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The Home Solar Blueprint

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Introduction

Most homeowners discover solar the same way: a power bill arrives that's higher than expected, or a storm knocks out electricity for hours or days, and the conversation at the kitchen table shifts from "Should we?" to "How, exactly, would we do this?" The Home Solar Blueprint is written for that exact moment. It is a practical, step-by-step field guide you can keep open on a workbench or a coffee table. Our promise is simple: by the time you finish this book, you will know how to assess your site, size a system, specify equipment, navigate permits and incentives, install and commission a safe and durable solar-plus-battery system (yourself or with a contractor), and manage and maintain it for decades of performance.

Why solar with battery storage, and why now? Residential electricity prices generally track upward over time; extreme weather events and aging distribution infrastructure make outages more common in many regions; and many households want a measure of independence alongside lower operating costs and reduced emissions. A properly designed solar-plus-storage system addresses all three: it can cut bills, keep critical loads running during grid failures, and reduce the carbon footprint of your home. This book approaches those goals with a conservative, engineering-minded methodology—grounded in first principles, verified by real-world case studies, and translated into plain language without sacrificing accuracy.

Who is this book for? If you are an owner-occupant who wants to trim bills or add resilience, a competent DIYer who is comfortable with tools and basic electrical tasks, or a small contractor expanding into residential solar, you are the primary audience. Property managers and sustainability-minded readers will also find the checklists, cost frameworks, and decision trees indispensable. We assume curiosity, care, and a willingness to measure twice and cut once. We do not assume prior expertise. When the work crosses into tasks that, by code or common sense, belong to a licensed electrician or structural engineer, we say so clearly and explain how to scope and supervise that work.

What will you be able to do by the end of this book? Among other outcomes, you will be able to:

- Read and interpret your electric bills, including time-of-use rate structures, to quantify savings potential.
- Build a load profile and estimate daily, seasonal, and critical-backup energy needs.
- Size PV and battery systems using transparent assumptions (e.g., depth of discharge, round-trip efficiency, days of autonomy).
- Compare panels, inverters, and batteries using the specifications that actually

matter in homes.

- Evaluate your roof or site, select racking, and plan wiring runs with safety top-of-mind.
- Navigate permitting and interconnection, prepare submittals, and pass inspections.
- Choose between hiring an installer and a DIY or hybrid approach—and manage quotes apples-to-apples.
- Model cash flow, incentives, and payback using simple worksheets and a spreadsheet template.
- Install, commission, monitor, and maintain your system—and troubleshoot the most common issues.
- Plan upgrades over time as your needs change (adding EVs, heat pumps, or more storage).

How to use this book. Each chapter opens with a short real-world vignette to anchor the topic in lived experience. You'll find sidebars labeled Quick Checklist, Common Mistakes, and When to Call a Pro to keep you oriented and safe. Diagrams and single-line drawings illustrate concepts and typical residential topologies; tables summarize key specifications and selection criteria. Throughout, we include conservative cost examples with upper- and lower-bound scenarios and a clear explanation of what drives the range. At the back of the book, Appendices provide a glossary, sample permit checklist, wiring diagram legend, a curated list of authoritative resources (NREL, SEIA, state incentive databases, local code bodies), and suggested spreadsheet templates you can download. Where codes and incentives change frequently, we point you to the exact authoritative sources and suggest a quick verification routine before you purchase equipment or submit applications.

Two words shape the approach here: safety and context. Electricity is unforgiving, and codes exist for good reasons. We elevate safe procedures, personal protective equipment, lock-out/tag-out practices, and fall protection. We also emphasize context: the “best” inverter or battery depends on your loads, roof geometry, utility tariff, climate, and whether your aim is savings, resilience, or both. Rather than endorse brands, we teach you to read datasheets, weigh trade-offs, and build a system architecture that matches your goals. If you already have part of a system—say, an existing string inverter or a subpanel—we show how to design around constraints and plan for future upgrades with minimal stranded cost.

