ELECTRIFY EVERYTHING

in Your Home

A GUIDE TO COMFY, HEALTHY, CARBON-FREE LIVING

BY JOEL ROSENBERG, REWIRING AMERICA

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By Joel Rosenberg, Rewiring America

REWIRING AMERICA

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Check **rewiringamerica.org/electrify-home-guide** for a FREE download of this ebook, updates, and other info.

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Why electrify?

At Rewiring America, we're convinced that the future will be awesome — if we electrify everything. Around 40% of the United States carbon emissions come from our homes and the vehicles we drive. Simply switching everything in our lives to be powered by electricity from renewable energy will go a long way toward getting our emissions down and reducing the impact of climate change. Rewiring America estimates that to achieve zero emissions, we need to install 1 billion new machines, or 50 million machines a year for the next 20-25 years.[1] It's a lot, but it's very doable if everyone stops buying fossil-fueled machines. As a bonus, you'll also get better performance and lower utility bills from your new electric appliances.

This is not to say that all of the responsibility for fixing climate change rests on your individual choices and "carbon footprint" — we also need large-scale changes in policy around renewable energy, government subsidies, and industry accountability. But because our homes and cars are such a large part of U.S. emissions, we have to start electrifying them now, and get to 100% adoption of electric replacements as quickly as possible. We need both policy changes and individual action to solve this crisis, and every day we wait just makes it harder.

The actions in this handbook are one-time decisions that update your personal infrastructure for lower energy use and lower carbon emissions. There are also a number of changes in your behavior that would help reduce your emissions, such as eating less meat, buying fewer things of higher quality that will last longer, and flying and driving less. Those are all fine choices as well. But by far the biggest impact

you can make is by electrifying everything in your home.

To electrify everything, you'll need to replace any machines that currently burn fossil fuels — your gas-powered car, furnace, water heater, kitchen stove, and dryer. You might also install some new electric machines, like solar panels and a home storage battery. You don't have to do this all at once — you can wait until the next time your car or heater dies and needs to be replaced. This handbook is a tool to help you convert your household to run fully on electricity, backed by renewable energy. And even if you're a renter, there are things you can do, too, to reduce carbon emissions in your home.

The machines you'll learn about in this handbook are *better* than the fossil-fuel versions they're replacing. Here are some examples:

- Heat pumps, which can both heat and cool your home, do a better job of keeping your home at a constant, comfy temperature than an oil or natural gas furnace, while using only 30% of the energy to do so.
- Many people think their Electric Vehicles (EVs) are more fun to drive than their gasoline cars, and much cheaper to charge and maintain. A typical EV costs you 5¢ per mile to drive, while a typical gasoline vehicle costs you 13¢ per mile.[2]
- Induction cooktops deliver better performance than gas stovetops, with higher heat and improved control, which is why many professional chefs and home cooks prefer them. They can boil water in half the time, for example. Plus, you won't hurt your hand if you touch the burner when it's on – they only heat the pan.[3]

Even though these are the machines of the future, they aren't new inventions: heat pumps use the same basic technology as your refrigerator; electric cars were first popular in the late-1800s before gasoline cars dominated the 20th century;[4] and induction cooking was invented in the early-1900s.[5] It's because of more recent improvements in these technologies, including better batteries and computerized control, that these machines got their performance advantages. But there are other benefits as well:

- They're **healthier and safer** since you're not burning fossil fuels inside your kitchen and causing indoor air pollution, you're not storing fossil fuels in your basement or garage, and you can get rid of the explosive methane gas flowing into your home.
- They can **save you money** since they use less energy, which makes them cheaper to run over their

10-25 year lifetimes. Rewiring America estimates that more than 103 million American households would start saving money on their monthly utility bill right away if electric heat pumps for space and water heating cost the same to buy and install as the fossil-fueled machines they're replacing (i.e., those that run on oil, propane, or outdated, inefficient electric resistance heaters). Check out our Bringing Infrastructure Home report — **rewiringamerica.org/policy/bringing-infrastructure-home-report**.

→ If your electricity comes from renewable sources like solar and wind, they will run without producing any carbon emissions, and that helps us **beat climate change**. Even if your electricity comes from fossil fuel power plants run by your local utility, these modern home machines are so much more efficient they'll still have lower total carbon emissions than burning fossil fuel directly at home. Plus, as your grid switches to 100% renewable sources, the emissions will drop to zero — they are "appreciating climate assets" (they get more valuable over time).

ELECTRIFICATION FOR EVERYONE

This guide is geared mostly towards single family homeowners, but Rewiring America is a strong advocate of electrification for everyone. Indeed, our position is that electrification is the most equity-centered of our climate strategies. It applies to all households, and when combined with the right policies, results in economic savings and health benefits that disproportionately benefit low income and historically disinvested communities. Further, many of the electrification projects below can be done by renters.

Right now, some electric machines are more expensive to buy than their fossil fueled versions — though they usually lower your bills once installed. Rewiring America is working on policy initiatives to help eliminate this extra up-front cost through rebates, with an emphasis on helping Low and Middle Income (LMI) households get these machines and the lower bills they provide.

All of the recommendations in this handbook are meant for everyone, even if they're not yet within everyone's budget. As we dial in the correct policy measures, and as industry produces more of the machines that will help us mitigate climate change, their costs will drop even further.

ADDITIONAL RESOURCES

In addition to this *Electrify Everything* guide, two other resources are worth getting:

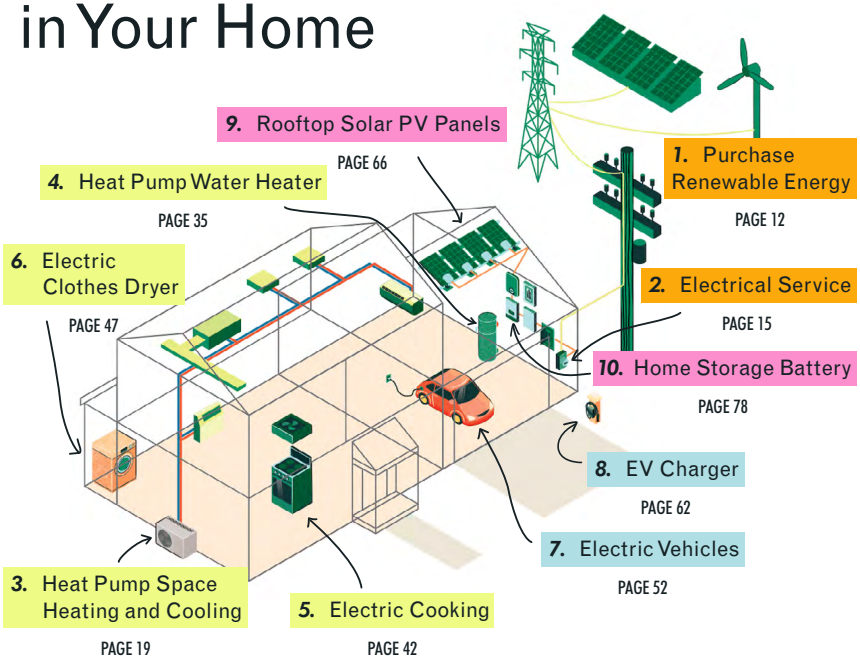
→ Redwood Energy's *Pocket Guide to All-Electric Retrofits of Single-Family Homes* includes a comprehensive guide to many electric appliances on the market, along with case studies and other useful background:

- Retrofit Guide — **redwood energy.net/research**
- Webinar — **www.youtube.com/watch?v=uUoyweC0mSE**

→ Nate Adams (aka Nate the House Whisperer) "Electrify Everything" course is a series of 12 emails and videos with an emphasis on space heating and cooling, which is the most complex step.

- Emails — **natethehousewhisperer.com/electrify-everything-course.html**
- Videos — **youtube.com/playlist?list=PLLTtM5Ga_CUtT-SB20vtU2y2EwtrwC6B6**

Where to Electrify Everything in Your Home



How to use this handbook

Because we're at the start of this electric transition, there aren't companies (yet) that will come and replace all of your fossil fuel machines. For now, you have to do more of the legwork yourself. But you can start small, and you don't have to do everything all at once — you just need to be ready for an electric replacement when the time comes (though it's helpful to retire machines early if your concern is reducing emissions).

Each chapter of this guide goes into detail about one aspect of upgrading your machines. The goal is to help you make a plan, and support you as you go through each process — from understanding what the change is, to hiring the contractors who will do the work, to using your new machines.

GETTING STARTED NOW!

The tables on the next two pages can help you make a plan. The first table lets you prioritize replacing your machines based on their age, their cost and potential savings, or their share of home emissions (cars, space heat, then hot water are the biggest). Harder upgrades might require more design, more permits, or take longer. For items that need an electrical upgrade, consider having an electrician install circuits and outlets in advance, so you're ready the next time you buy a replacement (see *Chapter 2: Electrical Service*). For renters, upgrades you control are marked with an R.

The second table summaries concrete actions you can "Do Now" to start making progress immediately. If you're a renter, consider working with your landlord on upgrades you can't do without them.

Overall, the recommendation is to buy machines with lower energy needs and operating costs. These also have lower emissions, and help you delay (or avoid) needing to upsize your electrical service to 200A, while still providing comfort and performance.

	LIFE IN YEARS	ELECTRICAL UPGRADE	UP FRONT COST BEFORE REBATES	ANNUAL OPERATING SAVINGS	HARDER	% HOME EMISSIONS	IMPROVES AIR QUALITY	RENTER CONTROLS
1. Purchase Renewable electricity								
			$0					R
2. Electrical Service								
	20-25 YRS		$750-4,000		✓			
3. Heat Pump Space Heating and Cooling								
	15-20 YRS	AT INSTALL	$1,000 DIY, TO $20,000+	$$$	✓	25%		R
4. Heat Pump Water Heater								
	10-15 YRS	MAYBE	$1,500 DIY, $4,000 INSTALLED	$		10%		
5. Electric Cooking								
	13-15 YRS	YES	$2,000-3,000			5%		R
6. Electric Clothes Dryer								
	10-13 YRS	MAYBE	$1,000-2,000	$$		3%		R
7. Electric Vehicles								
	20-25 YRS		$10K (USED) AND UP	$$$		50%		R
8. EV Charger (240V EVSE)								
	10-15 YRS	YES	$500-2,500					R
9. Rooftop Solar PV Panels								
	20-30 YRS	AT INSTALL	$15,000-30,000	$$$	✓	HELPS ALL		
10. Home Battery Storage								
	5-15 YRS[6]		$10,000-20,000	$	✓	HELPS ALL		

KEY:

$ SAVE $50+ PER YEAR
$$ SAVE $200+ PER YEAR
$$$ SAVE $500+ PER YEAR

INDOOR & OUTDOOR
OUTDOOR

DO NOW

1. Purchase Renewable electricity

Log on to your utility account (or call) and switch to a renewable power plan if it's available. If not, look for a Community Solar or Wind project to join. **RENTER**: Same.

2. Electrical Service

Check your electrical panel to figure out how it's sized (see *Chapter 2: Electrical Service* for instructions). **RENTER**: Same.

3. Heat Pump Space Heating and Cooling

Get a "home energy audit" or "home energy assessment" (including a blower door test), and/or schedule at least one heat pump contractor to come to your home and give you an initial quote/ proposal. **RENTER**: Get a window unit or portable heat pump.

4. Heat Pump Water Heater

Find your current water heater and determine how old it is (see *Chapter 4: Heat Pump Water Heater* for instructions). Plan to replace it if it's over 10 years old. **RENTER**: Show your landlord heat pump replacement options & EnergyGuide savings.

5. Electric Cooking

Hold a magnet to your pans, and if the magnet sticks it will work with an induction cooktop. Buy a $50+ portable induction burner now, and plan to have a 240V / 40A outlet installed before you next replace your stove. **RENTER**: Buy a $50+ portable induction burner.

6. Electric Clothes Dryer

Check if you have a gas dryer, or if you already have a 240V appliance outlet behind your dryer. Get a clothes drying rack or clothesline. **RENTER**: Get a clothes drying rack or clothesline, and consider a combo washer & condensing dryer that runs on 120V (if allowed).

7. Electric Vehicles

Consider how far you drive in a day to start thinking about range, and look online for public charging stations nearby to start thinking about where else you can charge. **RENTER**: Same.

8. EV Charger (240V EVSE)

If you have a garage, check if you already have a 240V appliance outlet for a faster "Level 2" charger. **RENTER**: Ask your landlord and employer about installing a Level 2 charger.

9. Rooftop Solar PV Panels

Use a website to check your address's potential for sun. Use **energysage.com** to get initial quotes. **RENTER**: Send quotes to your landlord, along with financing options.

10. Home Battery Storage

If you have rooftop solar, check with your installer about whether they also offer a storage option. **RENTER**: Get a standalone backup battery.

How to pay for it

Full electrification of your home can be costly up front, but many of the upgrades pay for themselves over time with lower operating costs. There are also rebates and financing available, which are described more below. But there are also affordable things every household can do to lower their emissions. Consider your budget, and what initial projects make the most sense:

- → $0 up front: Purchase renewable energy from your utility or co-op — it might save you money or cost a little more.
- → $50-100: Buy an induction burner cooktop to start cooking *without* gas.
- → $300: Hire a "home energy auditor" to do a blower door test and suggest ways to reduce your home's energy leaks (might be free through your utility or government).[7]
- → $1,000: Get a mini-split heat pump and install it yourself using YouTube videos.
- → $1,500: Get a heat pump hot water (HPHW) heater and install it yourself using YouTube videos (check with your state that you don't need a licensed installer)
- → $4,000: Get a HPWH installed, or a heat pump space heater/cooler for your 1,000 square foot home.
- → $10,000 to $20,000: Upgrade to a heat pump space heater/cooler for your 3,000 square foot home, or buy a used Electric Vehicle (EV).
- → $20,000+: Start aiming to completely electrify everything in your home.

REBATES

There are many electrification rebates available — from federal tax credits for residential solar PV[8] and EVs,[9] to state and regional rebates for heat pumps and other appliances.[10] These are addressed in chapters that

follow. But here are some general places to check for rebates:

- DSIRE (Database of State Incentives for Renewables & Efficiency), where you can find rebates by zip code, as well as policies by state — **www.dsireusa.org**
- Energy Star Rebate Finder by zip code — **energystar.gov/rebate-finder**
- Search online for "[YOUR STATE NAME] + [YOUR UTILITY NAME] + electrification energy efficiency rebate".
- Ask any contractor you talk to if they will help you find and apply for rebates.

FINANCING

Many people borrow money to buy a car — often from the dealer they're buying it from. And the same can be true for an EV you buy, either new or used. But it's also possible to get financing for energy upgrades like better insulation for your home and switching to electric appliances. This is also true if you're a landlord looking to electrify your rental properties.

A loan helps spread your costs over time. And since interest rates are low and energy upgrades will start paying back immediately, financing can make sense to greatly accelerate your electrification timeline. Here's a brief summary of some options:[11]

- **Energy Efficient Mortgages (EEMs):**[12] EEMs, also known as "Green Mortgages," are available when you buy or refinance your home. But this isn't a second mortgage — it gets added to your original mortgage. And if you qualify for a mortgage, you probably also qualify for an EEM. They're available through most lenders, and the three main loan backers are Fannie Mae, the Federal Housing Authority, or the Veterans Administration.[13] A "home energy assessment" (aka "home energy audit") by a qualified energy assessor is required to evalute the costs and benefits of proposed changes. This is worth doing anyway (see *Chapter 3. Heat Pump Space Heating & Cooling* for more details).
- **Renovation Loans:** These loans help pay for upgrades that improve the value of the home, including energy efficiency. They're available when you buy or refinance. Not all banks and lenders offer renovation loans, so you should check around for one that does.[14]
- **Home Equity Line of Credit (HELOC):** Also called a second mortgage, a Home Equity Line of Credit (HELOC) can finance energy-efficient home upgrades. Check with your bank or mortgage holder.

- **Credit Union Loans:** Credit unions are nonprofit banks that are member-owned, and that have Federally insured deposits — just like for-profit banks. Check around to see which credit unions offer Green Energy Loans.[15] Or check with Clean Energy Credit Union, a new, nationally chartered, online-only credit union that's focused on clean energy lending — **cleanenergycu.org/home/about-us/faqs**. Besides retail banking, they give loans for everything from a home energy assessment or electric bike to a full rooftop solar installation.[16]
- **PACE Financing:**[17] PACE (Property Assessed Clean Energy) is not a loan, but rather a property tax lien on your house, where you pay it back as part of your property taxes. This can be a useful option, but you should be aware that having this lien recorded against your house can make it more difficult to sell or refinance it without first paying off the lien.[18] Buying or refinancing using Fannie Mae's EEM HomeStyle Energy Mortgage[19] can be used to pay off a PACE loan and remove the lien.
- **On-bill financing (aka On-bill repayment):**[20] Some utilities offer energy upgrade loans that get repaid through your utility bill, and the bill savings from the upgrades offset the payments, making it appear "free." You can search the utilities with on-bill financing using an interactive map from the Environmental and Energy Study Institute — **eesi.org/obf/map**. If your utility isn't listed there, try searching for "[YOUR STATE NAME] + energy efficiency financing" to see if a state or local government program is available. Also search for your state in the DSIRE database (see "Rebates" section above).
- **Unsecured personal loan:** Based on your FICO credit score, you can get a loan without needing collateral (aka unsecured). These loans might be available through your contractor, the store where you buy an appliance, or the manufacturer directly. Interest rates depend on your credit score and term length, and your contractor might offer a "buydown" to give you a lower interest rate in exchange for a higher overall job price.[21]
- **Solar financing:** See *Chapter 9. Rooftop Solar PV Panels* for info about a solar lease or PPA (Power Purchase Agreement).
- **Multi-family homes, commercial or institutional organizations:** Check with the Department of Energy's Better Buildings program for help identifying financing options — **betterbuildingssolutioncenter.energy.gov/financing-navigator**

1

Purchase Renewable Energy

DIFFICULTY:	EASY from utility or an existing Community Solar or Wind project
UPFRONT COST:	$0 (might save money or cost a little more)
IMPACT:	Medium
CONTRACTORS:	None
DO NOW:	Log on to your utility account (or call) and switch to a renewable power plan if it's available. If not, look for a Community Solar or Wind project to join.
RENTER:	Same.

Nearly everyone in the U.S. can now buy renewable energy for their electricity supply, whether you rent or own a home. This is one of the easiest and most effective things you can do to immediately reduce your climate impact. And the benefit will keep increasing as you electrify your machines and use more electricity, because it will force your energy provider to buy more renewable energy to match your growing demand.

Below are steps you can take to start purchasing renewable power — from simplest to more involved.

SWITCH WITH YOUR EXISTING UTILITY COMPANY

As a first option, check with your utility to see if they have a 100% renewable electricity plan you could switch to. It might be called Solar Choice, or Renewable Choice, or something similar.

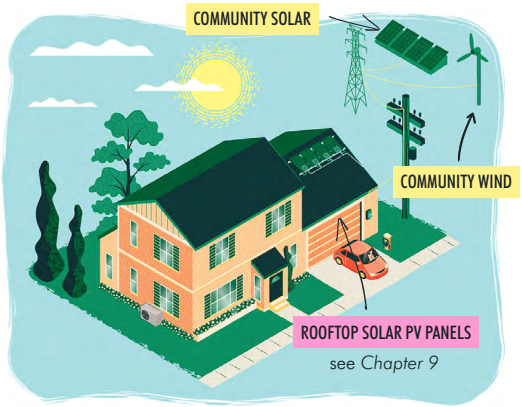
Even if you live in an apartment or mobile home with a single meter for the whole complex, you should ask your homeowners association about switching to a renewable energy plan. This is true of renters as well — ask your landlord about switching!

JOIN A COMMUNITY SOLAR OR COMMUNITY WIND PROJECT

If you can't switch with your utility, you might be able to enroll in a local Community Solar or Community Wind project, where you buy (or subscribe to) solar panels or windmills that feed their power to the grid, and then you get credits to offset your utility bill.

Learn more about Community Solar from Solar United Neighbors — **solarunitedneighbors.org/learn-the-issues/community-solar**. Then look for a project to join from:

- → Energy Sage's marketplace — **communitysolar.energysage.com**
- → NREL's list of "Sharing the Sun" Community Solar projects — **nrel.gov/state-local-tribal/community-solar.html**
- → Search for "[YOUR STATE NAME] + community solar"



Before signing any Community Solar agreement, read SEIA's "Residential Consumer Guide to Community Solar" — **seia.org/news/interested-community-solar-new-seiaccsa-guide-you**.

We don't know of a Community Wind marketplace, but you can try searching "[YOUR STATE] + community wind" to see if there's a project near you.

