electrification 60-Home study demonstrates the benefits of a comprehensive and strategic approach to home energy upgrades for California homeowners. By modeling a range of potential solar and electrification combinations for a variety of homes of different sizes and vintages, the study quantified the risks and benefits of different upgrade strategies.

This analysis found that the Do Nothing approach was the riskiest for homeowners concerned about rapidly rising energy prices. Sticking with grid electricity and natural gas leaves homeowners exposed to rapidly rising and volatile energy prices that are likely to continue eating away at household budgets in the foreseeable future. In addition, doing nothing exposes homeowners to grid outages with no backup.

Electrification upgrades without solar (Electrify on Grid) provided some long-term savings for many, but not all, homes. While electrifying on grid reduces or eliminates natural gas imports, these homes remain dependent on and vulnerable to high and increasing electricity rates. In addition, homes that did not already have air conditioning ran the risk of increasing their energy costs by adding a heat pump that provided summer cooling.

Installing a traditionally sized solar system (Install Solar) designed to meet 100% of current consumption provided more savings than electrification alone. However, without electrification, this approach still leaves customers dependent on utility-imported natural gas for most of the home's energy needs. In addition, sizing for 100% of current annual consumption is often inadequate to address the hourly variability of supply and demand throughout the year.

In most cases, a combination of solar and electrification (Electrify with Solar) offered the best financial outcomes for homeowners. Combining a robust solar + storage system with

the electrification of gas appliances maximizes energy produced and consumed at home and minimizes utility energy imports. This approach reduces operating costs immediately, protects homeowners from future rate hikes, and offers resiliency against grid outages.

However, electrifying with solar is not a one-size-fits-all approach. For example, in some cases, a home might save more by installing solar without electrifying if the home does not currently have air conditioning. These differences highlight the need for a comprehensive modeling approach that assesses solar potential and energy consumption for each home. In all cases, understanding the homeowner's goals is critical to designing a system that meets their needs.

Since the original study was conducted, the Agile Electrification team has made significant progress in streamlining and automating the different steps of the Solar-Led Electrification process. They are partnering with startups that specialize in building software platforms that connect previously siloed data sources and modeling tools into a unified, end-to-end solar-led electrification system.

The Agile Electrification Team is currently building on this integrated foundation to develop a sensitivity analysis that can assess how different combinations of key variables such as rebates, tax credits, and utility rate structures affect the NPV of the different scenarios.

This analysis recognizes that in the current political climate, there is substantial uncertainty around incentives, especially at the federal level, and it is an open question of whether or not states will step in where the federal government steps back. But while the precise outcomes are unknown, the team will have the tools ready to quickly assess each scenario to ensure that customer investments in solar and electrification are financially viable.

The Agile Electrification Playbook incorporates the methods developed in this study to give solar contractors a set of tools they can use to model and design optimal solar and electrification strategies for each of their customers. In addition, the Playbook will provide guidance on communicating customer benefits across all upgrade scenarios, phasing investments, and harnessing incentives.

We hope you join us as we enter the next phase of clean energy in California. Learn more and follow us at the Agile Electrification website: agileelectrification.org

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