Below is a brief overview of how the book unfolds, chapter by chapter, so you can see the arc from concepts to commissioning to long-term ownership:

- Chapter 1 establishes why home energy independence matters, surveying price trends, outage realities, and emissions impacts while helping you articulate your own objectives.
- Chapter 2 explains electricity and solar basics—photons to electrons, DC vs AC, power vs energy—with simple diagrams and a primer on series/parallel wiring.
- Chapter 3 shows how to understand your energy use via bills, time-of-use rates, smart plugs, and a simple weekly load analysis spreadsheet.

- Chapter 4 walks through sizing PV and batteries using a clear, repeatable methodology and worked examples for different home types.
- Chapter 5 compares panel technologies and performance metrics and provides a decision table to narrow choices.
- Chapter 6 demystifies inverters, optimizers, and MPPT, with selection criteria and example specs for common residential scenarios.
- Chapter 7 surveys storage technologies—especially LFP lithium batteries—covering cycle life, safety, and sizing for backup and bill management.
- Chapter 8 covers mounting and racking, roof assessments, flashing and waterproofing, and when to call a structural engineer.
- Chapter 9 focuses on wiring fundamentals, panels and breakers, grounding and bonding, and essential safety practices.
- Chapter 10 contrasts grid-tied, off-grid, and hybrid system topologies and explains anti-islanding and when off-grid makes sense.
- Chapter 11 is your roadmap to permits, inspections, NEC highlights for residential PV, interconnection agreements, and realistic timelines.
- Chapter 12 details financing and economics: incentives, loans, leases/PPAs, and step-by-step payback, IRR, and NPV examples with worksheets.
- Chapter 13 helps you choose an installer or plan a DIY/hybrid project, evaluate quotes fairly, and spot red flags.
- Chapter 14 teaches design for performance and longevity—tilt/azimuth optimization, shading mitigation, thermal considerations, and commissioning best practices.
- Chapter 15 provides a step-by-step rooftop installation walkthrough with materials lists, safety measures, and commissioning checks.
- Chapter 16 does the same for ground-mounts, portables, and carports, including foundations and wind/snow considerations.
- Chapter 17 covers monitoring and energy management—dashboards, automation, demand response, and interpreting alerts and trends.
- Chapter 18 integrates EVs and heat pumps, with guidance on charger types, load management, and vehicle-to-home readiness.
- Chapter 19 addresses maintenance and troubleshooting, seasonal tasks, common inverter and battery issues, and realistic upkeep costs.
- Chapter 20 compiles safety, fire codes, rapid shutdown, emergency procedures, and storm preparation best practices.
- Chapter 21 shows how to scale—adding panels or batteries, replacing inverters, and planning upgrades over a 20-plus-year system life.
- Chapter 22 presents urban rooftop case studies with design choices, costs, and actual vs projected generation.
- Chapter 23 offers rural and off-grid case studies, highlighting autonomy trade-offs and maintenance realities.
- Chapter 24 explores community solar and co-ops—legal/financial structures, allocation models, and success stories.
- Chapter 25 steps back to the big picture: lifecycle impacts, recycling, carbon payback, and how to advocate locally.

Choose your reading path. While the book works linearly, different readers will benefit from targeted routes:

- DIY Fast-Track: Read Chapters 2–4 to master fundamentals and sizing, then 8–11 for mechanical/electrical and permitting, and 15–17 for installation and

- commissioning. Keep Chapter 20 at hand for safety.
- Hiring an Installer: Focus on Chapters 3–6 to understand proposals, 12 for financing and economics, 13 for evaluating bids, and 14 for design quality; skim 11 to know what to expect in permitting and inspections.
 - Financing First: Start with Chapters 3 and 12 to quantify savings and structure funding, then loop back to 4–6 to confirm the technical scope aligns with your financial goals.
 - Resilience-First/Off-Grid Curious: Read Chapters 1, 4, 7, 10, 18, and 21 to design for autonomy and critical-load coverage, then study the off-grid case studies in Chapter 23.