OTHER WAYS TO BUY RENEWABLE ENERGY

If renewable energy isn't available from your utility or Community Solar or Wind, you might be able to buy clean energy through other companies, such as:

- → Arcadia Power, which buys clean energy to offset your use — **arcadia.com**
- → Inspire, which charges a flat monthly price for unlimited clean energy use — **inspirecleanenergy.com**

CREATE A COMMUNITY SOLAR OR COMMUNITY WIND PROJECT

It is possible to start a community renewable energy project,[22] though this is a more difficult route than just buying energy from other projects. Your project could revolve around a school, a church, or a block. The Department of Energy has useful resources:

- → "A Guide to Community Solar" — **nrel.gov/docs/fy11osti/49930.pdf**
- → "Community Wind Handbooks" for Small and Large communities — **windexchange.energy.gov/markets/community**
- → Your project might be eligible for technical assistance through the Department of Energy's National Community Solar Partnership — **solarinyourcommunity.org**

DEMAND YOUR RURAL ELECTRIC COOPERATIVE GO RENEWABLE

Rural Electric Cooperatives (REC) are member-owned utilities that have been around since the 1930s. Members might not realize they're also owners who can demand solar or wind. If you or someone you know is part of a REC, check out:

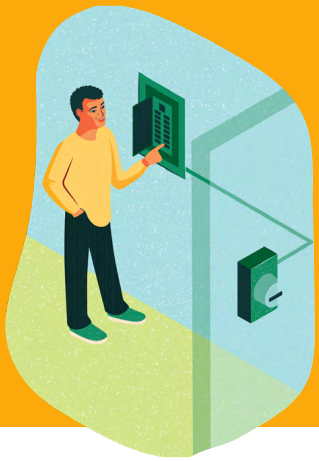
- → "Best Practice Solar Policies for Rural Electric Cooperatives" — **solarunitedneighbors.org/learn-the-issues/rural-electric-cooperatives**
- → The Rural Area Distributed Wind Integration Network Development (RADWIND) site for case studies and other info — **cooperative.com/programs-services/bts/radwind**

BUY OR LEASE ROOFTOP SOLAR

If you own a home, you can install solar panels on your roof (or yard / field). See *Chapter 9: Rooftop Solar PV Panels* for details. If you do install rooftop solar but can't produce enough to cover all your home's electricity usage, local rules often allow you to sign up for a renewable energy plan or Community Solar or Wind subscription to make up the difference.

2

Electrical Service



DIFFICULTY:	HARDER
UPFRONT COST:	$750-$4,000
IMPACT:	Can enable more electrification
CONTRACTORS:	Electrician
DO NOW:	Check your electrical panel to figure out how it's sized (see below).
RENTER:	Same.

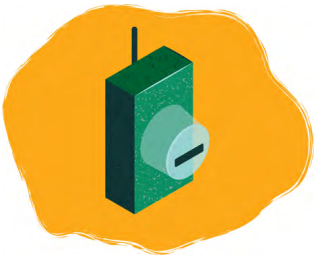
Your home gets its electrical service from the electric grid, and distributes it through your home's electrical panel — sometimes called the breaker box, load center, fuse box, distribution center, or distribution box. You can think of the big wires coming into your home like pipes delivering electricity, with the incoming flow rate of that electricity measured in Amps (See Appendix I for an extremely brief intro to electricity). Older homes might have panels that can handle 60 or 100 Amps (60A or 100A), while newer homes can handle 200A or higher. It might be possible to electrify everything in your home with 100A, but you might also need or want to upsize it to 200A (or more).

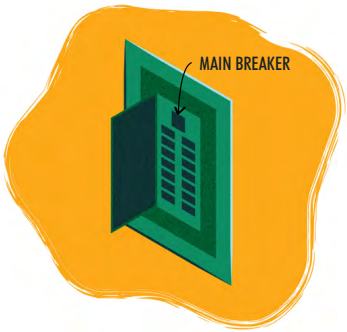
One recent report estimates that 35-45 million homes can fully electrify now without a panel upgrade, while another 48 million might need a larger panel.[23] As you make your electrification plans, consider buying machines that use less power (lower Amps & lower Volts) so they'll use less of your electrical service, and will also cost less to operate over time.

DETERMINE YOUR PANEL SIZE

One of the first things you should do on the path to electrify everything in your home is to check the size of your home's electrical service. Finding this out is safe to do yourself, but you can also have an electrician do it for you. Here are three places to check:[24]

Electric meter—Your meter is probably outside your home, and it's how the electric utility measures your usage. It'll look like this picture to the right. See if your meter has an amperage rating printed on its face, or on a label affixed to its body. It might say CL200, which means it can handle a maximum of 200A.





Electrical panel—
Your main electrical panel is inside your home, perhaps in the basement or a closet on the other side of the wall from your outside meter. It looks like this picture to the left. Find a label that indicates the panel's amperage rating. The label may be affixed by the manufacturer, or by an inspector when your panel was first installed or inspected.

Main breaker or fuse—The main breaker may or may not be inside your electrical panel, but it will usually be the largest breaker, and should have its capacity written on it or next to it.

Compare the three ratings to find the lowest one, which is probably your home's electrical service capacity. To electrify everything, you're going to need at least 100A electrical service, which is the minimum the National Building Code now requires.

UPSIZING YOUR PANEL

If you don't have at least 100A, or if you want to move to 200A to future-proof your panel:

1. Call your utility and ask what the maximum Amp service is that you could have in your home without upgrading the wires into your home. Consider going to 200A (or more) if available, which should be enough for electrifying most homes, including adding solar PV and multiple electric vehicles.

2. Budget between $750 and $4,000 to have the upgrade done by an electrician, including parts and labor.[25] It's an 8-10 hour job, but it might take a month or more to schedule with your utility. And it's worth doing this before any of your fossil-fueled appliances fail, so you're ready to replace them with an electric version when that stressful moment arrives. For example, you don't want to run out and buy a new natural gas stove that will last another 15 years because you aren't prepared to handle a new electric induction stove.

"WATT DIET" FOR ELECTRIFYING WITHIN 100A

If you do have 100A available — especially if you have central air conditioning — then upgrading your electrical service is not immediately necessary, and the money can be better spent on other electrification projects. Devices called "Smart Circuit Splitters" allow two higher-powered devices, such as an Electric Vehicle charger and an electric dryer, to share a single 240V circuit. This keeps the total load at a given time below the 100A limit. An example is the NeoCharge Smart Splitter,[26] which costs around $500 and can avoid a panel upgrade.

For more advice about electrifying everything using a 100A panel limit, see Redwood Energy's Watt Diet in their "Pocket Guide to All-Electric Retrofits of Single-Family Homes," and the Watt Diet spreadsheet (scroll down on their research page) — **redwoodenergy.net/research**.

CONSIDER AN ENERGY MANAGEMENT SYSTEM

If you are planning to install rooftop solar PV panels and a home battery, consider buying an "Energy Management System," which is like a computer-controlled, app-connected electrical panel. It is more expensive, but it can be rolled into the cost of the solar/batteries, and might be eligible for tax credits and financing.

One example is the SPAN Smart Electrical Panel.[27] It costs $3,500 (plus installation), and the cost is coming down. One reviewer. calls it "almost essential if you have a backup battery."[28] Other brands include Eaton and Koben.

INSTALL EXTRA WIRING IN ADVANCE

If you're upgrading your panel, or have an electrician come out for any other project, consider having them install dedicated circuits and outlets for other appliances you might want to electrify. Then it won't be an obstacle if you

have to replace a broken machine in an emergency, and you can save money by not needing the electrician to come multiple times.

Below are the circuits and outlets that are worth pre-wiring, though you can check to see if you already have some of them (e.g. clothes dryer outlet). If you have space on your electrical panel, you can oversize the circuits (e.g. 50A instead of 40A). These outlets should cost between $250-$750 and take 2-3 hours to install, depending on where the electrical panel and appliances are located.[29] Other machines not in this list (e.g. heat pump, rooftop PV panels) will be wired during their installation.

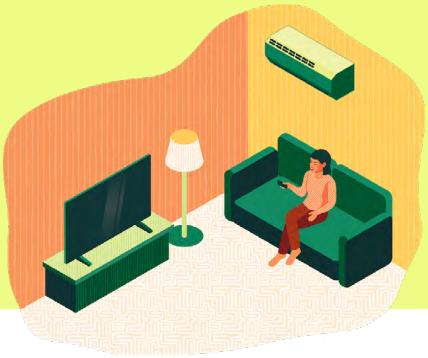
- → Heat pump water heater: 240V / 15A-30A circuit (or avoid by planning to get a 120V retrofit-ready version)
- → Combo induction stove and electric oven: 240V / 40A-50A circuit and outlet
- → Heat pump dryer or condensing dryer: 240V / 20A-30A circuit and outlet (or avoid by planning to get a 120V combo washer/condensing dryer)
- → EV Level 2 Charger: 240V / 20A-40A (or avoid by planning to use standard 120V Level 1 charging)

ADDITIONAL RESOURCES

- → This Old House videos demonstrating what's involved in upgrading a panel to 200A — **thisoldhouse.com/electrical/21015640/how-to-upgrade-an-electric-meter-and-panel-to-200-amp-service**
- → How to Determine the Size of Your Main Electrical Service — **thespruce.com/electrical-service-size-of-my-home-1152752**
- → Nate Adams, "What Size Electric Panel?" (part of his free Electrify Everything course) — **youtube.com/watch?v=47dl0FGKJWE**
- → "Does Your Electrification Project Require a Service Upgrade?" — **greenbuildingadvisor.com/article/does-your-electrification-project-require-a-service-upgrade**

3

Heat Pump Space Heating & Cooling



DIFFICULTY:	HARDER
UPFRONT COST:	$1,000 (DIY) to $20,000
IMPACT:	High
CONTRACTORS:	HVAC Contractor
DO NOW:	Get a "home energy audit" or "home energy assessment" (including a blower door test), and/or schedule at least one heat pump contractor to come to your home and give you an initial quote/proposal.
RENTER:	Get a window unit or portable heat pump.

RECOMMENDATIONS

ALL CLIMATES: Inverter-driven, HSPF of 10.5 and SEER 20 or higher (COP of 3 or better). The higher your electric rate is, the better your savings from higher efficiency.

COLD CLIMATE: Get a cold climate heat pump that works well down to -5°F or lower. The technology has improved dramatically for cold climates.

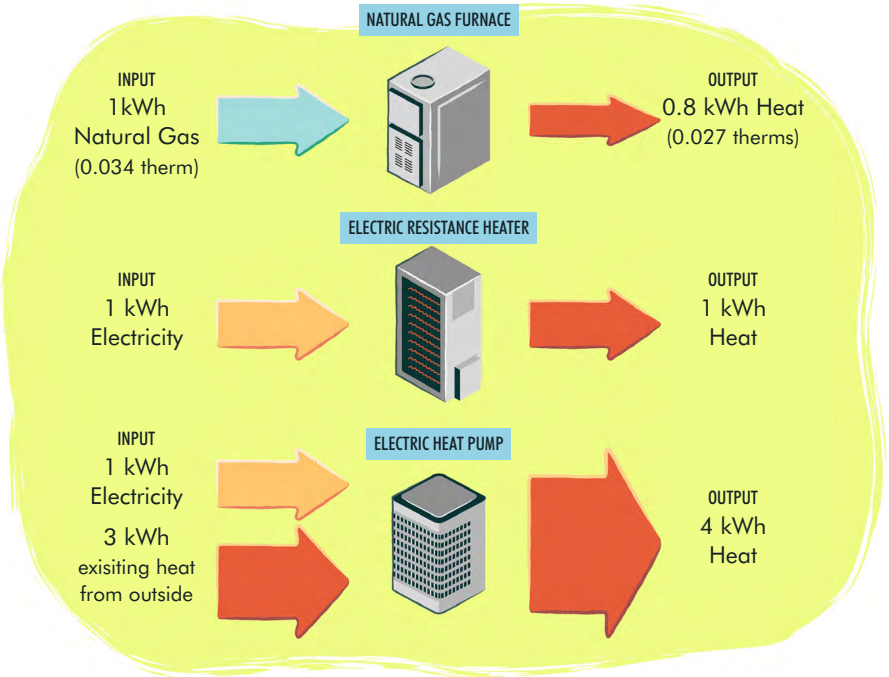
WARM CLIMATE & DRY CLIMATE (WESTERN U.S.): Avoid or downsize backup resistance strip heaters if possible.

DISTRIBUTION: Choosing ductless can help you abandon ducts you no longer want. Ducts in an attic lose more energy than ducts in a basement or crawlspace.

AVOID: Don't buy a stand-alone Air Conditioner. Most major AC brands make a Heat Pump version that both heats and cool. Demand this of your contractor, spend an extra $100-$400, and you can stop using your inefficient gas furnace. And don't buy a new natural gas furnace!

If you've never heard of a heat pump before, it might be because they go by many names, such as "refrigerator" and "air conditioner." If you feel the back of your refrigerator, it's warm because heat is being pumped out of the fridge, leaving it colder inside. An air conditioner is very similar, pumping heat out of your home. A heat pump is like a reversed air conditioner, where heat is pumped from outside air *into* your home (and leaving it slightly colder outside).

The amazing thing about this is that even freezing cold air contains heat that can be pumped inside, and it's much more efficient to move heat than to create it. So while a natural gas furnace might deliver 80% of the heat produced from burning the gas, and an electric resistance heater can use 100% of the electrical energy to produce heat, a heat pump can pump 300-450% worth of heat into your home for the same electrical energy input! The height of each arrow in the image[30] below visually represents the amount of energy input and output for these devices. The colors are: blue for natural gas, yellow for electricity, red for heat. The heat pump takes existing heat from outside as an input, which is why it's such a huge improvement over a natural gas furnace or an electric resistance heater.



DO NOW: START PREPARING FOR YOUR HEAT PUMP

Upgrading to a heat pump is more complex than the rest of the things in this guide, in large part because it's not just swapping out an appliance like your gas stove for an electric, but instead designing the heat pump to work well with your existing home. For that, you're going to need an HVAC (Heating, Ventilation, Air Conditioning) contractor. Three things you can do now to start planning for a heat pump are:

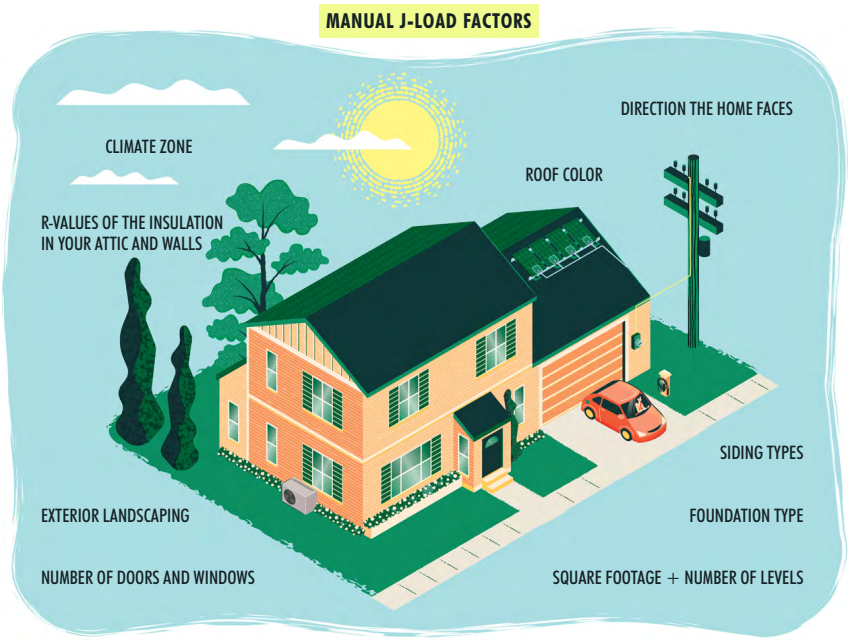
1. **Get a home energy assessment (aka home energy audit):** This can be very helpful if you live in a cold climate, but it's also useful in a warm climate. It involves someone coming to your home to perform some tests to see how well your home is insulated and sealed against air leaks and drafts. The Department of Energy has a video on what to expect from an audit — **energy.gov/energysaver/weatherize/home-energy-audits**. It can cost between $100-$300, but check with your local utility to see if there are programs to make it cheaper, or free. You should also check with your utility, or your state or local energy/weatherization office, for a list of certified energy auditors in your area. Make sure your audit will include a blower door test, where a fan blows air through your front door to measure your home for air leaks.

2. **Pre-contractor prep:** Before you start finding contractors for quotes, make a list of any places in your home that are uncomfortable because they're too hot or cold. Based on your home energy audit results, consider if you want to seal leaks or better insulate your home (see "Weatherizing your home" section below). And be sure to read through the "Understanding Your Heat Pump Options" section below to get a sense of what you're looking for, so you can request quotes on similar units from multiple contractors.

3. **Get quotes for inverter-driven heat pumps:** This might be done by your home energy auditor if they're also an HVAC contractor, or by a separate contractor. By getting initial quotes, you'll get suggestions for what options can work in your home. Check with your state or utility to see if there is a list of contractors who regularly install heat pumps.[31] Working with a state-certified contractor might also help unlock additional state and local rebates. And make sure you ask for quotes on "inverter-driven" heat pumps (see "Variable capacity" section below).

Your contractor has to know how to properly size your heat pump, which requires knowing how much energy your home gains and loses over the course of a day — known as the "load calculation." This calculation has been standardized as "Manual J," and the graphic below shows the standard inputs

such as your climate and home position, the quality of the insulation, and the size and number of openings.[32] You might ask any potential contractor what software program they use for their Manual J calculation, since it will give you an idea of how seriously they take this step.[33] See "Finding and working with a contractor" section below.



"WEATHERIZING" YOUR HOME

The blower door test from your energy assessment will give you a sense of how much air your home leaks. Ideally, your blower door number will be either similar to or less than the square footage of your home.[34] If it's higher than that, you should consider sealing your home, which is an affordable step you could even do yourself — see the Department of Energy's "A Do-it-yourself Guide to Sealing and Insulating with Energy Star" — **energystar.gov/ia/partners/publications/pubdocs/DIY_Guide_May_2008.pdf**.

Beyond sealing leaks, you can also add insulation to your home, but it might not be necessary. Talk to your HVAC contractor about where to focus — your walls, attic, floors, or windows.

If you are interested in continuing to use your existing ducting, it may only perform well with a smaller unit (maximum size around 3 tons, or 36 kBtu/h). Air sealing and insulation will allow you to install a smaller unit.

FINDING AND WORKING WITH A CONTRACTOR

To help you engage a contractor, below is a collection of recommendations from several different sources:[35]

To find a contractor:

- → Ask for suggestions and referrals from your friends, neighbors, co-workers, and local trade organizations. Aim to get proposals from at least three contractors.
- → For central heat pumps, consider reaching out to a local HVAC distributor for major brands (such as Carrier, Bryant, Mitsubishi, Fujitsu, Trane, and American Standard) and asking which contractors buy a lot of "inverter-driven heat pumps."
- → Before calling for quotes, know the model of your current system and maintenance history, and note any uncomfortable rooms.

QUESTIONS TO ASK A CONTRACTOR WHEN ENGAGING:

- ☐ Make sure they're licensed in your state, and that you verify it with the state license board. Also make sure they have insurance — both general liability and worker's comp. This might be a requirement for a state license.
- ☐ Do you install inverter-driven air source heat pumps? What percentage of your business are they?
- ☐ Do you use a computer program to do load calculations? Which one? (Good contractors will use WrightSoft, EDS, or CoolCalc.)
- ☐ Will you do a home evaluation with a blower door?
- ☐ Have you participated in manufacturer training for the systems you would install?
- ☐ Do you know about available incentives or rebates, and will you provide assistance in applying for them?
- ☐ Where will you mount the outdoor unit(s), and how? (Brackets bolted to an exterior wall may create unwanted noise in a sensitive area like a bedroom; ground-mounted units should always be on a stand to keep them above the normal snow line. Units should

also be shielded from rain and snowmelt dripping off the roof.)

- ☐ If exterior "line sets" (piping) will be visible, where will they be placed?
- ☐ What type of indoor units are you recommending, where will they be located, and why?
- ☐ Do you recommend a wall-mounted thermostat or control? (This is needed for ducted systems. For ductless units serving larger spaces, it can enhance comfort by sensing the temperature in a central location.)
- ☐ Do you always perform a triple evacuation before charging the refrigerant lines?
- ☐ Will I need to hire my own electrician to provide the electrical work? Will I need any electrical service upgrade to accommodate the heat pumps? (This is not unusual in older homes.)
- ☐ Will you use any subcontractors in the process? If so, who are they and what jobs will they do?
- ☐ Will you provide training on how to properly operate and maintain the system?
- ☐ Do you provide a warranty for the systems you install, and how long is it?
- ☐ Can you provide references from previous customers with similar systems?
- ☐ If in a cold climate, do you use the NEEP Sizing and Selecting Guide and Cold Climate Installation Guide[36] to inform your work? Will you choose equipment from the NEEP cold-climate air source heat pump list,[37] and use the information in the listing to help size the system properly?
- ☐ Do you recommend I add Heat Recovery Ventilation (HRV) or Energy Recovery Ventilation (ERV)?

GETTING PROPOSALS FROM A CONTRACTOR, AND SIGNING A CONTRACT:

- ☐ Call the contractor's references to ask about their installation and service performance, and whether the job was done on time and within budget.
- ☐ Get written, itemized estimates. Ask for options for two or three alternatives from each contractor, along with an explanation of the differences and benefits of each alternative.
- ☐ Proposals should include:
  - specific brands, manufacturer's model numbers and all relevant specs;
  - itemized lists of any other parts and accessories that you'll be charged for;
  - planned date of completion (including any subcontractors);

- a schedule of payments for the complete job — in dollars and cents and NOT percentages;
- a down payment (if any) doesn't exceed $1,000 or 10% of the contract, whichever is less.

☐ Sign a written proposal with a contractor before work gets started. It'll protect you by specifying project costs, model numbers, job schedule and warranty information.

WORKING WITH YOUR CONTRACTOR:

☐ Treat your contractors well.
- Have drinks and snacks handy, and tell them which bathroom they can use.
- If there is something you want to incentivize, tell them up front rather than as an end-of-job bonus.
- Only pay for work that's been performed — never in advance.

☐ Make sure all contract changes are in writing and signed by the contractor.

☐ Don't make final payments until you have seen receipts for bills paid by the contractor to any subcontractors and suppliers, or written waivers proving they've paid for materials and labor on the completed job.

☐ Make sure the system is set up well, you're trained in how to properly operate and maintain it, and clear on if and when they'll be back for inspection or service.

UNDERSTANDING YOUR HEAT PUMP OPTIONS

To retrofit an existing home, most people will get an air-source heat pump that extracts heat from the air. There are also ground-source heat pumps with pipes buried near the home to get heat from the ground, and water-source heat pumps if your home happens to be close to water, but these are less common.[38] And if you have radiant floor heating or another type of forced hot water heating, there are hydronic heat pumps that transfer heat from the air to water, which can also be used for heating swimming pools and hot tubs.

Check out Redwood Energy's "Pocket Guide to All-Electric Retrofits of Single-Family Homes" for many different heat pump product options — **redwoodenergy.net/research**.

AIR SOURCE HEAT PUMPS

There are a number of different configurations for air source heat pumps, and it can be a little confusing to understand the differences. New York State's "Heat Pump Planner" is a useful reference for understanding your options beyond what's below — **nyserda.ny.gov/All-Programs/Programs/Heat-Pump-Program/Heat-Pump-Planner**.

To start, let's look at how a refrigerator works as a kind of "air conditioner" for the inside of the fridge.

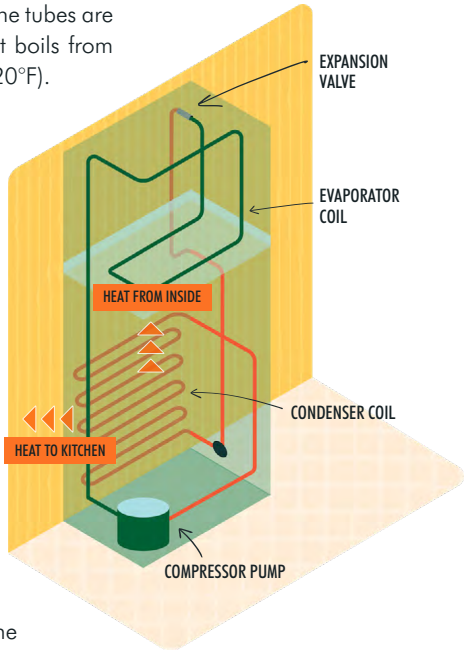
A refrigerator "pumps" heat out

Two coiled tubes are connected together, one running inside the fridge, one outside on the back. The tubes are filled with a fluid called a "refrigerant" that boils from liquid into gas at a low temperature (e.g. -20°F).

Inside the fridge, heat is absorbed by liquid refrigerant in the "Evaporator" coil, and the heat boils the liquid into gas. The refrigerant gas carries more heat than the liquid, the same way steam carries more heat than water.

The "hot" refrigerant gas is then squeezed by a compressor, which heats it even more. The gas then moves to the "Condenser" coil behind the fridge, where it dumps the heat to the kitchen. The refrigerant gas cools down enough to condense back into liquid.

Every refrigerator, air conditioner, and heat pump has these two parts — the Evaporator and Condenser. Where they're located is key to understanding the differences between heat pump configurations.



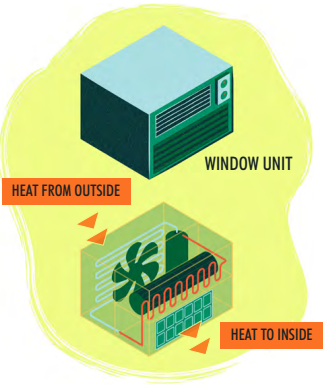
A. Packaged Heat Pumps—A packaged heat pump is an all-in-one unit, with the Evaporator and Condenser coils in the same "package."

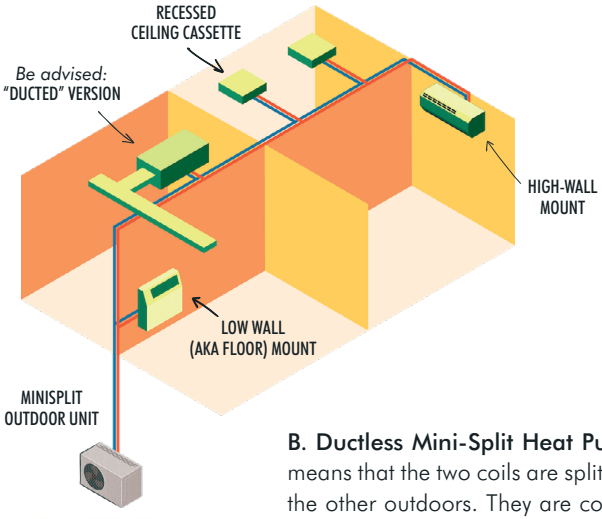
It can look like a window air conditioner. The main difference between an air conditioner and a heat pump is that the heat pump can reverse direction, and either

coil can act as the Evaporator or Condenser.

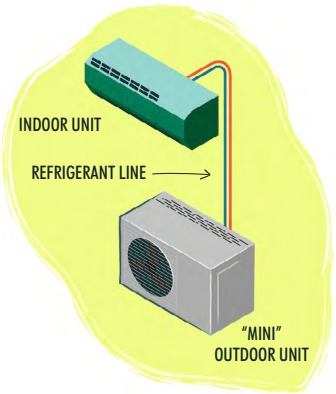
Besides window units, there are also portable stand-alone units (often with hoses that mount in your window), and through-wall mounted units. They cost between $500-$2,000, and can usually be self-installed.

Be advised: There are also larger "packaged" units that could replace your outdoor central air conditioning unit, and even run multi-family homes. This can be confusing, since it's not a window unit. See below on ducted split heat pumps.





MINI-SPLIT HEAT PUMP

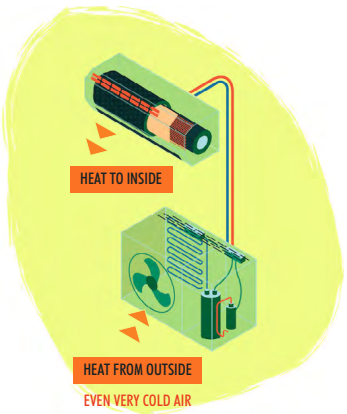


B. Ductless Mini-Split Heat Pump—The term "split" means that the two coils are split, with one indoors and the other outdoors. They are connected together by a refrigerant line that passes through the wall. The term "mini" refers to the outdoor unit, which is the size of a suitcase.

They are called "ductless" because they don't use air ducts to move heated and cooled air around the home.

Consider a mini-split if your home uses:

- baseboard heaters,
- wall or floor heater,
- portable heater,
- window air-conditioner,
- wood stove,
- nothing in a cold space (garage, attic).[39]



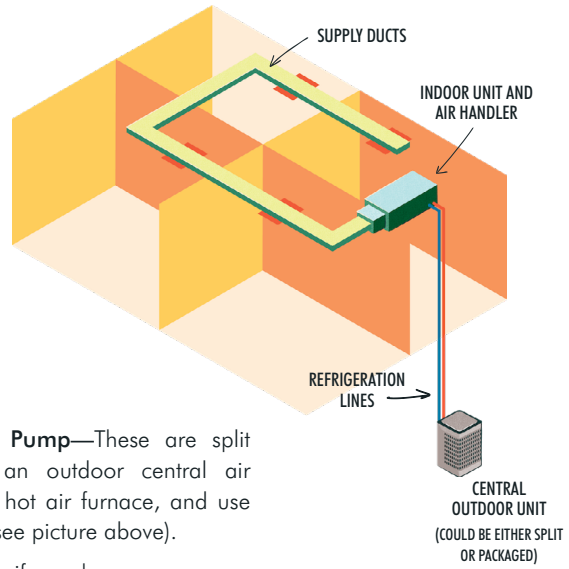
Each room or heating zone needs its own indoor unit, and multi-zone indoor units can share one outdoor unit.

Different brands might have multiple options for indoor units, including high wall mount, low-wall (aka floor) mount, and recessed ceiling cassette (see picture on previous page). Be sure to ask your contractor about which options best fit your situation. You might be able to mix and match.

Be advised: You can also have a "ducted" mini-split that uses air ducts to share a single indoor unit among a few rooms (also in picture on previous page).

Do-It-Yourself (DIY): If you're handy, you might consider installing a "retrofit-ready" mini-split yourself from brands like Pioneer, Gree, and MRCOOL. They work with 120V outlets and come with pre-charged refrigerant lines. Check the manual to see if you need an inspection to get the warranty.[40]

DUCTED CENTRAL HEAT PUMP



C. Ducted Central Heat Pump—These are split systems that can replace an outdoor central air conditioning unit, or central hot air furnace, and use existing ducts in your home (see picture above).

Consider a central heat pump if your home uses:

- Ducted furnace / air conditioner (forced air)
- Boiler / radiant heating (forced hot water).

It is important for your contractor to check your existing ducts to see if they'll work well with a heat pump. They

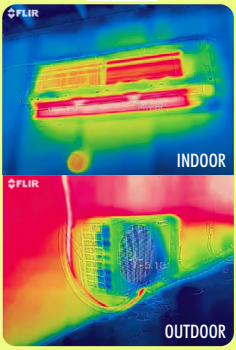
might be: poorly designed (lots of bends), undersized, oversized, dirty, leak air, run through cold spaces (like an attic), under-insulated, or some combo.

Central heat pumps also need an air handler, and those are typically 240V. Your current furnace has an air handler, and it's 120V. Request a model that has an electric line from the outdoor unit that powers the indoor unit, which also frees up your old furnace air handler circuit for other electrification projects.

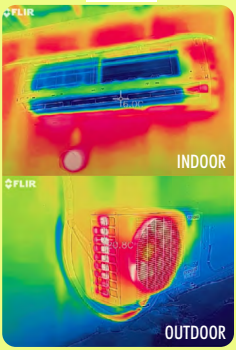
REVERSIBLE HEATING & COOLING

To make the reversible operation of a heat pump clearer, to the right are thermal camera images of the indoor and outdoor units of a mini-split system, taken from Technology Connection's fun video, "Heat Pumps: the Future of Home Heating" — **youtube.com/watch?v=7J52mDjZzto**. In the top pair of pictures, it's working as a heater — the indoor unit is warm (red) and the outdoor unit is cool (blue). In the bottom pair of pictures, it's working as an air conditioner, and now the indoor unit is cool (blue) while the heat is pumped outdoors (red).

HEATING



COOLING



COLD CLIMATES

There is an outdated misconception that air-source heat pumps only work well in warmer climates. That is no longer the case — recent advances have made them very suitable for cold climates too. NEEP has a list of cold-climate air source heat pumps — **ashp.neep.org**, and a buying guide — **neep.org/air-source-heat-pump-buying-guide**. One manufacturer has a video showing their heat pump working well in winter in the coldest continental U.S. town of Grand Forks, North Dakota — **youtube.com/watch?v=_v8vizQXwss**.

SIZING

The first recommendation your contractor might give is for the size of the unit you'll need, in units of "tons" or BTU/hour.[41] For a mild climate, here are unit size estimates based on floor area:[42]

- → 500 square feet: 1 ton (12,000 BTU/hour)
- → 1,000 square feet: 2 tons (24,000 BTU/hour)
- → 1,500 square feet: 3 tons (36,000 BTU/hour)

These sizes might be much lower than your current furnace, because the furnace has to turn on at 3,000°F and then turn off before it melts. This "cycle" happens three to eight times an hour, even when it's working well. Variable speed (inverter driven) heat pumps put out constant heat at about 120-130°F, so they can be right-sized to stay on and operate quietly. They adjust their fan speed and compressor speed to keep the home temperature stable, which is much more energy efficient, and also makes the space feel more comfortable than with a furnace that keeps turning on and off.

If you have central air conditioning, you can use its capacity as a guide to what you'll need in a heat pump (which is just a reversible air conditioner). So if you need 3 tons of cooling, you need 3 tons of heating too.

Note that the size of the furnace will depend on the Manual J calculations done by your contractor (see the "Do Now" section above). Your contractor should also consider using Manual S (for sizing) and Manual D (for ductwork) calculations when recommending a system.

VARIABLE CAPACITY

You have several options for the amount of control over the heat pump's output. More control can be more energy efficient and thus less expensive to run, but it might be more expensive up front. Here are the main variations:

- → **Single-stage:** This is the simplest and least expensive type of heat pump, and it's either turned on at 100% capacity, or turned off, making it the cheapest but least efficient.
- → **Two-stage:** This heat pump uses a compressor that can run at either 70% or 100% capacity, depending on what your home requires. Better than single-stage.
- → **RECOMMENDED — Inverter-driven (aka "Variable speed" or "Modulating"):** The best heat pumps use an electrical device called an "inverter" to enable variable speed of the compressor, which in turn varies (or "modulates") the capacity between 20% and 100%.[43] This is the most efficient option, and is worth requesting for its operating cost savings and comfort. Ask for quotes on "inverter-driven" heat pumps.

SURGE PROTECTOR FOR INVERTER-DRIVEN COMPRESSOR

Nate Adams notes that power fluctuations can kill an inverter compressor, and recommends using an ICM493 surge protector on outdoor units to protect your investment.[44] Ask your contractors about including one in their proposals.

"HYBRID" RESISTANCE BACKUP

Some heat pumps are called "hybrid" because they come with resistance heating elements that turn on when the temperature drops below a certain threshold. In general, the performance of heat pumps decreases with falling temperature, but some newer heat pumps rated for cold climates eliminate the need for this backup. Even though resistance heating uses a lot more energy than the heat pump itself in cold climates, it can make sense to get this as backup.

FURNACE BACKUP

Some heat pumps can also be installed so that they use an existing fossil-fuel furnace as backup. This might only make sense in severe cold climates with fluctuating electric rates, and the Massachusetts Clean Energy Center, for example, is no longer recommending fossil fueled backups after an extended study of whole home heat pumps.[45]

If you keep a fossil fueled furnace backup, your installer should help you set it up — with either a new thermostat, or a second thermostat — so that the furnace backup only comes on when the heat pump can no longer comfortably heat your home because it's too cold outside to provide enough heat. If the heat pump and furnace are controlled by separate thermostats, they should be set at least several degrees apart so that they don't overlap.

If you want to stick with a furnace backup in other climates, you can add a mini-split heat pump for much of the year, and use the furnace only on a few cold mornings. You can later add additional mini-splits or a central heat pump to replace the furnace entirely.

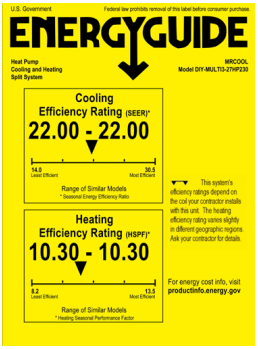
PERFORMANCE

Heat pump performance is measured with two numbers — SEER (Seasonal Energy Efficiency Rating) for cooling in summer, and HSPF (Heating Seasonal Performance Factor) for heating in winter. These are the measures that appear on each appliance's yellow Energy Guide label required by the U.S. Government.

In the label to the right, the SEER is 22.0 and the HSPF is 10.3, which is an average device, as indicated by the mid-range arrows on the scale below the big bold numbers.

When shopping for a high-performance heat pump:

- **GOOD** heat pumps have SEER above 20, and HSPF above 10.5.
- The current **BEST** heat pumps available in the U.S. are mini-split systems that have SEER of 30, and HSPF of 15.2.
- For reference, an electric resistance heater might have an HSPF of 3.4, which is **MUCH WORSE** than the heat pump.



REFRIGERANTS

It's worth knowing that refrigerants — the stuff moving between the Evaporator and Condenser to transport heat — can themselves be contributors to climate change. Make sure that you don't vent your refrigerants when it's time for maintenance.

LOOKING UP HEAT PUMP UNITS

CEE (Consortium for Energy Efficiency) maintains a Directory of Efficient Equipment — **ceedirectory.org/site/1/Home**. You can search for heat pump units by brand and model number, as well as a number of other criteria including SEER.

If you live in a cold climate, you should also check NEEP's (Northwest Energy Efficiency Partnerships) Cold Climate Air Source Heat Pump List — **ashp.neep.org**.

VENTILATION

Having a well-sealed home is great for keeping heat in (or out), but you still want to be able to let in fresh air, while also filtering out pollen, smoke, and germs. Ask your contractor about two specific types of ventilation — Heat Recovery Ventilation (HRV) and Energy Recovery Ventilation (ERV). The main difference is that an ERV will make your home less humid in summer and more humid in winter, compared with an HRV. See Redwood Energy's "Pocket Guide to All-Electric Retrofits of Single Family Homes" for more info — **redwoodenergy.net/research**.

COST FOR EQUIPMENT AND INSTALLATION

Most heat pumps are purchased through a contractor, who includes the equipment and installation costs together. The cost for an installed air-source 1-ton heat pump with a single zone is around $4,000, and a 2-ton is around $5,000. The cost can be lower for a multi-family home, and can be much higher for larger units, multiple zones, and high quality brands. Additional costs can include:[46]

- → Sealing your home for air leaks.
- → Duct installation or repair ($2,000 - $4,000).
- → A new hybrid furnace ($2,000 - $6,000).
- → A replacement air handler ($2,000 - $3,500).

Again, the best thing to do is to get quotes for recommended systems from a few different contractors, so you can further research and compare what your next steps should be.

INSTALLATION, SETTINGS, & MAINTENANCE

It should take an experienced contractor 2-4 hours to install a 1-ton ductless heat pump. It will take longer to install a central heat pump.

Before the contractor leaves, make sure they explain to you how it's set up, and how to operate and maintain it. You should read about the settings in your owner's manual. Here are some suggestions for getting the most out of your heat pump:[47]

1. Use your heat pump year-round — even on the coldest days if you have a cold-climate heat pump.

2. Set it and forget it — don't try to turn it up and down throughout the day and night (though you can make it cooler at night if that's more comfortable).

3. Minimize thermostat changes. Pick a comfortable temperature, even if it needs to be warmer than your old furnace setting.

4. Give your heat pump its own zone. Close non-heat pump dampers/radiators in spaces heated by the heat pump, and if you have a backup boiler/furnace, move the thermostat out of the heat pump zone.

5. Maximize the heating zone by opening doors between rooms the heat pump can reach (and closing off doors to rooms you don't need to heat).

6. Prioritize your heat pump over another heating system by setting your backup boiler/furnace thermostat at least several degrees below the heat pump's.

7. Avoid "auto" mode for heating and cooling — set it to "Heat" in winter and "Cool" in summer.

8. But do use "auto" mode for fan speed. If that doesn't spread the heated or cooled air far enough, set the speed to the lowest fixed speed that will meet your needs.

9. Optimize air flow direction by pointing the vents towards the open space that is the farthest away from the indoor unit, and away from any obstructions. Warm air should be directed down towards the floor, away from occupants, and cool air directed up, or at occupants.

10. Expect new sounds. Heat pumps are mostly silent, but sometimes make quiet gurgling and clicking noises as they cycle through their settings.

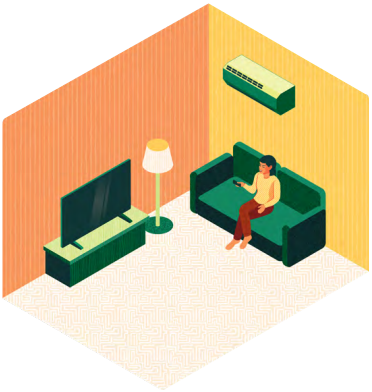
11. Watch for indicator lights, and check the user manual for their meanings.

12. Clean your dust filters by vacuuming or rinsing and drying them every few weeks to months, according to the user manual (and how dirty they get). Also pay attention to the allergen filter if your unit has one.

13. Check on your system once a season. Keep your outdoor unit clear of shrubs, leaves, ice, and snow drifts.

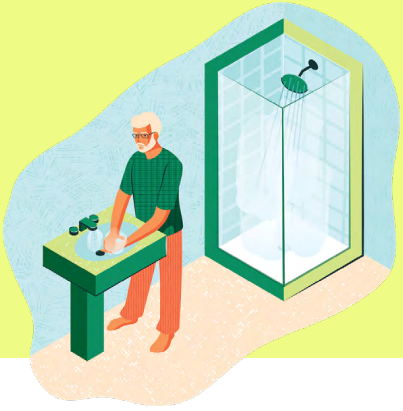
14. If you are in a coastal climate, rinse off your outdoor unit every few months to remove saltwater.

15. Have your heat pump serviced professionally every year or two. Follow the manufacturer's recommendations, and ask your contractor if they include service. Under normal use, modern heat pumps need very little service.



4

Heat Pump Water Heater



DIFFICULTY:	EASY
UPFRONT COST:	$1,500 (DIY) to $4,000 installed
IMPACT:	High
CONTRACTORS:	Plumber (might subcontract electrician if necessary)
DO NOW:	Find your current water heater and determine how old it is (see below for instructions). Plan to replace it if it's over 10 years old.
RENTER:	Show your landlord heat pump replacement options & EnergyGuide savings.

RECOMMENDATIONS:

COLD CLIMATE: 240V / 15A, with a larger tank and a mixing valve.

WARM CLIMATE: Forthcoming retrofit-ready 120V / 15A version, or 240V / 15A, with a larger tank and mixing valve.

ALL CLIMATES: Plan where the condensed water will go (it dehumidifies).