A note on costs, incentives, and codes. Numbers in solar are not static: equipment prices, utility tariffs, tax credits, and interconnection rules evolve. Rather than anchor your decisions to a single snapshot, we teach a durable approach: identify the authoritative source, verify the current rule or rate, and run the math yourself using our worksheets. Each cost example in the book shows assumptions and sensitivity ranges so you can swap in your local values. We also call out known decision points—like net metering vs export rates, or main-panel upgrades—that can materially change project economics and scope.

What tools will you need as a reader and (if you choose) as a DIYer? To follow along: your last twelve months of electric bills, a notebook or spreadsheet, and a willingness to measure your actual loads with a clamp meter or smart plugs. For hands-on work: basic PPE (gloves, safety glasses), a multimeter rated for the voltages you'll encounter, torque tools for electrical terminations, and fall-protection gear for any roof work. We provide exact tool lists where needed and highlight tasks best left to licensed professionals.

Finally, this is a blueprint, not a one-size-fits-all prescription. Your roof, climate, utility rate, and goals make your project unique. The method is universal: clarify objectives, measure and model honestly, design for safety and longevity, and execute step-by-step with quality checks. If you take nothing else from this book, take this: a well-designed residential solar-plus-storage system is attainable for ordinary households when approached methodically. Turn the page, gather your bills, and schedule your first site assessment. By the end of this journey, you'll have the confidence and tools to power your home on your own terms—saving money, keeping the lights on when it matters most, and doing your part for a more resilient energy future.

CHAPTER ONE: Why Home Energy Independence Matters

Maria kept a single-cup coffee maker on her kitchen counter, the kind with a red light that blinked like a tiny heartbeat. One summer afternoon in Phoenix, the grid faltered under the weight of a heat wave, and that light went dark. She opened her refrigerator just enough to grab a bottle of water, worried about the milk for her toddler, and waited. The outage lasted nine hours. “If I had a battery,” she told me later, “even a small one, we could have kept the fridge going and charged our phones. Instead, we sat in the dark and worried.” Six months later, she called a local installer. Not because the outage was the first time she had thought about power, but because it was the first time she felt the cost of doing nothing.

Energy independence at home doesn't mean living in a cabin in the woods, surviving on hand-cranked radios and beans. It means keeping essential circuits running when the grid goes down, making your monthly expenses more predictable, and choosing when you buy electricity instead of letting the utility set the terms. For most households, the path to that independence runs through solar panels and batteries. The idea sounds grand; the reality is practical and incremental. It begins with an honest assessment of what you use, what you can generate, and what you want to keep powered when the street is dark.

Residential electricity prices in the United States have trended upward for decades. Data from the U.S. Energy Information Administration (EIA) shows average retail rates rising since the early 2000s, with notable spikes in the last few years driven by fuel costs, grid upgrades, and extreme weather.¹ While regional variation is wide—households in the West and Northeast often pay more than those in the Midwest—most customers see at least moderate increases annually. Time-of-use rates, which charge more during peak hours, are now common in many states. If your utility shifts more costs into “on-peak” periods, your bill can rise even if your total kilowatt-hours stay flat.

Outages are also becoming more frequent and longer in many regions. Wildfires, hurricanes, ice storms, and heat waves stress the distribution system. The national average for outage duration has fluctuated year to year, but recent events illustrate the trend: storms can leave neighborhoods without power for a day or more, and in some cases, for several days. The typical American home has loads that cannot wait—refrigeration, medical devices, a modem and router for remote work, basic lighting. Solar panels alone cannot keep the lights on during a grid outage unless you have an inverter designed for “islanding” and a battery to supply power when the sun

isn't shining. This is not a technical loophole; it's a safety requirement.

A separate motivation sits in the climate ledger. Electricity generation accounts for a significant share of U.S. greenhouse gas emissions. Adding rooftop solar and storage at home can reduce your household's carbon footprint, especially in regions where the grid mix leans on fossil fuels. The exact impact depends on local generation and the timing of your loads. On a sunny afternoon, rooftop panels may displace natural gas peaker plants; at night, your battery may draw from a cleaner mix or avoid costly generation altogether. You don't need to be an environmentalist to appreciate that lower emissions and lower bills can come from the same design.