AVOID: 240V / 30A Heat Pump Water Heater — just get a larger tank.

AVOID: Tankless water heater, even if it's electric. A tank will also provide you with backup water in an emergency or natural disaster.

AVOID: Solar Thermal water heating — it's much more expensive, much more complicated, and performs worse than a Heat Pump Water Heater.

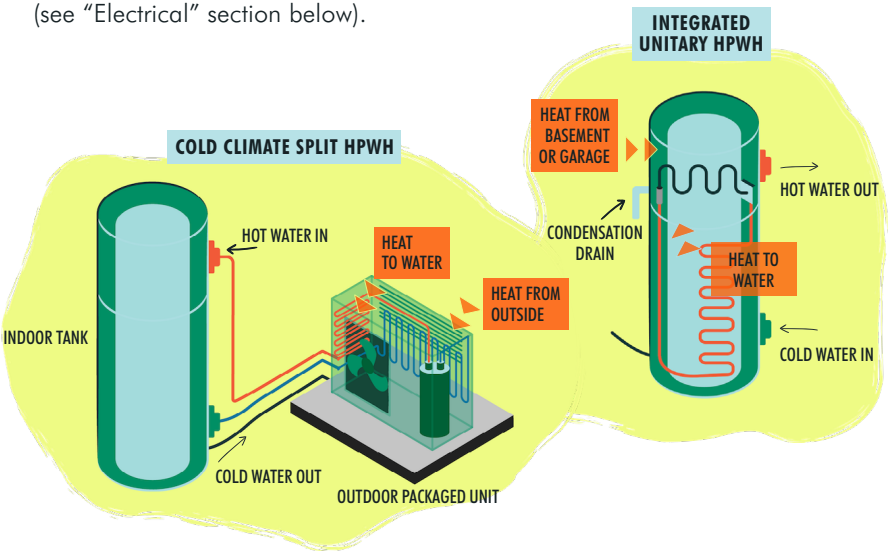
Compared to switching your home heating and cooling to a heat pump, getting a Heat Pump Water Heater (HPWH) is MUCH more straightforward. It's more like simply replacing your boiler with another one, with a few

additional considerations. And since your water heater is 10% of your home's emissions, it's a great one to target for electrification. Depending on your hot water use, a HPWH might save you hundreds of dollars a year on your utility bill, which would pay for itself in only a few years.

The HPWH works the same as an air source heat pump for space heating, except it doesn't reverse direction to also cool the water. The heat pump is either integrated with the tank, or it's split from the tank for colder climates.

Natural gas water heaters last between 8-12 years. You might be able to see how old your existing one is — and how close to replacement it is — by looking at its attached manufacturer label. If the label isn't there, you can try to decode the serial number using data from this site — **hotwatersolutionsnw.org/news/how-old-is-my-water-heater**.

Before your current water heater fails, you should pick a tank size, pick a location that has enough space heat available, and decide if you want a 240V HPWH, or a forthcoing 120V retrofit-ready version (see "Electrical" section below).



TANK SIZE

Think of HPWHs as water-based batteries that store energy as hot water instead of electricity. Larger tanks are more efficient, store more hot water, and can help reduce costs by avoiding higher time-of-use electricity rates. Therefore,

your tank size should be a similar size or larger than your existing tank — 80 gallons is a good target if you can fit it. If you currently have a tankless water heater, you'll need a place to put a tank, such as a basement or garage.

A note on Tankless (aka Demand) water heaters: Tankless water heaters have been billed as more efficient than Tank (aka Storage) natural gas water heaters, since there is no heat loss from hot water waiting in the tank to be used. But HPWHs are much more efficient than either Tank or Tankless water heaters. Since the heat comes from the surrounding air for the HPWH, any heat loss can just be pumped back into the water to maintain it at a given temperature. In fact, bigger tanks kept at higher temperatures are the MOST efficient.

Here's more info from the Department of Energy on sizing a water heater — **energy.gov/energysaver/sizing-new-water-heater**. If you work with a contractor, they should be able to recommend a unit, and you can double-check that it's a good fit.

GETTING MORE HOT WATER[48]

You can use any of these methods individually or combined to get more hot water from your HPWH:

1. Set the tank to a higher temperature like 140°F. Use a mixing valve to mix it with cold water down to 105°F to avoid scalding, and to make the hot water last longer. This is a best practice that your installer should do whether you need more hot water or not.

2. Select a larger volume tank, such as 80 gallons if you have space. Bigger is better — especially if you're considering a 120V "retrofit-ready" model (see "Electrical" section below).

3. Select a higher power HPWH that is 240V / 30A. This will use more power, and need more space on your electrical panel, but does give you more hot water. This is not recommended for most homes. Even in cold climates a 240V / 15A HPWH should be enough.

REDUCING YOUR HOT WATER NEEDS

It's worth pointing out that when upgrading to a HPWH, it also makes sense to reduce your need for hot water, which will allow you to buy a lower-power (240V / 15A, or 120V / 15A) unit. This includes fixing leaks, installing low-flow water faucets & aerators, low-flow shower heads, and getting energy

efficient dishwashers and clothes washers (and washing clothes using cold water instead of warm or hot).[49] Renters can do this too.

SPACE CONSIDERATIONS

Since the heat pump is removing heat from the air, the space your HPWH is in needs to be big enough to have enough air to supply the heat. Or if you put it in a smaller space, there needs to be some ventilation to a larger space. A room 10-foot x 9-foot x 8-foot or larger is recommended, ideally one that stays above 45°F all year. Your HPWH also needs enough clearance around it, perhaps 3-feet on the air-inlet side, 5-feet on the air-discharge side, and 6-inches from the back wall.[50] In a warmer climate, the garage can be a good location, and in a colder climate, the basement.

One major advantage of a HPWH vs. a gas boiler is that there is no exhaust from burning fossil fuel that needs to be vented outside. This lets you put the unit anywhere you'd like, and if you're installing a new outlet, you have a lot of flexibility in its placement.

Since the heat pump is acting like an air conditioner for the space it's in, it will also dehumidify the space, which can be another advantage for a damp space like a basement or garage. But you'll need to plan for how to handle drainage for the water that's removed from the air.

Avoid putting a HPWH next to a bedroom if possible, since the noise and vibration, while not too significant, might be disruptive to someone trying to sleep.

COST & REBATES

HPWHs cost between $1,500-$2,500, which is more than many natural gas water heaters, but can be much cheaper to operate than a gas water heater. In addition, rebates between $300-$1,500 — which can be the whole cost of the HPWH — are becoming available. Check with your utility and state for rebates, and ask your contractor for help identifying and getting the rebates.

It might cost $600-800 for a contractor to install the heat pump, and take 6 hours.

If you need to add a 240V outlet, an electrician might charge $200-$500 and take a couple hours.

ELECTRICAL

Many HPWHs require 240V single-phase electricity, and either a 30A or 15A circuit breaker. This requires them to either be installed near an existing 240V appliance-style outlet, or for a new 240V circuit to be installed. If you're having other electrical work done, consider having your electrician install a 240V circuit for a future HPWH at the same time (see *Chapter 2: Electrical Service* for info about other circuits you might want).

"Retrofit-ready" 120V / 15-20A models are becoming available in 2021 from companies like Rheem, GE, and A.O. Smith. The big advantage is that they will have a cord and plug into a regular 120V outlet that's either dedicated to the water heater or shared with other appliances. It will not require an electrician, which can be a big hurdle when your water heater breaks and it's an emergency situation. The tradeoff is that the 120V HPWH is slower to heat water, but a bigger tank will provide more hot water (see "Getting more hot water" section above).

When shopping for a HPWH, get either a 240V / 15A version, or a 120V / 15-20A version, and the biggest tank you can fit. They'll use less energy, and take up less space on your electrical panel.

PERFORMANCE

The "First Hour Rating" of the HPWH is the amount of water it can deliver in an hour of usage, and can be larger than the tank capacity since the tank can be heating the incoming cold water as hot water is used. On the EnergyGuide shown to the left, the tank size is 72 gallons, but the First Hour Rating is 87 gallons. Since most U.S. households use about 65 gallons a day, this should be plenty of hot water, especially if used with a mixing valve (see "Getting more hot water" section above).[51]

The Uniform Energy Factor (UEF) is a measure of the energy efficiency of the HPWH. Look for a UEF of at least 3.1. The EnergyGuide label to the left lists the UEF as 4.

HYBRID HPWH WITH RESISTANCE BACKUP

Many HPWHs are "hybrid," meaning that in addition to the heat pump there is also a resistance heater that will come on if the heat pump can't source enough heat from the room to maintain the setpoint temperature. The resistance heater can be configured to not turn on, and it will still produce plenty of hot water.

For reference, each resistance backup strip uses 15A. So the 240V / 30A hybrid HPWH has two strips, the 240V / 15A HPWH has one strip, and the 120V retrofit-ready HPWH has no resistance backup at all.

COLD CLIMATE HPWH

While most HPWHs integrate the heat pump and tank into a single unit, the SANCO2 is a split unit that uses CO2 as the refrigerant, and works well in very cold climates, down to -30°F.[52] Other cold-climate models are also becoming available.[53] These units are currently more expensive, and may not be necessary if you can locate a HPWH in your basement or garage that stays above 45°F. But it's worth considering if you live in a very cold location.

DIY INSTALLATION

If you have a 240V outlet available, or you go with a 120V version, you could potentially install a HPWH yourself. This "Installation Best Practices" guide might be helpful if you want to go that route, or if you just want to know what your contractor is (or should be) doing — **hotwatersolutionsnw.org/preview/resources/best-practices-installation-guide**.

CONTRACTORS AND INSTALLATION

Most people will have their HPWH installed by a licensed contractor or licensed handyperson. The HPWH needs to be connected to the electrical service panel, and the existing gas line to your gas water heater needs to be capped. It can take from one to several hours to install.

If you go with a contractor/handyperson, you should get recommendations from friends and family, and then interview them, check references, and request written quotes from at least three of them. You should also check their license status with your state license board, and check for complaints with the Better Business Bureau.[54]

Here are some questions to ask HPWH installers during the interview:[55]

- ☐ How many HPWHs have you installed?
- ☐ Which model and size do you recommend and why?
- ☐ Where do you recommend the unit be installed?
- ☐ Where will the condensate drain to?
- ☐ Will you be installing a mixing valve?
- ☐ Will any electrical upgrades be needed at the installation location or the electrical service panel? Will the cost of the electrical work be included in the estimate?
- ☐ Will you help me get all rebates available to me?
- ☐ How do you recommend I operate the HPWH for optimal performance and cost savings?

LIFETIME USE

Heat pump water heaters will last between 10-15 years. They often have a 10-year warranty, and should last longer than gas boilers.

You should clean the heat pump air filter regularly — check the manual for a schedule. You can also consider discharging water from the tank regularly, descaling the tank,[56] and having the unit inspected annually, or as recommended by the manufacturer.[57]

USEFUL RESOURCES

- → Carbonswitch Buyer's Guide — **carbonswitch.co/heat-pump-water-heater-buyers-guide**
- → Silicon Valley Clean Energy's HPWH Buyer's Guide — **svcleanenergy.org/wp-content/uploads/2020/02/Heat-Pump-Water-Heater-Buyers-Guide-Digital-Updated-2020.pdf**
- → To search for a unit, use CEE's (Consortium for Energy Efficiency) Directory of Efficient Equipment, and choose "Heat Pump with tank" for Energy Source — **ahridirectory.org/NewSearch?programId=24&searchTypeId=4**
- → NEEA's (Northwest Energy Efficiency Alliance) list of HPWHs that meet their "advanced" requirements — **neea.org/img/documents/HPWH-qualified-products-list.pdf**

5

Electric Cooking

DIFFICULTY:	EASY
UPFRONT COST:	$2,000-3,000
IMPACT:	Low on emissions, High on indoor air quality
CONTRACTORS:	Electrician
DO NOW:	Hold a magnet to your pans, and if the magnet sticks it will work with an induction cooktop. Buy a $50+ portable induction burner now, and plan to have a 240V / 40A outlet installed before you next replace your stove.
RENTER:	Buy a $50+ portable induction burner.

RECOMMENDATION:

A range (combined induction cooktop and oven) uses less space on your electrical panel than a separate cooktop and oven.

AVOID: Don't expose your family to gas cooking fumes, such as formaldehyde and NOx. Always use your exhaust fan when cooking. Get a $50+ portable induction burner to start using immediately.

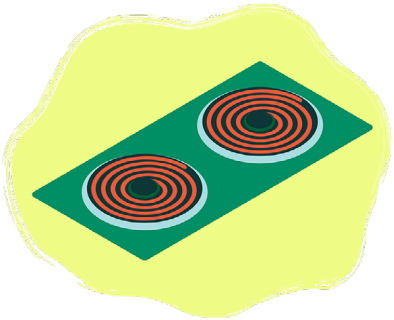
The phrase "cooking with gas" is a marketing slogan first used by the fossil fuel industry in the 1930s, and ever since it has helped people ignore the fact that they're burning toxic, explosive methane (aka natural gas) in their kitchen.[58] It's only recently that the negative health effects of this indoor air pollutant have been getting more attention.[59] But because residential gas customers are so important to the natural gas industry, they are trying to fight electrification.[60]

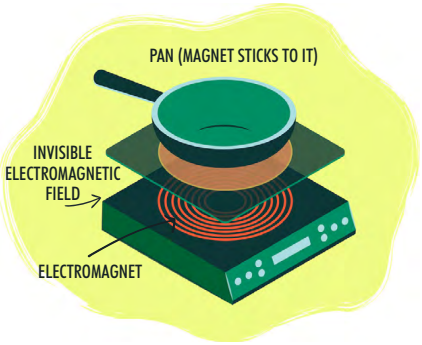
Let's clarify some lingo: kitchens usually have two main parts, a cooktop for heating pots and pans, and an oven. The cooktop and oven can be purchased and installed separately, for example as a cooktop in a kitchen counter, and a wall oven. If they're combined together in one unit we call it a "range" or "stove" (though a cooktop is sometimes called a "stovetop").

A combo range saves Amps on your electrical service, and leaves more room on your electrical panel for other electrification projects. If you're thinking of splitting up your range in a kitchen remodel, be aware that you might also require an electrical service upgrade (see *Chapter 2: Electrical Service* for more info).

INDUCTION COOKTOPS

Electric resistance burners (right) — often in the shape of a coil — have been sold for decades, and it's what you probably think of when you hear "electric stove." They're disliked because they take a long time to get hot, and they're difficult to control. They get hot as electricity passes through a resistance heater, which is how your toaster and hair dryer also get hot. They're not very energy efficient, but at least they're electric.





Modern "induction cooktops" (such as this portable version, left) are a totally different form of electric burner. Energy is transferred directly from electricity to the iron in a cooking pan through a magnetic field. The induction burner itself doesn't get hot, so there's less chance of getting burned. They heat super-fast and can be accurately controlled — think of it more like computerized cooking.[61]

CHECK YOUR PANS

Because induction heats pans using magnetism, your pans need to be attracted to magnets. You can check your existing pans using a simple magnet

— if the magnet sticks, the pan should work. Pure aluminum and copper aren't magnetic, but cast iron is, as are some types of stainless steel.

For any non-magnetic items you don't want to replace (e.g. aluminum stovetop coffee maker), you can buy an "induction converter" (aka "induction interface"). It's basically just an iron plate with a handle, where the plate gets hot and heats your item like an electric resistance stove. It's less energy efficient, but it should work just fine.

SETTING THE INDUCTION HEAT

Most induction stoves use a number that you can adjust (e.g. from 1 to 10 in half steps). It takes a little getting used to, but after that it allows for precise, repeatable heating. Here's an Induction Cooking Temperature Table that might be helpful — **cookeryspace.com/induction-cooking-temperature-guide**. Samsung brand induction cooktops have a "virtual flame" of LED lights as a visual indicator similar to the flame of a gas stove. This is a nice-to-have feature, but it's not necessary to cook well with induction.

BOTH RENTERS AND OWNERS CAN TRY A PORTABLE INDUCTION BURNER

For $50+, you can get a portable induction burner that plugs into a regular 120V outlet to start testing out, which will let you immediately start reducing your gas use. If you like it, consider using it with friends to spread the idea. Many professional chefs are switching to induction, and have no regrets.[62] You can watch some testimonials — **youtube.com/watch?v=7p6buePWKII**.

Cooking is a relatively small part of home energy use, but it is an emotional obstacle to going all electric that the gas industry is exploiting. A $50 portable induction burner can help break through this obstacle. Reducing your indoor air pollution is a pretty great bonus.

RADIANT COOKTOPS

Most radiant cooktops are similar to old-school coiled electric resistance burners, but covered with a flat surface that's sometimes called a ceramic glass top or smooth top. They are generally cheaper than induction stoves, but their performance is worse. If you already have a radiant stove, you can consider upgrading to an induction stove next time. For now, your cooktop is already electric.

ELECTRIC OVENS

Since the burning flame in a gas oven isn't visible like the flame in a gas cooktop, people have less emotional attachment to their gas oven. In fact, most wall ovens are electric since they don't need exhaust, and many people have experience with electric toaster ovens — electric ovens are basically just bigger versions.

Most electric ovens have a broil heating element at the top for directly cooking solid foods like meat, fish, and fruits and vegetables, like an upside-down barbeque.[63] They also have a baking heating element at the bottom for heating up the air in the oven to evenly surround cookies, cakes, and baked meals with little direct heat that would burn them.

A convection oven is an upgrade that has an extra heating element wrapped around a fan for moving hot air around the oven. This lets you preheat the oven faster, cook things without rotating them, and cook multiple dishes together.

ELECTRICAL

Portable induction burners run on a regular wall outlet with 120V / 15A. But induction cooktops and ovens need appliance outlets that are 240V and 40 to 50A. If you have an electrician come for another electrification job, consider having them run an outlet to your kitchen to make it easier to replace when you're ready to electrify. It should be under $500, and take several hours to install (see *Chapter 2: Electrical Service* for other circuits to consider installing).

POTENTIAL HEALTH CONCERNS

There are two health concerns you might encounter around induction cooktops — the first about pacemakers, the second about cancer. The concerns are because the cooktop uses EMF (Electromagnetic Field) to transfer energy to the pan.

Pacemakers: There is some evidence that EMF from induction cooktops can interfere with some types of pacemakers. If you have a pacemaker, the British Heart Association suggests staying two feet (60 cm) away from the induction cooktop.[64] Switzerland's Federal Office of Public Health recommends you talk to your doctor before using an induction cooktop, don't touch the pan for extended periods while it's on the cooktop, and don't use metal utensils with it.[65]

Cancer: There is no conclusive evidence that EMF has any long-term effect on health, whether the EMF is from your induction cooktop, your cell phone, or your microwave. This article from The Rational Kitchen addresses many questions about this — **https://therationalkitchen.com/induction-cooking-safe.**

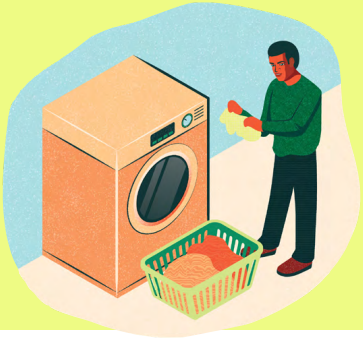
If you're concerned about getting an induction cooktop, you can avoid it completely and get an electric resistance or radiant cooktop instead.

If you do get induction, here are some additional precautionary tips:

- → Read and follow the operating and safety instructions in your cooktop's manual.
- → Use a pan that completely covers the cooking zone on the glass ceramic surface, and always place the pan in the middle of the cooking zone.
- → Don't use damaged pans with buckled or rounded bases, even if they can still be heated easily.
- → If you stand close to the cooktop or touch it with your body during cooking, use the rear burners, or the front burners at lower power.
- → Keep 2 to 4 inches (5-10 cm) of space between your body and the burner to greatly reduce your exposure to magnetic fields.
- → Check that your cookware is strongly magnetic to make sure the energy is transmitted efficiently to the pan. You can also get pans that are specially labeled by the manufacturer as induction compatible.

6

Electric Clothes Dryer



DIFFICULTY:	EASY
UPFRONT COST:	$1,000-$2,000
IMPACT:	Low
CONTRACTORS:	Electrician for 240V dryers
DO NOW:	Check if you have a gas dryer, or if you already have a 240V appliance outlet behind your dryer. Get a clothes drying rack or clothesline.
RENTER:	Get a clothes drying rack or clothesline, and consider a combo washer/condensing dryer that runs on 120V (if allowed)

RECOMMENDATIONS

Get a ventless heat pump dryer, condensing dryer, or combo washer/condensing dryer. You'll use less energy, and can seal up the vent hole in your wall.

Hang dry some or all of your clothes.

AVOID: Plan to replace your natural gas dryer, or your inefficient vented electric resistance dryer.

The most energy-efficient way to dry your clothes is to just hang them up, but a dryer is useful for making it go faster. Still, the dryer is one of the most power-hungry appliances in your home, since it takes a lot of energy to evaporate water out of clothes.

If you have a natural gas clothes dryer (which an estimated 12% of homes have), you should plan on electrifying it.

If you already have an electric dryer, it's probably an inefficient resistance heat dryer, and you can consider the options below for when you need to replace it. But if your electrification budget is limited, it's better to spend it on other appliances first.

If you want to free up more space on your electrical panel, look for a ventless dryer that runs on 120V.

Renters, consider getting a combo washer/condensing dryer that runs on 120V. Check your lease (or with your landlord) to make sure they're allowed.

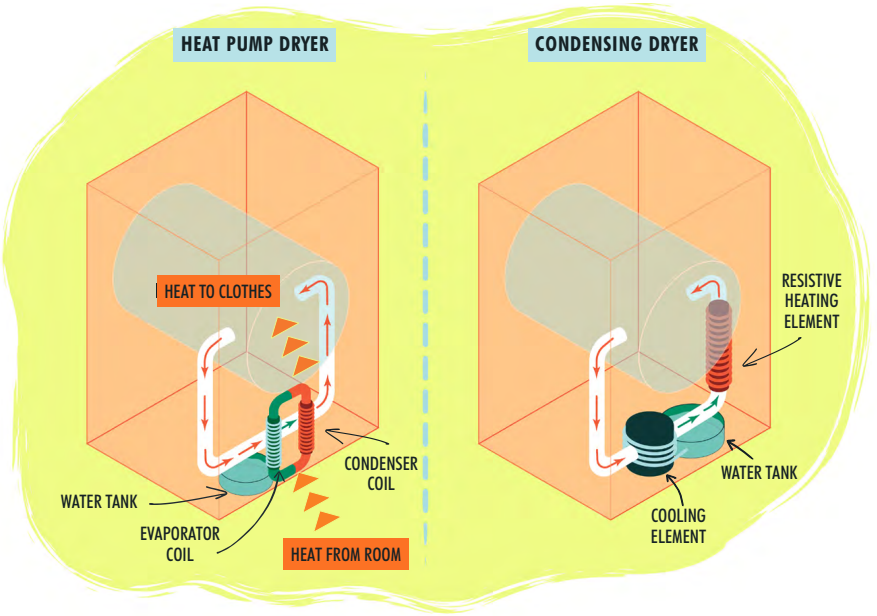
VENTED OR VENTLESS?

Most dryers in the U.S. are vented, meaning that they take air from the room, heat it up to remove moisture from the clothes, and then exhaust the damp, warm air outside your home using a duct through the wall or window. This is pretty inefficient — not only does it dump warm air, it's also removing climate-controlled air from the room, and leaves a hole in your wall for more air to escape through.

Most dryers in Europe are ventless, and have been for a long time. Ventless dryers take in a much smaller amount of room air, heat it up to remove moisture from the clothes, and then cool the air down to cause the moisture to condense back into liquid water, where it can be collected in a water tank or dumped down a drain. The air is then recirculated until the clothes are dry. No vent (or hole in the wall) is required, and the process is much more energy efficient than with a vented dryer.[66]

Two types of ventless

- → Condensing dryers use a resistive heating element to heat up the room air for moisture removal, and then the hot, damp air passes by cooler air taken from the room, or coils with cold water in them. As the hot air cools down, liquid water condenses out of the air and into either a water tank or down a drain.
- → Heat pump dryers use a heat pump to both heat up the room air on one side, and cool down the air on the other side. The idea is basically the same as a condenser dryer, but the heat pump is even more energy efficient. You can watch a video from This Old House about how they work — **thisoldhouse.com/21097178/exploring-a-heat-pump-clothes-dryer**.



Pros and cons of ventless

Besides the lower energy use of ventless dryers compared to vented, another big advantage is that they can be located just about anywhere, since they don't need to vent to the outside. They're also good for renters and condo owners who can't punch a hole in the wall.

Ventless dryers heat the air to lower temperatures, which means they take longer to dry your clothes — a 50 minute load in a vented dryer might take 90 minutes in a ventless one. But this lower temperature is better for your clothes, since most fabric damage happens during overdrying, and that doesn't happen with condenser and heat pump dryers.

Since ventless dryers don't exhaust outside, there can be a bit more humidity around the dryer. You'll want to make sure the dryer is not in an enclosed space, to avoid mold growth.[67]

Some heat pump dryers are "hybrid," with a resistance heat backup. They use more energy when using the resistance backup.

Electrical

There are both 120V and 240V ventless dryers available. If you already have a 240V electrical socket from a previous dryer, you might want to take a picture of it so you can get a matching plug (see *Chapter 8. EV Charger* for pictures of different 240V socket types).

SIZING

Since dryers need space inside for the warm air to circulate and the clothes to tumble freely, a common recommendation is to size your dryer with about twice the capacity of your washing machine. But if space is an issue, you can get a smaller capacity dryer, and just hang some clothes on a drying rack or clothesline (most clothes last longer if they're hang dried).

The two main dryer outside sizes are compact (around 24" wide) and full-size (around 27" wide). Most condenser dryers are compact, and have a 3.5 to 4 cubic foot drum. There are some full-size heat pump dryers with a 7.4 cubic foot drum that are comparable to regular vented dryers.

Check the height, width, and depth of the space you plan to put the dryer, along with any doorways, hallways, and stairs to get there. Also consider whether you'd want to stack a washer and dryer, or have them side-by-side.

INCENTIVES AND REBATES

Ventless dryers are more expensive, costing between $1,000-$2,000, while standard vented dryers are closer to $400-$700. But depending on how often you use your dryer, you can save up to $75 a year on your utility bill.

Some states and utilities offer rebates ranging from $50 to $300 for an ENERGY STAR or heat pump dryer. Search online, or ask your retailer if they know of other incentives.

USE AND MAINTENANCE

As with any dryer, you should clean the lint trap before every load. Ventless dryers might also have additional filters that need to be cleaned. And if you have a ventless dryer with no drainage, you'll also need to empty the water from the water tank so it doesn't fill up.

When using your dryer, you can save energy by using the sensor settings (e.g. dry, very dry) instead of the standard countdown timers. If your clothes are still dripping wet when you take them out of the washer, run them through an extra spin cycle before moving them to the dryer.[68]

ALL-IN-ONE WASHER AND DRYER

It's worth noting that there are also machines that combine a washing machine and condensing dryer into a single machine. These can be good for renters and space-limited homes, and can run on a single 120V outlet — about the same energy as a hair dryer. It can take 2 to 4 hours for a complete load to be washed and dried, but it's a simpler job than having to also move the clothes in the middle. Dirty clothes in, clean & dry clothes out.

A NEW WASHER TOO?

You might also consider buying a new washing machine with a high spin speed at the same time that you buy a new dryer. This will reduce both the time and energy needed for clothes drying.

7

Electric Vehicles

DIFFICULTY:	EASY
UPFRONT COST:	$10,000 (used) and up
IMPACT:	High
CONTRACTORS:	None if charging on 120V standard outlet
DO NOW:	Consider how far you drive in a day to start thinking about range, and look online for public charging stations nearby to start planning where else you can charge.
RENTER:	Same.

RECOMMENDATION

Try the included 120V / 15A Level 1 charger that comes with your EV. It charges around 4 to 5 miles of range for every hour it's charging, and it's fairly low power. If that's not enough, you can get a Level 2 charger (see *Chapter 8: EV Charger*).

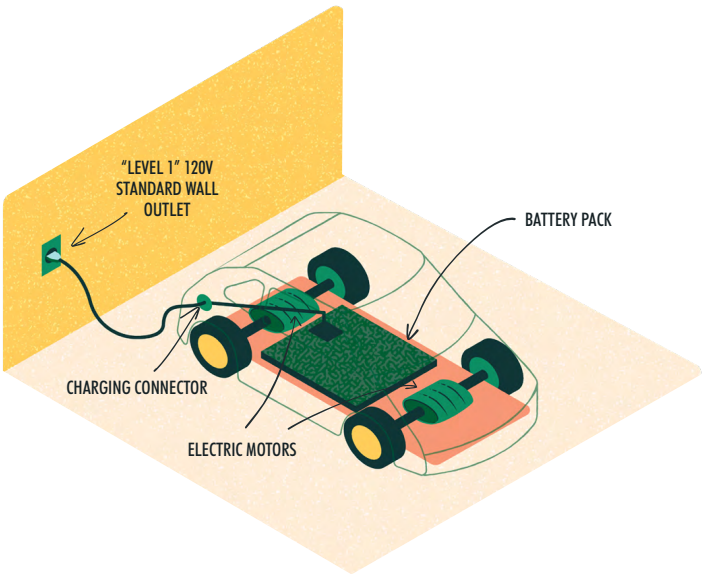
AVOID: If you can afford it, don't drive your gas car until it's breaking down. Getting an EV is one of the highest impact things you can do.

Electric Vehicles (EVs) might be the best-known electrification project from this whole guide. Getting an electric car is much more visible to your neighbors than getting a heat pump. And the change is pretty seamless once you sort out where, when, and for how long you can charge. Once you switch, EVs are better in almost every way than gas cars. Still, there are some things to consider before heading to the dealership for a test drive.

FEWER PARTS, BETTER PERFORMANCE

EVs use batteries and electric motors to move the car, versus the gasoline burning in the complex internal combustion engine of gasoline cars. EVs also don't need a radiator, exhaust system, or catalytic converter, so there are fewer things to break down, and thus maintenance costs are lower. Regenerative braking puts energy from stopping back into the battery, and also preserves the brakes.

Fewer parts also allows for more space in the vehicle. In most EVs, the space under the hood where the engine would be is now storage space (called a "frunk" for "front trunk"), and the interiors are roomier. Since the batteries are often below the floor, it can help improve vehicle handling, and make the vehicle less likely to flip. Electric motors can also deliver 100% of their power instantly, which lets them accelerate quicker than gas vehicles — these are no go-karts.



LESS POLLUTION & LOWER LIFETIME COST

EVs really are better for the environment. On average, EVs in the U.S. produce the carbon dioxide emissions equivalent of a car that drives 88 miles-per-gallon of gasoline. But that depends a lot on how the grid is powered. In places where the grid supplying the electricity is cleaner, EVs get well over 100 miles-

per-gallon-equivalent emissions, while dirtier power generation puts it closer to 39 miles-per-gallon-equivalent — still close to very efficient gasoline cars, and which will just keep getting better as the grid adds renewable energy.[69] Studies also show that in addition to much lower emissions due to EVs, they also have considerably lower lifetime costs when compared to gasoline cars.[70]

UNDERSTANDING YOUR EV OPTIONS

There are now a wide variety of EVs to choose from, with more options constantly coming to market. The two main types are:

- **Plug-in Hybrid Electric Vehicles (PHEV):** These have both gasoline engines and batteries and motors, working together in some combination to drive the car. As the name implies, they get plugged in to charge, but can also be filled at the gas station. Some versions have limited electric-only driving ranges, while others mostly run on electric and only use the engine to generate electricity and extend the range.
- **Electric Vehicles (EV):** These run fully on batteries turning electric motors. EVs have no engine, and need to be recharged either at home or at a recharging station.

Car finders

With so many choices, a number of sites have appeared where you can filter cars based on manufacturer, model, type of EV, range, and other criteria. Try searching here:

- PlugStar Shopping Assistant — **plugstar.com/guide**: Helps you drill down using several criteria, including where and how you plan to charge.
- PG&E's EV Savings Calculator — **ev.pge.com**: The page for each individual car gives the relative cost savings versus an equivalent gasoline car over ten years. Note that any incentive pricing listed is California-based.
- Department of Energy's Find and Compare Cars — **fueleconomy.gov/feg/findacar.shtml**: Shows the MPGe (miles-per-gallon equivalent) and total range for both current and older cars, which can be helpful for researching used cars. You can also compare cars side-by-side.
- EVLife — **evlife.co**: Has car pricing with incentives listed, and you can enter your zip code to look for other state and local incentives.
- MyEV — **myev.com/cars-for-sale**: Has used cars for sale, searchable by zip code (other used car sites can also be searched for EVs).

RANGE IS THE MAIN DIFFERENCE

There are now enough EVs on the market to let you choose based on the type of vehicle you need (e.g. sedan, SUV, truck), number of doors, interior space, and other common vehicle purchasing criteria. The main difference between EVs is the "range," which is how far it can drive before needing to be refueled.

Most new EVs have a range over 200 miles, which is comparable to a tank of gasoline. But you can also find EVs for around $10,000 with a range of 60 miles that might be good enough for commuting and getting around town. For now, EV prices are largely determined by the range, so figure out how much you need to drive, and see if your budget matches the car prices for that range.

BATTERY DEGRADATION AND WARRANTIES

Concerns about EV batteries wearing out and requiring expensive replacements have turned out to basically be a non-issue. Most batteries are lasting the life of the car.[71] One estimate is that on average, batteries lose about 2.3% of their capacity each year, which means a 150 mile range car might lose 17 miles over five years.[72] You can get a sense of the degradation for a car you're interested in — **geotab.com/fleet-management-solutions/ev-battery-degradation-tool**.

Federal regulations mandate EV battery warranty at eight years or 100,000 miles. Some manufacturers will replace the battery if it reaches a specified reduced capacity percentage — usually 60%-70% — while under warranty.[73] The warranty for the rest of the vehicle varies by manufacturer.

You should ask the dealer about the most up-to-date warranties for all aspects of the vehicle you're considering, including basic coverage, powertrain, corrosion, battery, and roadside assistance. MyEV has a chart comparing 2019 warranties for particular EVs — **myev.com/research/buyers-sellers-advice/evaluating-electric-vehicle-warranties**.

RANGE DROPS ON COLD AND HOT DAYS

Batteries work best in temperatures that are comfortable for people, around 70°F. At both lower and higher temperatures, the range decreases. You can use GeoTab's Temperature Tool for EV Range to check on how the cars you're considering perform as you slide the temperature up and down — **geotab.com/fleet-management-solutions/ev-temperature-tool**.

Most EVs include a thermal management system for the batteries to keep them around 70°F. Many EVs also use heat pumps to efficiently heat and cool the interior space — check whether the EVs you're interested in have a heat pump available as part of standard equipment, as part of a cold-weather upgrade, or as a feature.[74]

Since space heating is part of what uses a lot of battery power on hot and cold days, some tips for extending the range include:[75]

- → Use heated seats and steering wheel: If your car has them, this can save a lot of battery power instead of using the cabin space heating on a cold day.
- → Pre-condition your vehicle: Before unplugging to go out on a hot or cold day, get the cabin to a comfortable temperature to help preserve the battery while out.
- → Keep your vehicle plugged in on extreme cold or hot days, both at home and when parked. This lets your car's battery thermal management keep working without using the battery.

INCENTIVES & FINANCING

There is a Federal Tax Credit worth up to $7,500 available for people who purchase new EVs. That means that if you owe taxes over $7,500, this can reduce your bill when you file your taxes, but you don't get back extra money if you owe less tax. The amount varies depending on whether it's a full EV or a PHEV, and depending on how many cars the manufacturer has already sold, phasing out for more popular EVs. The Department of Energy maintains a list — **fueleconomy.gov/feg/taxevb.shtml**.

The Federal Tax Credit only goes to the registered owner of the vehicle, so if you lease, the manufacturer gets the credit. If you're leasing, look for a dealer that will roll the credit into a lower monthly payment.[76]

A number of states also offer rebates on EVs (California, New York, Oregon, Massachusetts, Oregon, and New Jersey).[77] The Department of Energy maintains a database that lets you search for such programs in your state — **afdc.energy.gov/laws/search**. Make sure to also check with your utility to see if there are additional incentives, and ask your dealer if they know of other programs like HOV or carpool lane access for EVs, and emissions testing exemptions.[78]

LEASE OR BUY?

A report from 2018 found that around 80% of EVs are leased, which is much higher than the 30% of all vehicles that are leased.[79]

One argument in favor of leasing an EV is that since the technology is changing so quickly, you can get the newest tech when your lease ends. Leasing also lets you get a new car, with a new battery after a few years (but note that battery wear is proving not to be a big deal in the real world — see "Battery degradation and warranties" section above). Another argument in favor of leasing is that it puts more EVs on the market, because when your lease expires, your car becomes a used EV for someone else.

One reason to buy instead of lease is that you'll be eligible for the federal tax credit and other rebates, which can greatly reduce the cost of the car (though some states give rebates for leased and used EVs).[80] Another benefit of buying over leasing is that you won't have a car payment after you pay off the car.

NEW OR USED?

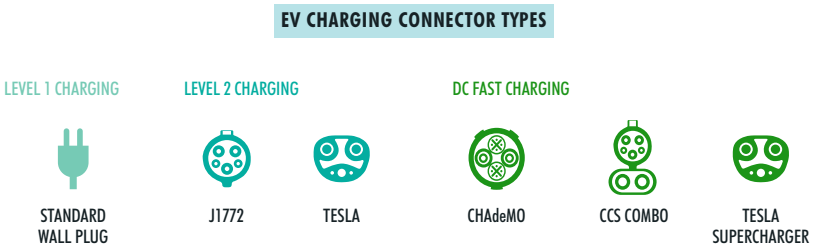
EVs break down slower than gasoline vehicles because they have so many fewer parts. They don't leak oil, their single-speed transmission doesn't fail, and they don't have issues passing inspection. And the price of a used EV might be lower than a comparable gasoline car, though that might be changing as people realize how durable used EVs are.

Used EVs are generally priced according to their range. Something to consider with both new and used EVs is that if over time your car's range decreases below what you need, you can sell it to someone else who is looking for that range — whether it's 60-mile, 100-mile, 150-mile, or 200+ mile.

If you're buying a used EV and you're concerned about the battery health, ask the owner or dealer for a copy of a recent scan of the battery. You could also try a service like Recurrent, which can help you understand battery degradation for a specific car you're looking at — **recurrentauto.com/for-shoppers**.

TYPES OF CHARGING

To charge an EV, you have to plug it in. Since the actual battery charging electronics are built into the EV, the different plugs are basically just extension cables for connecting to an outlet. That said, the type of outlet varies by how quickly they can charge. Below are images of the charging connector types found in the U.S., followed by descriptions of the charging levels.[81]



Home charging

- → **Level 1:** Your car will come with a cable that plugs your car into a regular 120V AC standard wall outlet. This is called a "Level 1" charger, and will charge your car 4 to 5 miles every hour. If you're driving 40-ish miles a day (e.g. 15,000 miles per year), you should be fine with Level 1 charging overnight. You can try using this initially to see if it will work for you. Note that the outlet you use should be on a dedicated circuit from your electrical panel, with no other appliances on it. You might also want a hook or shelf for the cord so it doesn't pull on the outlet.[82]
- → **Level 2, home:** If you need faster charging or more range, consider installing a faster "Level 2" charger. It uses a 240V AC outlet and can charge 15 to 25 miles every hour — useful if you drive 200-ish miles a day (e.g. 70,000 miles per year). The standard connector is the J1772, and Tesla's proprietary connector has an adapter for this. See *Chapter 8: EV Charger* for more details.

Public charging stations

- → **Level 2, public:** Many parking lots outside shopping centers and office buildings now have public Level 2 chargers. The cost for using them ranges from free for some chargers, to about twice the cost of charging at home. See "Finding public charging stations" section below.
- → **Level 3, aka "DC Fast Charging":** As the name implies, this is the fastest available charging method. It uses up to 800V DC, and can add 50 to 90 miles in 30 minutes. Tesla's Supercharger stations can charge even faster, up to 170 miles in 30 minutes. Non-Teslas can't yet use Supercharger stations, but Tesla is working on changing that.[83] Most U.S. EVs use the CCS ("Combined Charging System") Combo connector for DC fast charging. The Nissan Leaf and Mitsubishi Outlander use a Japanese standard called CHAdeMO, but that connector is being phased out in the U.S.[84]

Finding public charging stations

Here are some places to search for public charging stations, both to plan your local day-to-day charging, and to plan road trips:

- PlugShare — **plugshare.com**: Has a map of public charging stations, and includes a trip planner if you register. It maps out the thousands of stations from companies like Electrify America, EVGo, and ChargePoint, which let you charge your car using an app or card.[85]
- Open Charge Map — **openchargemap.io**: A free & open option for locating chargers.
- EVmatch — **evmatch.com**: It's like Airbnb for EV chargers, where you join to either rent time on someone else's charger, or rent out your own home or business charger.

CHARGING COSTS

The cost to "fill up" an EV using electricity is a lot cheaper than gasoline.[86] The average person in the U.S. drives around 1,000 miles every month,[87] and the average U.S. car gets 24 miles per gallon,[88] which means each driver burns almost 42 gallons of gasoline every month. If gas is $3.00 per gallon, that's $125 a a month (and even more at $4 or $5 per gallon).

For home charging, the average U.S. cost for a "kWh" (kilowatt-hour) of electric energy is around $0.12 cents (though it varies widely by location — check your utility bill). If a rule of thumb is that electric cars get 3 miles of range for every kWh, it takes around 333 kWh to be able to drive 1,000 miles, which is $40 a month. In this example, that's a savings of around $85 a month, or $1,000 a year by using electricity instead of gasoline.

For public charging, in California it's around $0.30 cents per kWh to charge on Level 2 (~$100 a month for 1,000 miles), and $0.40 cents per kWh for DC fast charging ($133 a month for 1,000 miles).[89] So even if you only used DC fast charging, it would still be about the same cost as driving on $3.00 gasoline.

FUEL USE COMPARISONS

The fuel efficiency of gas vehicles is given in MPG ("miles-per-gallon"), while EVs are rated in MPGe ("miles-per-gallon-equivalent"). An efficient gas car might get 40 MPG, while a Tesla Model 3 can get more like 121 MPGe — a significant improvement![90]

EVs are also rated in "kWh/100 mi" (kilowatt-hours per hundred miles), which is more useful for getting a sense of how much it will cost to charge the car. For example, 121 MPGe is equivalent to 28 kWh/100 mi. If your home electricity costs $0.12 cents for each kWh, then it will cost $3.36 to charge up for driving 100 miles.