But what does "independence" actually mean for a grid-tied home? Practically, it has three layers. First is bill control: generating power you would otherwise buy, and in some cases selling excess to the grid when rates are favorable. Second is resilience: critical load coverage during outages, so the fridge stays cold, the internet stays up, and a few lights stay on. Third is autonomy of choice: deciding when to charge your battery, when to run high-load appliances, and how to integrate future additions like electric vehicles or heat pumps. These layers are achievable at different scales. A small system might keep your modem, fridge, and a few lights running for a day. A larger system can cover most daily loads and ride through multiple outage days with careful management.

Let's ground the idea with a realistic scenario. The Martinez family lives in a 2,000 square-foot, all-electric home in northern California. Their average daily consumption is 18 kWh. They install a 6 kW solar array and a 13.5 kWh lithium battery. In their net metering environment, the system covers about 80 percent of their annual usage, and they get credit for excess production. On a typical summer day, the solar generates more than the house uses during midday, charging the battery. When clouds roll through in the late afternoon, the battery discharges to cover the "duck curve" peak. At night, they draw modestly from the grid, but their bill is dominated by the solar credits they banked earlier. During an outage, they manually shift a few critical loads—fridge, internet, lights—to a subpanel backed by the battery. They do not run the electric dryer or heat pump during outages, but they stay comfortable and connected for 24–36 hours.

This book is about how to design and build systems like the Martinez example, or smaller or larger versions suited to your needs. That said, it's important to note that not every home is a prime candidate. Roofs with heavy shading, structural issues, or poor orientation may still pencil out with the right design, but they may require ground mounts, microinverters, or a focus on resilience rather than maximum bill offset. Some utilities limit the size of systems you can interconnect or pay less for exported power than they charge for imports. Some states offer excellent incentives; others do not. Your independence is bounded by local rules and physics, but within those bounds, there's usually a smart path forward.

Let's clarify common terms to set expectations. Kilowatts (kW) are power—the instantaneous rate electricity is produced or consumed. Kilowatt-hours (kWh) are energy—the total amount used or stored over time. Solar panels produce DC (direct current) electricity. An inverter converts DC to AC (alternating current) for household use. A “grid-tied” system uses the grid as its backup; an “off-grid” system must meet all loads with local generation and storage; a “hybrid” system can operate in both modes, with automatic or manual switching. Net metering is a billing arrangement where exports to the grid offset imports, often at a one-to-one rate, though some utilities now use “net billing” with different values for exports. Battery capacity is usually given in kWh, and power in kW. Lithium-iron-phosphate (LFP) batteries are common for homes because of safety and cycle life advantages.

Why focus on solar-plus-storage instead of a generator? Generators provide robust backup, but they are noisy, require fuel storage and maintenance, and often run at low efficiency for hours. Batteries are silent, fast-acting, and can be charged by the grid or solar. They also enable time-of-use arbitrage: you charge the battery when rates are low (or from solar at midday) and discharge when rates are high. A generator is still a reasonable option in some off-grid or high-outage scenarios, and we will discuss hybrid generator-battery setups, but for most urban and suburban homes, a battery integrated with solar offers a cleaner, more flexible solution.

Resilience looks different depending on where you live. In the Northeast, winter storms can knock out power for days; a battery can keep a few essentials running while you wait for crews, assuming you have a way to keep the battery charged. In the Southeast, hurricanes can interrupt service for a week; pairing solar with storage and a generator can keep a home running nearly continuously. In the Southwest, heat waves stress the grid; a battery can help avoid peak rates and ride through short outages, while a well-sized array can meet most daytime loads. The design changes based on climate and risk profile, but the core objective is the same: match generation and storage to your critical loads, weather patterns, and utility rules.