GAS-POWERED BACKUP CAR

When getting an EV, you can potentially keep a gasoline car around as a backup. Or get rid of the gasoline car and consider using a bicycle, public transit, ride-share, taxi, or car rental as needed.

HOME POWER BACKUP USING YOUR CAR

Currently, the Nissan Leaf and Mitsubishi Outlander allow you to plug your car into your home to use it like a backup battery. More cars are coming that allow such "bi-directional charging," also known as Vehicle-to-Home (V2H). Audi is working on a system for its e-tron line,[91] Volkswagon is planning to make all of its EVs bi-directional in 2022,[92] and Ford's new electric F-150 Lightning is planned to be bi-directional.[93]

Taking advantage of bi-directional charging requires a Level 2 charger, so see *Chapter 8: EV Charger* for more info. You can also see *Chapter 10: Home Battery Storage* to get an idea of how a backup battery works.

USING THE EV AND PRESERVING THE BATTERY

Note that battery degradation is turning out to not be a big problem, with EVs from 2011-2013 still having 80% capacity, and newer cars demonstrating even slower degradation. But here are some suggestions for how operate your battery extra cautiously:

→ Don't fully charge or fully discharge your battery. Aim to charge to 80% and discharge to 30%, which is better for the battery. You can charge to full capacity when you need to drive farther.

- → Try not to quick-charge too often. Since your battery gets hot during quick charging, and hot batteries degrade faster, it's better to quick charge only when necessary. But don't go crazy worrying about it — regular use might cost 1% of capacity per year.[94]
- → If leaving your EV for a while (e.g. vacation), keep it plugged in and charging to around 50% if possible.[95]
- → Try not to expose your car to extreme temperatures — park in the shade or a garage when possible to keep the battery closer to 70°F.
- → Before taking a road trip, practice charging a few times locally first.
- → Driving slower will let your battery last longer.
- → If you run completely out of power, try shutting the car down and leave it for a short while, maybe half an hour to an hour, and you might have enough power to drive a couple more miles.[96]

ELECTRIC BICYCLES, SCOOTERS, & SKATEBOARDS

Instead of (or in addition to) an EV car or truck, you might also consider getting an electric bicycle. They range from a few hundred to a few thousand dollars, they've gotten much better in recent years, and they might eliminate many of your car trips — including your commute. Start learning more — **rei.com/learn/expert-advice/how-to-choose-an-ebike.html**. You can also consider electric scooters and electric skateboards, which are now pretty advanced.

8

EV Charger (240V EVSE)

DIFFICULTY:	EASY
UPFRONT COST:	$500-$2,500
IMPACT:	Low
CONTRACTORS:	Electrician
DO NOW:	If you have a garage, check if you already have a 240V appliance outlet for a faster "Level 2" charger.
RENTER:	Ask your landlord and employer about installing a Level 2 charger.

RECOMMENDATION

Buy a Level 2 charger with an adjustable current setting between 20A to 40A, and start with it set to 20A.

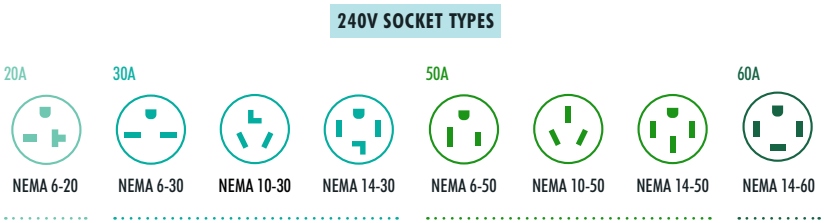
The Level 1 charger that comes with your EV plugs into a regular 120V outlet and adds around 4 to 5 miles of range every hour, good for 40-ish miles per day (or 15,000 miles per year). If that's not fast enough for your needs, you can install a Level 2 Charger (15-30 miles every hour), also known as an EVSE ("Electric Vehicle Supply Equipment").

Technically an EVSE is not the "charger" that converts AC to DC electricity — the "charger" is built into the car itself. An EVSE is a way to connect your EV to a 240V outlet. One site says "you should not overthink the selection and installation of an EVSE."[97] That said, there are some things worth considering. Here's a checklist from PG&E that might be helpful — **pge.com/pge_global/common/pdfs/solar-and-vehicles/options/clean-vehicles/electric/EV-Charger-Install.pdf**.

FINDING AN ELECTRICIAN

An EVSE by itself can cost between $200 to $1,000, and installation can range from around $800 to $1,300. An electrician will do the installation, so get quotes from multiple electricians, and try to get one who installs lots of EVSEs. Permits might be required to install an EVSE, so check with your electrician or local government.

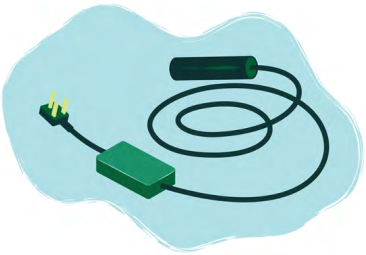
If you're having an electrician come to your home, consider adding outlets for other electrification projects at the same time (see *Chapter 2: Electrical Service*).



ELECTRICAL REQUIREMENTS

A rule of thumb is that an EVSE that can supply a current of 30A will give about 30 miles of range in an hour of charging, and that 30A charger will require a 40A circuit and two spaces on your electrical panel.[98]

You might already have a 240V appliance outlet in your garage, like the kind that clothes dryers plug into. If that's the case, you can get a portable EVSE that plugs into it (see image right). Just make sure the plug on your charger matches the socket you're planning to use, since there are multiple types of three- and four-prong socket configurations (see image above).[99]



You can also hardwire your EVSE. In that case, it should be around four feet off the ground. Consider how you want it mounted — whether attached to the building (see picture on previous page), or on a stand-alone post (left).[100] If you're installing it on a post and the wiring will run underground, check with DigSafe (or equivalent) before digging.[101] And if the charger is left exposed outside, consider having it covered in a cabinet, or with a small roof.

It's possible that your electrical panel won't have enough space for another 240V connection, in which case you might consider upgrading your electrical panel and electrical service (see *Chapter 2: Electrical Service*). You can also consider getting a "Smart Circuit Splitter" for sharing one outlet between the EVSE and another appliance you want to electrify, like a heat pump dryer (see "'Watt Diet' for electrifying within 100A" section in *Chapter 2: Electrical Service*).

INCENTIVES AND REBATES

There is a Federal Tax Credit for 30% of the cost of purchasing and installing an EV charger — up to $1,000 — if installed by December 31, 2021, when it expires (though it has been extended before).[102]

Individual states and utilities also have rebates for EVSEs. Some EVSE manufacturers maintain a list of rebate programs:

- → Chargepoint — **chargepoint.com/incentives**
- → ClipperCreek — **clippercreek.com/evse-rebates-and-tax-credits-by-state**
- → Search online for your specific utility's programs.

CHARGER SEARCH TOOLS

Here are a couple of sites to help find a charger that works for you:

- → Home Charging Advisor lets you set the estimated installation cost, and includes incentive discounts by zip code — **homecharging.electricforall.org**
- → PlugStar Shopping Assistant suggests chargers based on specific vehicles, but doesn't include incentives — **plugstar.com/chargers**

CHECK WITH YOUR UTILITY ABOUT EV RATES

Switching from paying the gas station to paying your electric utility to fill up your car is going to increase your electric bill (but overall save you money by eliminating your gasoline bill). Check with your utility to see if there is an EV rate plan that will reduce your costs if you charge during specific hours — especially at night, when the grid is being used less.

RENTER'S RIGHTS

Even if you're a renter or live in an apartment, you should consider asking your landlord or Home Owner's Association (HOA) if you can install either a 240V outlet or standalone charger. Some states, including California, Colorado, Florida, and Oregon, prohibit "unreasonably" denying a tenant's request to install an electric car charger.[103] Here are some resources to help you approach your HOA or landlord:

- → Chargepoint resources — **chargepoint.com/drivers/apartments-and-condos**
- → Tesla's form letter — **https://www.tesla.com/sites/default/files/support/home-charging-installation/letter-requesting-approval-charging-installation.docx**
- → Veloz tips — **veloz.org/wp-content/uploads/2017/08/MUD_Guidelines4web.pdf**
- → Department of Energy help — **afdc.energy.gov/fuels/electricity_charging_multi.html**

CHARGING AT WORK

If you drive to work and there's not yet a charging station there, ask your employer about installing one. Chargepoint has suggestions and a guidebook about bringing EV charging to your workplace, which you can share with your employer — **chargepoint.com/blog/six-tips-bringing-ev-charging-your-workplace**. California has also released an Electric Vehicle Charging Station Permitting Guidebook that could be useful — **businessportal.ca.gov/wp-content/uploads/2019/07/GoBIZ-EVCharging-Guidebook.pdf**. Search online to see if your state has a program for helping to finance business charging installations.[104]

EVSE AS ELECTRIFICATION HUB

It's worth noting that new types of EVSE are coming out as the EV market grows. One example is the dcbel r16, which supports bi-directional charging, allowing you to power your home from your car's battery instead of needing a separate home battery (see *Chapter 10: Home Battery Storage*). The r16 also connects to your PV array as the inverter, letting you directly charge your car with your solar panels (see *Chapter 9: Rooftop Solar PV Panels* for more info about inverters).[105] Ford and Sunrun are also teaming up to enable the F-150 Lightning electric pickup truck to power the home through the Ford Charge Station Pro.[106]

9

Rooftop Solar PV Panels

DIFFICULTY:	HARDER
UPFRONT COST:	$15,000-$30,000 before rebates
IMPACT:	High in places with lots of fossil fuel power plants
CONTRACTORS:	Solar Installer
DO NOW:	Use a website to check your address's potential for sun, and use energysage.com to get initial quotes.
RENTER:	Send quotes to your landlord, along with financing options.

Solar "photovoltaic" (PV) panels turn sunlight's photons ("photo") into electric voltage ("voltaic"). People have been putting PV panels on their roof since the 1970s, but improvements in the technology and huge decreases in cost have made it much more accessible. The cost of rooftop solar in 2020 was only 33% of what it was in 2010 — it's no longer a luxury purchase.[107] Putting solar panels on your roof and batteries in your garage (see *Chapter 10: Home Battery Storage*) can make you more resilient against losing power, and it is an increasingly valuable resource to the grid. It's also possible to have your solar array installed on your garage or ground instead of on your roof.

You'll probably want your solar panels installed by certified professionals, which means you're going to need a solar installer (aka contractor). See below for the section "Finding a solar installer." Before you start talking to solar installers, you should do some research into your options. Some useful references to read are:

- → SEIA's (Solar Energy Industries Association) Residential Consumer Guide to Solar Power — **seia.org/sites/default/files/2018-06/SEIA-Consumer-Guide-Solar-Power-v4-2018-June.pdf**
- → A Vermonter's Guide to Residential Solar — **cesa.org/resource-library/resource/a-vermonters-guide-to-residential-solar**
- → Solar United Neighbors Go Solar FAQs — **solarunitedneighbors.org/go-solar/faqs**

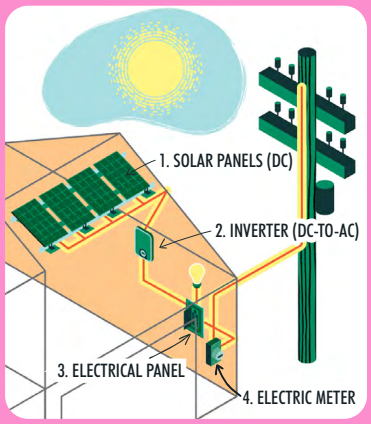
HOW SOLAR WORKS

1—Solar panels on your roof convert sunlight into Direct Current (DC) electricity.

2—An "inverter" converts the DC into Alternating Current (AC).

3—Your home consumes this AC electricity through your electrical panel.

4—Your home is also connected to the electric grid through your electric meter, so that you can sell any excess electricity, and continue getting grid power when the sun isn't shining.[108]



LIFETIME & WARRANTY

Solar panels typically have a production warranty of 20-25 years, which means they will produce the rated power for that long (though they might perform even longer). Panels also have a separate "workmanship" or product warranty that can range from 10 to 25 years, and covers defects. Check whether warranties are from the manufacturer or system installer.[109] System installers often provide installation warranties covering their work that can vary widely in length.

Inverters have a separate warranty, and can range from 5-25 years. This is discussed below under "Picking an inverter."

FIX YOUR ROOF FIRST

Since solar panels can last 25+ years, you should find out if your roof is going

to need replacing soon so you won't have to remove the panels during that time. You can't include the roof cost as part of the Federal tax credit, but it will save you potential repair costs later.[110]

In fact, many solar installers won't even work on an older roof. There are some roofers, however, that also install solar, so there is potential cost savings to do them both at the same time. Solar PV panels can also increase the life of a roof. Since the lifespan of solar is a bit unknown but already surpassing expectations, consider getting a longer life roof to avoid uninstall/reinstall costs.

KNOW (& REDUCE) YOUR LOAD BEFORE BUYING SOLAR

Look at your electric bills from the last 12 months to get a sense of your average monthly energy usage, how much your bill is and how much you pay for each kWh (kilowatt-hour) you use. If you don't have your bills, they might be available through your utility's web site, along with your daily or even hourly use.

Consider replacing any inefficient electric machines with better ones before you buy solar. For instance, it would be better to get a Heat Pump Water Heater that uses 100 kWh per month to replace an electric resistance water heater that uses 450 kWh per month. Over the course of a year, that's 4,200 kWh saved that doesn't have to come from solar. Consider all appliances, including:

- → Any machines you want to electrify that will increase your electricity use, especially car charging equipment.
- → Incandescent light bulbs (replace with LED lightbulbs).
- → Faucets and showerheads (replace with low-flow fixtures to reduce hot water needs).
- → Phantom loads (also called "energy vampires" and "standby power"), such as your TV and cable box, which can be put on a power strip to be fully shut off when not in use.

ROOFTOP POTENTIAL

How much power could your rooftop generate? Here are some sites where you can enter your address to learn about your home's solar potential:[111]

- → Google Project Sunroof — **google.com/get/sunroof**
- → Sun Number — **sunnumber.com**: Gives you a "score" to see how well suited your address is, along with an estimated system size and annual value of the electricity that would be generated.
- → EnergySage's calculator — **energysage.com/solar/calculator**: Gives you some estimates on costs and return on investment, based on your current electricity use (though you should consider if your use will increase if you electrify everything).
- → PVWatts Calculator — **pvwatts.nrel.gov**: This is a more detailed analysis of potential rooftop systems — including being able to draw the area where it could go on your roof. It can be useful for evaluating designs from contractors.[112]

PV PANELS, POWER (& ENERGY) OUTPUT

Buying solar panels is a little like buying a car, in that there are many options in price and performance. The best solar panels can turn over 22% of incoming sunlight into electricity (called the "efficiency"). Energy Sage has a Buyer's Guide that lets you sort solar panels by efficiency, search by brand, and download spec sheets — **energysage.com/solar-panels**. You can also compare updated lists of the best solar panels:

- → Clean Energy Reviews — **cleanenergyreviews.info/blog/best-solar-panels-review**
- → Energy Sage — **news.energysage.com/best-solar-panels-complete-ranking**

To give you a sense of scale, the average residential PV panel is a little over 5 feet long and 3 feet wide, and weighs about 40 pounds.[113] Using a mid-range power output of 290W per panel, it will require 17 panels to output around 5,000W.[114] How many panels you install will depend on your energy usage, the space available on your property, and your budget. Your selected installer will help you decide the best location for your installation.

As of 2021, solar in the U.S. costs around $2.76 per installed watt (including labor). For a 5,000 W array, that's $13,800, which comes down to $10,212 with the 26% federal solar tax credit (see "PV Incentives and rebates" section below).[115]

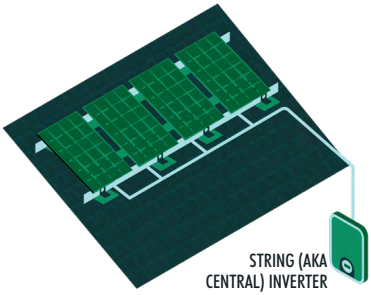
5,000 W can also be written as 5 kW (5 kilowatts), and the amount of energy a 5 kW PV system transfers to electricity in one hour is 5 kWh (kilowatt-hours).

Your utility charges you based on the number of kWh you use. A 5 kW system in sunny Las Vegas, NV could produce almost 8,000 kWh of energy in a year, while it would be closer to 5,000 kWh a year in rainy Seattle, WA. The average U.S. household uses 10,649 kWh a year.

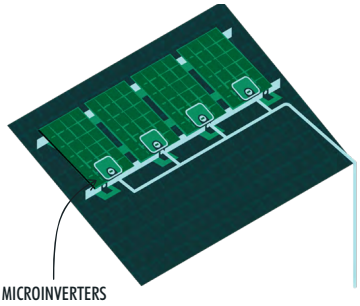
PICKING AN INVERTER

Inverters take the DC output from solar panels and convert it to the AC power your home uses. They are an important part of the system, and three main options are available:

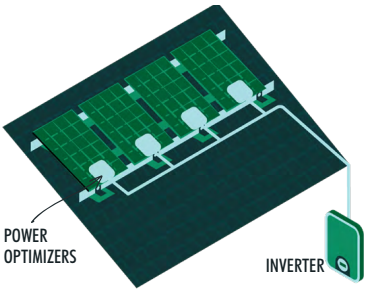
String inverter (aka "central inverter"): A standalone box that's usually installed at ground level and connects to a "string" of solar panels wired together. If one panel gets shaded they all reduce their output, and if one panel fails they all stop producing power. It is the least expensive option, with a 5-12 year standard warranty that can sometimes be extended to 20 years for a fee.

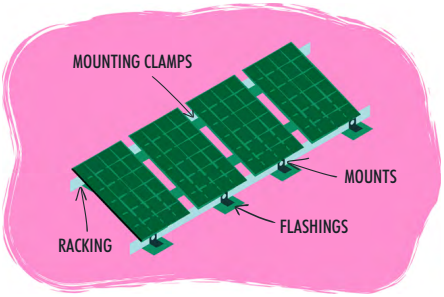


Microinverters: Smaller inverters built into each individual solar PV panel. This means the panels are independent, which can be good for later expansion. But there are more things that can fail, and finding and replacing a broken one on the roof can be challenging. They are more expensive up front, but can be more efficient than a central inverter and have warranties of 25-30 years — similar to the PV panels themselves.



Power optimizers (aka module optimizers): These are similar to microinverters in that there is one on each panel, but they "condition" the DC on its way to a central inverter. Their performance and cost is between microinverters and central inverters, with 25-year warranties.





MOUNTING

The traditional way solar panels are attached to a roof is with racking that is mounted to the roof through water-tight flashings (see image). You should ask your solar installer detailed questions about their mounting plans (see the "Finding a solar installer" section below).

SOLAR NEEDS BATTERIES IN A GRID OUTAGE

For safety reasons, grid-connected PV systems must be rapidly shut down during a grid outage, to make it safe for workers trying to bring the power back up. Inverters sense when grid power is out and stop producing solar power until the grid is back online. Unfortunately, this means your rooftop solar PV CAN'T power your home by itself when the grid is down.

However, if you have a home battery backing up your PV system, you CAN charge the battery with your solar panels (see *Chapter 10: Home Battery Storage*).

PV FINANCING OPTIONS

While the cost of solar PV panels has dropped a lot in recent years, it's still an expensive purchase that can run over $10,000 — comparable to a new car. But since you're locking in free electricity for the 20+ year life of the panels, and also increasing the resale value of your home, think of it more like an investment than as a home appliance. Rooftop solar can even generate cash by selling your excess power back to the grid (see "Net Metering" section below).

CESA (Clean Energy States Alliance) has "A Homeowner's Guide to Solar Financing" that provides details about the three main ways to finance rooftop solar — **cesa.org/wp-content/uploads/Homeowners-Guide-to-Solar-Financing.pdf**. For the first two options where you don't own the panels, you should clarify with the installer the maintenance and service responsibilities (including who is responsible for the inverter); whether the payments increase over time; and what your options are if you sell your home before the agreement is over.

- → **Solar lease:** A solar developer installs and owns the PV on your roof (not you), so you don't have to pay the upfront installation cost. Instead, you pay a monthly payment, which ideally replaces your monthly electric bill (unless you need more power than the panels provide and buy it from the grid).
- → **Power Purchase Agreement (PPA):** Here too a solar developer installs and owns the PV on your roof (not you). Instead of a monthly lease payment, you pay your installer for the electricity you use at a fixed rate, which should be lower than from your utility. Ask the installer to calculate projected rates and savings, and consider whether your utility's rates will increase in the future.
- → **Buy with a Loan:** Here you *do* own the PV on your roof, and the loan for the upfront purchase and installation cost is paid back like any other loan. A "home equity loan" would be one where your home is used as collateral, while an "unsecured loan" might have only the solar equipment itself as the collateral. Consider taking out two loans, as suggested by Clean Energy Credit Union:[116]
  - A bridge loan with a 12-18 month term, to cover the time until you get your 26% federal tax credit back (see "PV Incentives and rebates" section below), and
  - A second loan with a 12-20 year term, to cover the operational life of the solar panels themselves. Your monthly loan payment plus your remaining utility bill could be less than what you previously paid for electricity.