The financial side is equally varied. The federal Investment Tax Credit (ITC) currently allows homeowners to claim a percentage of solar and battery costs against federal taxes, with specific rules about eligibility. Many states and utilities offer additional rebates or performance-based incentives, and some run targeted programs for low-to-moderate-income households or resilience. These programs change frequently; the best practice is to verify current details on the DSIRE database (Database of State Incentives for Renewables & Efficiency) or your utility's interconnection webpage before you commit. On the equipment side, prices have fallen over the past decade for panels and have stabilized for batteries after recent supply chain volatility. However, labor, permitting, and electrical upgrades can still be significant, especially if your main panel needs modernization.

Let's put numbers to a conservative example. A mid-sized 8 kW rooftop system might cost \$24,000 before incentives. With the ITC applied, that drops to \$16,800. If your average bill is \$180 per month and the system covers 70 percent of your usage, you might save \$1,512 per year, for a simple payback around 11 years. If you add a 13.5 kWh battery for \$10,000 (after a \$3,000 state rebate), your annual bill savings might increase by \$300-\$600 due to time-of-use shifting, and you gain outage coverage for critical loads. This pushes the combined payback to roughly 12-14 years, depending on rate changes and usage patterns. These are "right-side-of-the-curve" estimates; some households achieve faster payback with high utility rates and favorable net metering, while others with low rates and weak export credits may see longer payback. The key is to build a model with your actual bill, your utility's rate structure, and the specific incentives you qualify for.

Financial metrics like payback, internal rate of return (IRR), and net present value (NPV) can sound abstract, but they're practical tools for comparing options. Payback is how long it takes for savings to equal the initial investment. IRR is the annualized return you effectively earn on that investment over the system's life. NPV translates future savings into today's dollars using a discount rate, helping you compare a solar investment to, say, paying down a mortgage or investing in the market. We will build simple worksheets for these later in the book. For now, the crucial idea is that solar-plus-storage can be evaluated as a financial asset with an expected life of 20-25 years for panels and 10-15 years for batteries, depending on chemistry, usage, and warranty terms.

The upfront price tag is a real barrier for many households. That's why financing matters as much as equipment selection. Solar loans can bring monthly payments close to or below your current electric bill, effectively creating immediate cash flow. Leases and power purchase agreements (PPAs) shift upfront costs to a third party in exchange for monthly payments and potential maintenance coverage, but the economics and tax benefits differ significantly from ownership. Some states allow property assessed clean energy (PACE) financing tied to your property tax bill. Choosing among these options depends on your tax situation, how long you plan to stay in your home, and your tolerance for complexity. In Chapter 12, we'll model these side by side with your actual utility rate.

You may be wondering: is solar plus storage worth it for every home? Not necessarily. If your roof is heavily shaded, if structural reinforcement is required, or if your utility pays very little for exports and offers no battery incentives, the financial case may be weak. If you rent, you may not be able to install on the roof, but community solar might be available, or you could install portable power solutions if your landlord permits. If your electricity rates are low and reliable, and outages are rare, you might prioritize resilience modestly and design a smaller, battery-focused system rather than a large solar array. Conversely, if you live in a wildfire-prone area with frequent Public Safety Power Shutoffs, a larger battery and potentially a generator may be justified

even if the pure financial payback is longer.

Practical outcomes are what count: keeping your home running smoothly, managing costs, and reducing emissions without creating a maintenance headache. Most of the homeowners who succeed with solar-plus-storage share a few habits. They start with an honest energy audit, not a guess. They design for their actual loads and expected changes (new EV, heat pump, growing family). They choose equipment that matches their goals rather than chasing the highest possible production. They install with safety first, commission thoroughly, and monitor their systems so they can spot issues early. They also keep good records—copies of permits, warranties, and commissioning reports—so service or warranty claims are easy later.

A quick reality check: the most common pitfalls are avoidable. Oversizing a system without checking export rate structures can reduce savings. Undersizing a battery for critical loads leads to disappointment during outages. Skipping shade analysis leads to underperformance. Ignoring roof condition can force an expensive re-roof mid-project. Neglecting to verify interconnection rules can cause long delays. Installing equipment you don't fully understand can create safety risks. The good news is that each of these has a straightforward fix, and the steps are laid out in the chapters ahead.

Let's talk about the skills needed to engage with this material. You don't need to be an engineer or an electrician to read and benefit from this book. You do need to be comfortable with careful measurement, following instructions, and asking for professional help when the task crosses safety or code lines. For readers who plan to hire an installer, Chapters 3–6 and 12–14 will help you ask precise questions, evaluate proposals critically, and avoid paying for things you don't need. For DIY-curious readers, Chapters 8–11, 15–17, and 19–20 provide a safe path for the parts you can reasonably tackle yourself, while highlighting where licensed professionals are required. In all cases, the north star is safety: lock out and tag out before touching wires, use fall protection on roofs, and respect that code requirements exist to prevent fires and shocks.

You may also be thinking about the planet. While this book does not lecture, it does offer facts. Modern panels have a carbon payback estimated in the one-to-three year range, depending on where they are made and the local grid mix. Over a 25-year life, a home system can offset many tons of CO₂. Batteries add some embedded emissions, but they also reduce reliance on fossil peakers and can improve grid reliability. End-of-life recycling programs are growing, and manufacturers increasingly offer take-back options. If those topics matter to you, Chapter 25 dives into lifecycle impacts and the policy landscape.

To get the most out of this book, keep a notebook or spreadsheet handy. You'll want to record your actual utility bills, note rate structures, and build a simple weekly load profile. When you start shopping for equipment, keep datasheets and warranties

organized. When you talk to installers, write down questions and answers, and request a single-line diagram in plain language. Use the checklists at the end of each chapter. If a concept feels fuzzy—like MPPT or net billing—bookmark it and revisit it when the relevant chapter arrives. The book is designed so you can jump to the sections that match your immediate need, but the overall arc will reinforce earlier fundamentals.

Here is a practical way to start today. Pull your last 12 months of electric bills. Calculate your average daily kWh use (total annual kWh divided by 365). Note whether you are on a flat rate or a time-of-use plan. Identify your highest bills months and think about what drives them—air conditioning, electric heat, pool pump, or something else. Walk your property and take photos of your roof from different angles, noting any shading objects like trees or chimneys. Find your main service panel and note its amperage (often 100A, 150A, or 200A) and whether there is space for new breakers. This simple exercise, taking about an hour, will anchor your design and help you follow the upcoming chapters with real numbers.

We will close this chapter with a brief look at three common starting points. If you are primarily motivated by bill savings, start by building a solid load profile (Chapter 3) and understanding your utility's rate structure; that will drive your system size and equipment selection (Chapters 4–7). If you are primarily motivated by outages, start with your critical loads—what must stay on during a blackout—and size a battery first, then add solar to recharge it (Chapters 4, 7, 10, and 20). If you are primarily motivated by financing and process—perhaps you've been burned by a confusing contractor quote before—start with Chapters 11, 12, and 13 to learn permitting, incentives, and how to compare proposals apples-to-apples. In each case, the path is similar: measure, model, design, source, install, commission, monitor, and maintain.

Before we move on, a note on data and sources. Incentive programs, utility tariffs, and code requirements change frequently. We will cite authoritative references—NREL, SEIA, DSIRE, the NEC, and utility interconnection guides—and provide dates of access where applicable. Treat any single number in this book as a starting point. The durable skill is knowing where to verify the current value and how to recalculate the result with your assumptions. This is your home, your money, and your resilience at stake; the effort you put into verification will pay off.

One last perspective from the field. An installer in Colorado told me, "The best customers are the ones who show up with a year of bills and a list of circuits they care about most." That simple preparation trumps fancy equipment every time. Another homeowner in Florida said, "I don't care if my payback is ten years. I care that my food doesn't spoil and my kids can do their homework when the neighborhood goes dark." Both views are valid. Your goals will shape your system, and your system will serve your goals. The next chapter will give you the electrical and solar basics so you can think clearly about how power moves from the sun to your outlets, and we'll keep the jargon to a minimum while we do it.

Footnotes: 1) U.S. Energy Information Administration, Electric Power Monthly, average residential retail price data (accessed via eia.gov, 2024).

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