SELLING YOUR SOLAR HOME

When you're ready to sell your home with solar panels, you should consider getting a realtor with a "Green Designation," and an appraiser who is trained in evaluating the impact of solar. If you don't own the panels, you'll need to consider whether to transfer the lease or PPA to the homebuyer, prepay it, or move it to your new home. Solar United Neighbors has a guide with more details and considerations — **solarunitedneighbors.org/sellingsolarhomes**.

CONSIDER GOING SOLAR IN A GROUP

In addition to Community Solar projects discussed in *Chapter 1: Purchase Renewable Energy*, there are also groups of individuals who band together when looking to get solar panels on their own roofs. Being in a group can help you make informed decisions, and negotiate better prices.

- → Solar United Neighbors has a list of solar co-ops in a number of states, along with "The Ultimate Solar Co-Op Guide" for going this route — **solarunitedneighbors.org/co-ops**.
- → "The Solarize Guidebook" from the Department of Energy has planning templates and case studies for collective group purchases — **nrel.gov/docs/fy12osti/54738.pdf**.

PV INCENTIVES AND REBATES

There is a federal tax credit for buying residential PV. Until the end of 2022, you can deduct 26% of the total cost — including the solar panels, inverter & mounting hardware, batteries, and installation. You can take the credit even if you finance the system, but you can't if it's leased or a PPA. The credit will drop to 22% in 2023. Read more in the "Homeowner's Guide to the Federal Tax Credit for Solar Photovoltaics." — **energy.gov/eere/solar/homeowners-guide-federal-tax-credit-solar-photovoltaics**. You can talk with a tax professional to make sure you're eligible.

Ask your solar installer for help finding and getting rebates. Check these sites for incentives that might be offered from your state or utility:

- → Energy Sage's "Solar panel incentives, rebates & tax breaks" (scroll down to find your state) — **energysage.com/solar/benefits-of-solar/solar-incentives/**
- → SEIA's "Solar State By State" — **seia.org/states-map**
- → Let's Go Solar's "Ultimate Guide to Solar Panels" — **letsgosolar.com/solar-panels**

NET METERING

If your PV system generates more electricity than you can use, many states let you sell that power back to your utility and receive credit on your electric bill. This is called "net metering" (or "feed-in tariff") and it varies widely by state. As of 2020, 34 states plus Washington D.C. and the U.S. territories had some kind of net metering, with most of the rest offering some kind of compensation.[117] Check with your solar installer about the net metering rules for your location, and how it affects the size of your PV system.

SRECS (SOLAR RENEWABLE ENERGY CREDITS)

When your solar cells generate electricity, they also generate a financial instrument called a "Solar Renewable Energy Credit," which can be sold like a stock on the stock market. Utility companies buy SRECs to try to meet state-mandated clean energy standards (called "renewable portfolio standards"), and corporations also buy them to offset their carbon footprint. Some states let you sell the SRECs from your rooftop solar.

If you're buying Solar PV outright, ask your installer who gets the SRECs. If it's you, consider not selling them (aka "retiring" them) to force polluters to purchase and install more solar.[118] If you're getting a lease or power purchase agreement (PPA), make sure you know who controls the SRECs. Typically in lease deals, the solar company will sell the system's SRECs for income as part of their financing model. Read more about SRECs here — **solarunitedneighbors.org/srecs**.

MAINTENANCE

Solar PV panels need very little maintenance but like any investment, should be inspected periodically. Check if your solar installer performs periodic inspections to look for any loose fittings or potential roof leaks, and periodic cleaning.[119] How frequently you need to clean your panels depends on your local conditions and how the panels are mounted — it could range from a few times a year to yearly or longer. Check with your installer for what they recommend. If they suggest doing it yourself, be careful if you have to go on your roof. Here's a maintenance guide — **solarreviews.com/blog/solar-panel-maintenance-everything-you-need-to-know**.

DIY INSTALLATION

You're probably not going to want to install your own solar PV, but if you were curious about going down that path, Solar Wholesale sells complete DIY kits — **solarwholesale.com**. And if you have a large lawn or land you want to use instead of a roof, PowerField makes stand-alone modular racks that get filled with rocks, but can later be emptied and moved — **powerfieldenergy.com**.

FINDING A SOLAR INSTALLER

The process for finding a solar installer is similar to that for finding a contractor to install a heat pump. You should get referrals from friends and family, and then get quotes from at least three potential installers. After picking an

installer, it can take two to four months to plan and permit, then the installation itself takes 1-2 days, plus time after the installation for inspections and utility company approval before you can turn your system on.

One easy route for getting some quotes is to use Energy Sage, where you type in your address and contact info, and installers will send back quotes — **energysage.com**.

Here are some questions to ask when interviewing potential installers:[120]

ABOUT THE INSTALLER:

- ☐ How much experience do you have installing residential solar systems? How many systems have you installed?
- ☐ Can you give me references (with phone numbers) for similar systems you've installed recently?
- ☐ What are your licenses or certifications?
- ☐ Will you be using subcontractors? For which parts of the project? What are their qualifications?
- ☐ Who specifically will be working on my roof?
- ☐ Do you have workers' compensation insurance? Can I have a copy?
- ☐ Is the installation company licensed and insured?
- ☐ Does your company follow the SEIA Solar Business Code? Do you agree to abide by SEIA's Complaint Resolution Process?

ECONOMICS, FINANCING, AND OWNERSHIP:

- ☐ What is the total cost of the system? Is that with or without the federal tax credit?
- ☐ How much is the total cost of the solar system if I add battery storage?
- ☐ What's the upfront cost?
- ☐ What will my monthly payment be? For how long?
- ☐ What will my net savings be? What utility rate assumptions are included in your calculations, and what are they based on?
- ☐ Does installing battery storage change how much money I can save with this system? If so, how much?
- ☐ Who gets the tax credit?
- ☐ Will my system be net-metered? How will I be compensated for excess electricity generated by the system?
- ☐ What financing options do you have available?

- ☐ Who gets the SRECs and how do they factor into the (financial) equation? Will you retire the SRECs on my behalf?
- ☐ If I want to sell my home and don't own the SRECs, how can I describe my home to potential buyers?
- ☐ Is residential Property Assessed Clean Energy (PACE) financing available in my state and locality?

SYSTEM DESIGN, PERMITTING, AND APPROVALS:

- ☐ What are my rights under state law?
- ☐ Can my HOA stop me from installing solar?
- ☐ What permits are needed? Who's responsible for securing the permits?
- ☐ Who deals with the utility and arranges for interconnection, inspections, and permission to operate?
- ☐ When will the installation be done, and how long will it take?
- ☐ Who's responsible for repairing my roof if it's damaged during installation? Do you replace any broken roof tiles?
- ☐ Who is the manufacturer of the solar panels and the inverter?
- ☐ What is the system size?
- ☐ How much electricity will the system generate in its first year?
- ☐ How much production decline is expected each year?
- ☐ Do system output calculations consider actual installation details of the system?
- ☐ Do you guarantee a minimum amount (a production guarantee)? Are there any other guarantees?
- ☐ If there is a grid outage, what will happen to my system?
- ☐ If I need battery storage in case of a grid outage, what size system and system attributes do I need?

INSTALLATION:

- ☐ What will the system look like once installed? Will I receive a system design for my review and approval before installation?
- ☐ Will I be required to make any changes to my home (e.g., roofing upgrades)?
- ☐ Do you use the SEIA residential disclosure form? Can you provide a completed copy of the form?
- ☐ What type of flashing will you use on my roof?
- ☐ What type of mounting hardware/footings will you use to attach the panels to my roof?
- ☐ What kind of rail system do you use to connect the footings to the solar panel?

- ☐ What do you use to seal the flashing to the roofing?
- ☐ What kind of conduit do you use? Where will you install the conduit?
- ☐ What type of inverter will you use? If there's a central inverter, where will you install it?
- ☐ Are the solar panels above the roof, or do they go directly on the roof?
- ☐ What disconnects are required, and where will they be located?

MAINTENANCE AND PERFORMANCE:

- ☐ What type of warranties come with the solar system? What do the warranties cover and what are their durations?
- ☐ Are there separate warranties for parts and labor?
- ☐ What type of maintenance or cleaning is required? Are any maintenance services included? If not, who should I contact?
- ☐ Is performance of the system monitored and, if so, by whom? How can I monitor system performance?
- ☐ Who should I contact if I have a question about the system following the installation? Who should I contact if my system stops working?
- ☐ If the company fails, who should I contact regarding panel and inverter warranties and replacement?

FOR LEASES AND PPAS ONLY:

- ☐ What is the length of the lease or PPA?
- ☐ Will my payments increase over time? How much will they increase?
- ☐ What happens if I wish to end the lease or PPA early?
- ☐ Can I purchase the system, either during the agreement or once it ends?
- ☐ What are my options when I sell my home?
- ☐ Am I free to sell my home or do I need the system owner's permission?
- ☐ Do I have to pay off the lease when my home is sold?
- ☐ Can you explain the UCC-1 filing to me? What happens if I want to refinance my mortgage?
- ☐ Are there fees to transfer the PPA or lease agreement to the new homeowner?
- ☐ What are the conditions for a new homeowner to take over the lease or PPA?
- ☐ Who is responsible for repairs and maintenance on the system?

10

Home Battery Storage

DIFFICULTY:	HARDER
UPFRONT COST:	$10,000-$20,000 before rebates
IMPACT:	Medium on emissions, High on personal resiliency
CONTRACTORS:	Home Battery Installer
DO NOW:	If you have rooftop solar, check with your installer about whether they also offer a storage option.
RENTER:	Get a standalone backup battery.

Getting a home battery to store energy generated by your rooftop solar PV can make a lot of sense. It adds resiliency to your home when the power goes out, which most solar PV systems can't do by themselves (see "Solar and batteries in a grid outage" section below).

Home battery storage also lets you store energy from the sun to use at night, which can avoid higher "Time-Of-Use" rates your utility might charge you for electricity during certain hours. It's a way to help avoid future electricity rate increases. And in the future, your rooftop solar PV and home battery storage might act as a "Virtual Power Plant" to help the utility avoid having to turn on natural gas power plants during times of peak use.

A home battery is not yet going to let you go "off grid" — they are still too small and expensive to provide enough power for most homes for full days. But the technology is being rapidly developed and scaled, making them

an increasingly viable and affordable option.[121] They can be worth the current cost, especially if you need reliable power, or you've already fully electrified your home. Here are some useful references for learning more about home batteries:

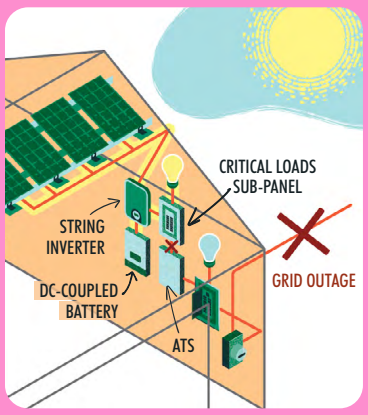
- → Solar United Neighbors' "Battery Storage Guide" — **solarunitedneighbors.org/storage**
- → Residential Solar PV Plus Battery Storage talk — **youtube.com/watch?v=iKVUP01_ld0**

BATTERIES FOR THOSE WITHOUT NET ENERGY METERING

Net Energy Metering means that your utility pays you for excess electricity generated by your solar panels (see "Net Metering" section in *Chapter 9. Rooftop Solar PV Panels*). Having home storage batteries can be a great addition to solar if your utility either doesn't have net energy metering, or pays you less for your excess electricity than what you pay them for it from the grid. In either case, you're better off storing the excess electricity in a home storage battery for later use.

SOLAR AND BATTERIES DURING A GRID OUTAGE

Batteries can be charged by your rooftop solar PV during a grid outage (see image). Since rooftop solar panels have to be disconnected by the inverter when the grid is down for safety reasons, an Automatic Transfer Switch (ATS) can isolate your PV & battery system. This will let you safely use your battery, and recharge it with your solar.



You should discuss this arrangement with your solar installer. It may require wiring just some select essential circuits to your battery through a critical loads sub-panel, since even a 20kWh battery won't be able to power your entire home (see "Home battery sizing" section below).

HOME BATTERY FINANCING AND LEASING

There are fewer options for financing a home battery than there are for solar PV, though you might be able to include them both together through a Home Equity Line of Credit (HELOC), a home improvement loan, or a solar loan. PACE (Property Assessed Clean Energy) loans might also be used. See the "How to pay for it" section near the beginning of this guide for more about financing options.

Some utilities and independent companies offer leases of home batteries, but it is not yet common. Note that you will not get a tax credit if you lease your home battery (see next section).

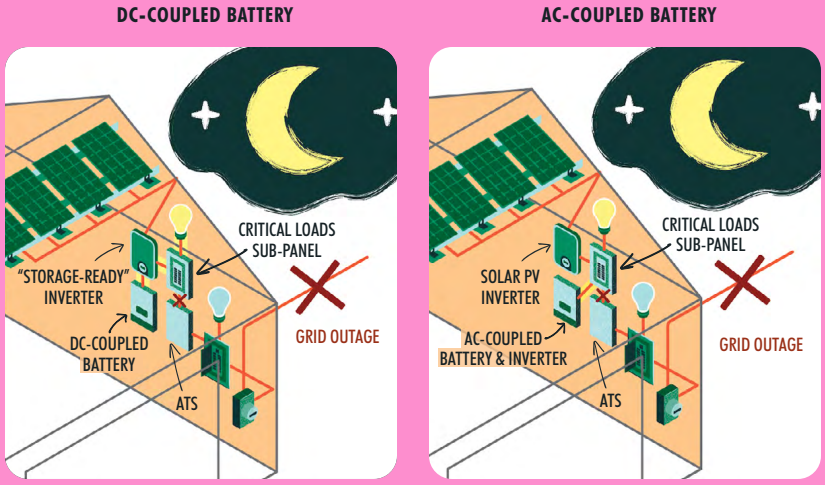
HOME BATTERY INCENTIVES AND REBATES

Home battery storage can be included as part of the Federal solar tax credit (see "PV incentives and rebates" in *Chapter 9: Rooftop Solar PV Panels*). It should be eligible even if it's installed separately, at a later time than the solar PV system.[122] To qualify, the battery has to be charged by your solar panels 100% of the time.[123]

Additional rebate programs exist for specific states, such as California' Self-Generation Incentive Program (SGIP) and Maryland's solar battery tax credit.[124] Ask your battery installer if there are other incentives available for storage.

AC VS. DC COUPLING

Batteries operate using direct current (DC), while the grid provides our homes with alternating current (AC). Just like with solar PV panels, which also use DC, an inverter is needed to convert the DC to AC for your home. There are two main ways to connect the battery to your home, and you can learn more here — **news.energysage.com/ac-vs-dc-solar-battery-coupling-what-you-need-to-know**.



DC coupled: If you have a "storage ready" solar PV inverter, a battery can be connected to it directly. This arrangement is useful for ensuring the battery is only charged by the solar panels, which is important for the federal tax credit (see "Home battery incentives and rebates" section above). It's also possible to replace your existing solar PV inverter to work with your battery, which could make sense if your inverter is more than five years old (since they last around 10 years). And some DC coupled battery systems aren't directly connected to your electric panel, which can leave more panel space for other home electrification projects without needing to upsize. But DC coupled batteries are more expensive and complicated than AC coupled.

AC coupled: Here the battery has its own inverter, separate from the solar PV inverter. The inverter might even be integrated with the battery, like Tesla's Powerwall 2. Having different inverters for your solar PV and home battery storage might be slightly less efficient than having them combined, but an advantage is that they can also be charged by the grid (though this will remove the federal tax credit).[125]

BATTERY CHEMISTRY

The most widely available home batteries use lithium-ion chemistry, similar to the batteries in laptops and cell phones. The cost has come down a lot recently due to their mass production for use in EVs. On average, home storage lithium ion batteries can be fully discharged and then recharged (or "cycled") 7,500 to 10,000 times, and have 10 year warranties.[126] There are some differences in the types of lithium ion batteries, which you can discuss further with your installer:[127]

- → **Lithium Nickel Manganese Cobalt Oxide (NMC):** Most common and least expensive lithium ion, found in cars and power tools. NMC is used in Tesla's Powerwall and LG Chem's Resu home storage batteries.
- → **Lithium Iron Phosphate (LFP):** These are cheaper than NMC because they don't use nickel or cobalt, but they store less energy. LFP is used in batteries from many manufacturers including Sonnen, SimpliPhi, and Enphase.
- → **Lithium Nickel Cobalt Aluminum Oxide (NCA):** Newer to the market, they store more energy than NMC. NCA is not widely used yet, but is available in the TrinaBESS system from Trina Solar.

Besides lithium ion batteries, there are also "sealed lead acid" batteries — similar to car batteries — that are used as home storage batteries. They are cheaper than lithium ion, but should only be discharged to 50% of their capacity, and they can't be cycled as much — more like 2,000 cycles, with 2-5 year warranties.

It's also worth mentioning that flow batteries are a newer design with long lifetimes and good electrical performance, and are currently being commercialized for grid-scale batteries. They are not yet ready for the home market or EVs, but they could be in a few years.[128]

BATTERY RECYCLING AND MATERIAL CONCERNS

Lead acid batteries are easily recycled, thanks to their long-time use in cars. It is both the value of the lead, and concern about its toxicity, that leads to very high recycling rates.

Lithium-ion batteries are more complex and not as easily recycled, though they have much longer lifetimes than lead acid batteries. Several startups are trying to make lithium battery recycling cost-effective, especially as the number of batteries manufactured skyrockets.[129]

There are some concerns about both the quantities and sources of raw materials for batteries, including lithium, cobalt, and nickel.[130] A lot of research is going into new battery chemistries right now that don't need cobalt and other supply-constrained materials[131] (see "Battery chemistry" above). As recycling grows, the need for newly mined materials will decrease.

Don't be discouraged from buying an EV or home storage battery today over concerns about materials in the batteries — the climate benefits outweigh the materials concerns.

HOME BATTERY SIZING

Because home batteries are still expensive, most people size them to only power critical appliances for around 24 hours while the grid is out.[132] The list usually includes: charging cell phones and other personal devices, running computers and the internet (modems & routers), food refrigeration, some lights and ceiling fans, some limited air conditioning (e.g. window units), and any other critical loads like well pumps and medical equipment. Your electrician might rewire key appliances into a separate critical loads sub-panel, powered by your battery (see pictures above in section "AC vs. DC coupling"). Smart Energy Management Systems can also replace your electrical panel, and manage critical loads (see *Chapter 2: Electrical Service*).

One way to think about sizing the battery is to multiply the kW of solar PV you have by 2 to 4 hours to get a kWh number, which represents the energy stored in the battery. So for a 5 kW array, you might get a 10 kWh battery. Your installer will provide more detail on sizing and justification for it.

WHERE TO INSTALL THE BATTERY

Both lead acid and lithium ion batteries need to be installed in non-living spaces, since there is the potential for them to offgas. If they need to be installed outside, it will probably have to be shaded and water-proofed. If inside, it will probably be in the garage or other non-living space. Your installer will size the battery in part based on where it will be located.

USE AND MAINTENANCE

Your installer will initially program your battery system and show you how to use it, including any custom settings and operating modes. Make sure you learn how to set the charge and discharge times to coincide with any time-of-use rates from your utility.

Maintenance includes visually checking your battery several times a year to make sure there are no alerts or warnings. The battery might also need a system check-up by the contractor at some point during its lifetime. Overall, they are very low maintenance.

USING YOUR EV FOR BACKUP

Instead of buying separate home battery storage, it could soon be possible to use your EV's battery to power your house, though the technology is still in development. See "Home power backup using your car" in *Chapter 7: Electric Vehicles* for more info.

THERMAL STORAGE

In addition to a home battery for storing electricity, you can also think of a tank of hot water as a "thermal battery" that can "store" heat for later use. Two examples are Heat Pump Water Heaters (see *Chapter 4: Heat Pump Water Heater*) and hydronic air-to-water heat pumps for radiant floor and hot water space heating (see *Chapter 3: Heat Pump Space Heating*). Your heat pump heating your space overnight in winter, or cooling it overnight in summer, can also store energy in your home.

Thermal storage won't give you electrical resiliency in a grid outage like a home battery, but it will give you some thermal resiliency, and can also help you manage varying "time-of-use" electricity rates.

FINDING A BATTERY INSTALLER

Check with your solar PV installer to see if they also offer battery storage.

INITIAL BACKGROUND QUESTIONS:

- ☐ Number of home storage batteries they've installed and how many in your area.
- ☐ Experience with the specific technology/equipment you are interested in.
- ☐ Availability of your preferred equipment (if you have a preference).
- ☐ Installer workmanship warranties
- ☐ NABCEP certification, a common certification for solar installers that includes battery knowledge
- ☐ Whether they take care of all permitting and inspection requirements.

QUESTIONS TO DISCUSS WITH YOUR INSTALLER[133]:

- ☐ What is the total installed cost of the battery storage system versus the expected output over its lifetime?
- ☐ Do you have an appropriate space to install the battery?
- ☐ Can the battery store and supply enough energy for your needs?
- ☐ Is the supplier a reputable company that can deliver on any potential warranty claims?
- ☐ Do you have any safety concerns?
- ☐ What do you want to use the battery for (e.g. backup for grid outages, saving money)?
- ☐ How much energy do you use between battery charges (both now and in the future)?
- ☐ How much power do you need to run your appliances?

- ☐ How much excess energy do you generate from your solar panels each day?

COMPARING SYSTEMS:

- ☐ How do I know what the system is doing (i.e. what is the user interface?)?
- ☐ How is it intended to be used (e.g. some systems are only intended for providing backup power while others can only charge from your solar panels and not from the electricity grid)?
- ☐ How much energy can it store?
- ☐ How fast can it store and supply energy?
- ☐ What are the maintenance and safety considerations of the system and technology?
- ☐ How big is it and where does it need to be installed?
- ☐ What is the battery storage system's operating temperature range? (Some systems cannot charge in cold weather or may not operate on very hot days.)
- ☐ Can the battery storage system be recycled?
- ☐ How long will the battery storage system last, and what is the product warranty period?
- ☐ Would it be simple to add more batteries to the system later if your needs change?
- ☐ Is it an 'all-in-one' device or are there multiple components that must also be installed, including any programming to ensure compatibility?
- ☐ Does the battery storage system only work with a specific inverter or is it compatible with multiple brands?
- ☐ What is the efficiency of the system (how much of the stored energy can be used)?
- ☐ Are there any additional state or local rebates or incentives available?

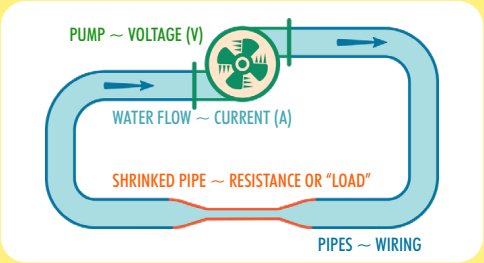
PROPOSALS SHOULD INCLUDE:

- ☐ Full cost of the storage system, installation, and additional equipment
- ☐ Payment milestones
- ☐ Equipment details
- ☐ Battery size (kW and kWh)
- ☐ Battery model and manufacturer
- ☐ Inverter model and manufacturer (if separate from battery)
- ☐ Battery management system (if used)
- ☐ List of all warranties (battery, inverter, installer workmanship)
- ☐ Details of additional work needed (electrical work, inverter swap, etc.)
- ☐ Pricing guarantee for all equipment
- ☐ Installer information (office location, point of contact, contact information)

An extremely brief intro to electricity

Electrification can be confusing because electricity can be confusing. We can't see it, we can't touch it, and most of us never learned much about it. We know the words — Volts, Amps, Watts, kilowatt-hours — but it all ends up just being lumped together as "electricity." So here is an extremely brief overview that might help you get an initial grasp on what's happening in the wires.

Main ideas in electricity: Here's a water flow analogy for thinking about it that might be helpful:



WATER ANALOGY	ELECTRICITY	FUNCTION
Pump	Battery/power plant	Provides the "oompf" (electric "Voltage")
Water flow (shown by arrows)	Current ("electric fluid" flow)	Stuff that carries energy through circuit
Shrinked pipe	Resistance or "Load"	Reduces flow & uses the energy
Pipes	Wiring	Provides low-resistance path for flow

Voltage: Provides the "oomph" in a circuit, measured in Volts (V). If we use a fluid analogy for electricity, you can think of voltage as the "pumping action" created by a pump that makes the "electric fluid" flow. For scale, USB outlets provide 5V, while regular U.S. wall outlets provide 120V, and many appliance

outlets provide 240V. Higher voltage loads more energy onto the flowing "electric fluid."

Current: Sticking with the fluid analogy, current is a measure of the flow rate of this "electric fluid" through a circuit — how much charge is flowing past a given point every second, measured in Amps (A). A USB outlet can provide a little less than 1A, while 120V wall outlets often provide up to 15A or 20A, and 240V appliance outlets up to 60A.

- → **Alternating current (AC):** Wall outlets provide AC, where the "electric fluid" moves back and forth 60 times every second ("alternating" direction). Think of the pump quickly reversing direction many times a second.
- → **Direct current (DC):** Batteries and USB provide DC, where the "electric fluid" is always pumped in the same direction, around and around the circuit.

Energy: As the "electric fluid" flows, it transfers energy from the source (e.g. battery or power plant) to the load (e.g. electric machine). Both AC and DC transfer energy. Measured in kilowatt-hours (kWh). Energy is what you pay for, and what appears on your electric utility bill.

- → **Power:** It might seem confusing that energy and power are different, but power is a measure of energy in motion, or the energy flow rate, measured in Watts (W). It measures how much energy is being transferred past a given point every second. A cell phone can charge using around 5 W of power, while a hair dryer can use around 1,800 W, and a clothes dryer around 5,000 W. Think of it this way — if you run a 5,000 W (5 kW) clothes dryer for 1 hour, you'll use 5 kWh of energy, whereas if you run it for 30 minutes, you'll use half as much energy, or 2.5 kWh. The power need in both cases is the same 5 kW, but it uses more energy (kWh) the longer it runs.

Efficiency: This is a measure of how much of the energy input to do something is used to accomplish that goal. When burning fuel in a gasoline engine, only 30% of the energy in the fuel goes to moving the car. For electricity you get from the grid, if it's generated burning coal or natural gas in a power plant that's only 30-40% efficient, then what you pay for in kWh ignores the 60-70% of the fossil fuel's energy released up the power plant's smokestack. Good solar cells are around 20% efficient, but the "wasted" energy from the sun was free anyway, and doesn't produce any carbon emissions.

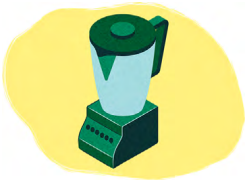
→ **Greater than 100% efficient:** When burning fossil fuel for heating, at most 100% of the energy in the fuel can go into the air or hot water being heated. But using a heat pump for space heating or water heating can be 300% efficient or more, since the electric energy input is only moving existing heat from lower to higher temperature instead of creating it. In the 300% example, the heat pump is pumping two units of heat energy from the yard outside, adding one unit of electric energy from the grid, and delivering all 3 units of heat into the house or water heater. It's almost magical that we can get out more heating's worth of energy out than the energy we put in.

Electrification is the Efficiency We Need

To give you a sense of how much more efficient electric machines can be, we can compare average monthly fossil fuel use BEFORE electrification, with the equivalent electricity use AFTER, along with potential cost savings. To do so, we have to convert the energy stored in fossil fuels to electrical energy units (kWh), and assume average fuel costs:

1 KILOWATT-HOUR (KWH)

Costs an average of $0.15



A battery that stores 1 kWh of energy can power a **1 KW BLENDER** for 1 hour.

1 THERM (= 29KWH)

Costs an average of $1.20

About 100 cubic feet of natural gas, which would fill **100 BALLOONS.**

1 GALLON OF GAS (= 33KWH)

Costs an average of $3.50

Imagine filling your car using **1 GALLON MILK JUGS** of gasoline, instead of the pump.

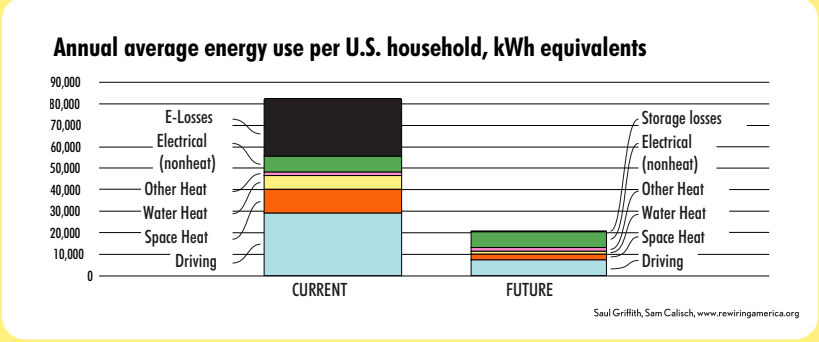
If you replace your 23 miles-per-gallon car, 87% efficient natural gas furnace, and 74% efficient natural gas water heater with electric replacements, you might get these results:

	BEFORE Average monthly fossil fuel use, (electrical equivalent) & monthly cost	AFTER Average monthly electrical use, (fossil fuel equivalent) & monthly cost	MONTHLY CASH SAVINGS
DRIVING	55 gallons *(1810 kWh)* $192	405 kWh *(12 gallons)* $60	$132
SPACE HEATING	53 therms *(1535 kWh)* $80	355 kWh *(12 therms)* $53	$27
WATER HEATING	20 therms *(578 kWh)* $30	114 kWh *(4 therms)* $17	$13

That's $172 in monthly savings, or around $2,000 a year. In addition to the potentially large cost savings, the energy savings will help reduce carbon emissions immediately, and will continue to do so as the grid is made more renewable. And if you add solar panels (or community solar) and a home storage battery, you can save even more money.

Below is a chart from Rewiring America's Household Savings Report — **rewiringamerica.org/policy/household-report**. By putting the above numbers in graphical form on an annual basis instead of monthly (and showing everything in kWh equivalents). It can add up to **HUGE** savings! Part of what's interesting about this is that the "e-losses" from generating electricity, shown in black, are basically eliminated as we stop burning fossil fuels in power plants that waste 50-70% of the energy up the smokestacks, and switch to clean, renewable electricity sources (including rooftop solar).

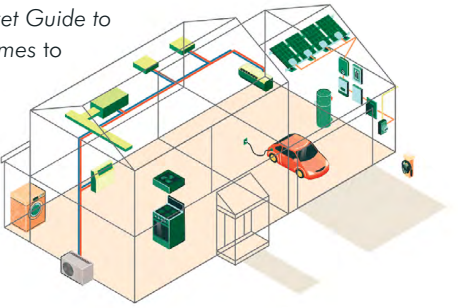
Let's electrify everything!



Homeowner and Landlord Checklist

→ If you're a homeowner or a landlord, this list will help you *Electrify Everything in Your Home* as you go through Rewiring America's guide: **rewiringamerica.org/electrify-home-guide**

→ Also download *Redwood Energy's Pocket Guide to All-Electric Retrofits of Single-Family Homes* to see product options for many of these items: **redwoodenergy.net/research**



Which of these modern electric options do you want working for you?

1. Purchase Renewable electricity	HAVE	WANT
Your utility's renewable plan	☐	☐
If shared meter ask homeowner's association to switch	☐	☐
Community Solar subscription	☐	☐
Community Wind subscription	☐	☐
Rooftop Solar PV Panels (see *9. Rooftop Solar PV Panels*)	☐	☐
Reduce your electricity needs	☐	☐
LED light bulbs	☐	☐
Power strips to shut off standby loads	☐	☐

2. Electrical Service	HAVE	WANT
100 Amp capacity	☐	☐
200 Amp capacity	☐	☐
Energy Management System	☐	☐
Smart Circuit Splitter for sharing circuits	☐	☐
New outlets and circuits to consider installing	☐	☐
Heat Pump Water Heater, 240V / 15-30A	☐	☐
EV Level 2 Charger, 240V / 20-40A	☐	☐
Heat pump dryer or condensing dryer, 240V / 20-30A	☐	☐
Combo Induction stove & oven, 240V/ 40-50A	☐	☐

3. Space Heating and Cooling	HAVE	WANT
Home Energy Assessment / Audit	☐	☐
Efficiency upgrades		
Air leaks sealed	☐	☐
Wall Insulation	☐	☐
Attic insulation	☐	☐
Floor insulation	☐	☐
Better windows	☐	☐
Packaged heat pumps:		
Window unit heat pump	☐	☐
Portable heat pump	☐	☐
Mini-split heat pump:		
Inverter-driven	☐	☐
SEER above 20	☐	☐
HSPF above 10.5	☐	☐
Indoor unit style:		
High wall mount	☐	☐
Floor mount	☐	☐
Recessed ceiling cassette	☐	☐
Ducted mini-split	☐	☐
Ducted central heat pump:		
Inverter-driven	☐	☐
SEER above 20	☐	☐
HSPF above 10.5	☐	☐
Air handler	☐	☐
ICM493 surge protector	☐	☐
Hybrid resistance backup	☐	☐
Furnace backup	☐	☐
Other types of heat pump:		
Ground-source heat pump	☐	☐
Hydronic air-to-water heat pump	☐	☐
Ventilation	☐	☐
Heat Recovery Ventilation (HRV)	☐	☐
Energy Recovery Ventilation (ERV)	☐	☐
Other heating options:		
Plug-in space heater	☐	☐
Electric blanket	☐	☐
Electric fireplace	☐	☐
Electric sauna heater	☐	☐
Electric outdoor patio heater	☐	☐

4. Hot Water	HAVE	WANT
Heat Pump Water Heater (HPWH)	☐	☐

	HAVE	WANT
UEF above 3.1	☐	☐
240V / 15A	☐	☐
120V retrofit-ready	☐	☐
Larger tank (80 gallon)	☐	☐
Mixing valve	☐	☐
Reduce your hot water needs:		
Leaks and drips fixed	☐	☐
Low-flow shower heads	☐	☐
Low-flow faucets & aerators	☐	☐
Energy-efficient dishwasher	☐	☐
Energy-efficient clothes washer	☐	☐
Other hot water options:		
Swimming pool heat pump	☐	☐
Hot tub heat pump	☐	☐

5. Electric Cooking	HAVE	WANT
$50+ portable induction burner	☐	☐
New 240V / 40-50A circuit (see 2. *Electrical Service*)	☐	☐
Induction stove (combo cooktop & oven)	☐	☐
Separate induction cooktop	☐	☐
Separate electric oven	☐	☐
Cooktop exhaust hood	☐	☐
Other electric cooking options:		
Electric crockpot	☐	☐
Electric multi-cooker	☐	☐
Electric wok	☐	☐
Countertop toaster oven	☐	☐
Electric camp stove	☐	☐
Electric barbeque	☐	☐

6. Clothes washing	HAVE	WANT
Clothes drying rack or clothesline	☐	☐
Combined washer / condensing dryer, 120V ventless	☐	☐
Condensing dryer, 120V ventless	☐	☐
Heat pump dryer, 240V ventless	☐	☐
New 240V / 20-30A outlet (see 2. *Electrical Service*)	☐	☐
Hybrid heat pump & resistance dryer	☐	☐
New washer with high speed spin	☐	☐

7. Electric Vehicles	HAVE	WANT
Driving plan	☐	☐

Plug-in Hybrid Electric Vehicle (PHEV)	☐	☐
All Electric Vehicle (EV)	☐	☐
120V Level 1 Charger (included with EV)	☐	☐
Other electric transportation:		
Electric bicycle	☐	☐
Electric scooter	☐	☐
Electric skateboard	☐	☐

8. EV Charger	HAVE	WANT
Try included 120V Level 1 charger first	☐	☐
Additional outlet (see *2. Electrical Service*)	☐	☐
240V Level 2 EVSE, with changeable 20-40A settings	☐	☐
Portable version	☐	☐
Installed hardwired version	☐	☐
Housing for installed hardwired version	☐	☐
Ask employer about installing Level 2 charger	☐	☐

9. Rooftop Solar PV Panels	HAVE	WANT
Check your roof's sun potential	☐	☐
Quotes from **energysage.org**	☐	☐
Inverter:		
String inverter	☐	☐
Microinverters	☐	☐
Power optimizers	☐	☐
Do-it-yourself version	☐	☐
Solar panels	☐	☐
Mounting system	☐	☐

10. Home Battery Storage	HAVE	WANT
AC coupled	☐	☐
DC coupled	☐	☐
Standalone backup battery	☐	☐

Other Activities	HAVE	WANT
Electric leaf blower	☐	☐
Electric chain saw	☐	☐
Electric hedge trimmer	☐	☐
Electric lawn mower	☐	☐
Electric snowblower	☐	☐
Electric snowmobile	☐	☐

Renter Checklist

→ If you're a renter, this list will help you *Electrify Everything in Your Home* as you go through Rewiring America's guide: **rewiringamerica.org/electrify-home-guide**

→ Also download *Redwood Energy's Pocket Guide to All-Electric Retrofits of Single-Family Homes* to see product options for many of these items: **redwoodenergy.net/research**

Which of these modern electric options do you want working for you?

1. Purchase Renewable electricity	HAVE	WANT
Your utility's renewable plan	☐	☐
If shared meter ask landlord to switch	☐	☐
Community Solar subscription	☐	☐
Community Wind subscription	☐	☐
Reduce your electricity needs	☐	☐
LED light bulbs	☐	☐
Power strips to shut off standby loads	☐	☐

3. Space Heating and Cooling	HAVE	WANT
Packaged heat pumps	☐	☐
Window unit heat pump	☐	☐
Portable heat pump	☐	☐
Other heating options:		
Plug-in space heater	☐	☐
Electric blanket	☐	☐
Electric fireplace	☐	☐
Electric outdoor patio heater	☐	☐

4. Hot Water	HAVE	WANT
Reduce your hot water needs	☐	☐
Leaks and drips fixed	☐	☐
Low-flow shower heads	☐	☐
Low-flow faucets & aerators	☐	☐

5. Electric cooking	HAVE	WANT
$50+ portable induction burner	☐	☐
Other electric cooking options:		
Electric crockpot	☐	☐
Electric multi-cooker	☐	☐
Electric wok	☐	☐
Countertop toaster oven	☐	☐
Electric camp stove	☐	☐
Electric barbeque	☐	☐

6. Clothes washing	HAVE	WANT
Clothes drying rack or clothesline	☐	☐
Combined washer / condensing dryer, 120V ventless	☐	☐

7. Electric Vehicles	HAVE	WANT
Driving plan	☐	☐
Plug-in Hybrid Electric Vehicle (PHEV)	☐	☐
All Electric Vehicle (EV)	☐	☐
120V Level 1 Charger (included with EV)	☐	☐
Other electric transportation:		
Electric bicycle	☐	☐
Electric scooter	☐	☐
Electric skateboard	☐	☐

8. EV Charger	HAVE	WANT
Try included 120V Level 1 charger first	☐	☐
Ask landlord about installing Level 2 charger	☐	☐
Ask employer about installing Level 2 charger	☐	☐

10. Home Battery Storage	HAVE	WANT
Standalone backup battery	☐	☐

Other activities	HAVE	WANT
Electric leaf blower	☐	☐
Electric chain saw	☐	☐
Electric hedge trimmer	☐	☐
Electric lawn mower	☐	☐
Electric snowblower	☐	☐
Electric snowmobile	☐	☐

Endnotes

1 https://www.rewiringamerica.org/policy/one-billion-machines

2 These numbers assume a U.S. grid average of 13.8¢/kWh in a 350Wh/mile vehicle, and U.S. gas average of $3.20/gallon in an average 25mpg vehicle.

3 https://www.reviewed.com/ovens/features/induction-101-better-cooking-through-science

4 https://slate.com/technology/2021/08/tom-standage-brief-history-of-motion-electric-cars.html

5 https://en.wikipedia.org/wiki/Induction_cooking#History

6 https://www.sunrun.com/go-solar-center/solar-articles/what-is-the-life-expectancy-of-a-solar-battery

7 https://www.energy.gov/energysaver/home-energy-audits/professional-home-energy-audits

8 https://www.energy.gov/sites/prod/files/2020/01/f70/Guide%20to%20Federal%20Tax%20Credit%20for%20Residential%20Solar%20PV.pdf

9 https://fueleconomy.gov/feg/taxevb.shtml

10 For example, the Association of Bay Area Governments https://www.bayrenresidential.org/get-rebates

11 This San Diego realtor has more detail, including some California-specific options: https://www.mylenemerlo.com/blog/finance-energy-efficient-upgrades/

12 https://www.mortgageloan.com/environment

13 https://www.energystar.gov/newhomes/mortgage_lending_programs/energy_efficient_mortgages

14 https://www.mylenemerlo.com/blog/renovation-loans/

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16 https://www.cleanenergycu.org/home/fiFiles/static/documents/Clean_Energy_CU_Eligible_Products.pdf

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19 https://www.knowyouroptions.com/buy-overview/affordable-mortgage-options/homestyle-energy-mortgage

20 https://earth911.com/home-garden/finance-energy-efficiency-upgrades/

21 https://www.investopedia.com/terms/b/buydown.asp

22 "Growing Your Own" from Solar United Neighbors, https://www.youtube.com/watch?v=CzuTKSbMX3Q

23 https://www.pecanstreet.org/panel-size-paper-update/

24 https://homeguides.sfgate.com/check-amp-size-houses-electrical-service-72409.html

25 https://www.angi.com/articles/ask-angie-what-does-it-cost-upgrade-200-amps.htm

26 https://www.getneocharge.com/products

27 https://www.span.io/smart-panel-product

28 https://www.wired.com/review/span-smart-electrical-panel/

29 https://clean-coalition.org/ecmr-guidelines/ and https://www.switchison.org/assets/pdfs/Electrical%20Panel%20Upgrades.pdf

30 https://newbuildings.org/webinar/its-getting-betr-the-building-electrification-technology-roadmap-is-here/

31 For example, New York State's Clean Heat Contractors list: https://www.nyserda.ny.gov/Contractors/Find-a-Contractor/NYS-Clean-Heat-Contractors And Massachusetts's Installers Directory: https://goclean.masscec.com/installers-directory/

32 You can also learn about load calculation from an episode of This Old House, from 6:40-14:10: https://www.thisoldhouse.com/jamestown-net-zero-house/21053794/hvac-of-the-future-the-jamestown-net-zero-house

33 This is just one question in Nate's useful "Electrify Everything/HVAC 2.0 Contractor Interview Form.": https://docs.google.com/forms/d/e/1FAIpQLSdqkjs2joY2XVtu89gRu8PtQ7BU9l21c1IU6pguiPOlmTNiPA/viewform

34 http://www.natethehousewhisperer.com/home-comfort-101.html

35 NEEP: https://neep.org/sites/default/files/resources/ASHP_buyingguide_5.pdf, Department of Energy: https://www.energystar.gov/campaign/heating_cooling/10_tips_hiring, SoCal Gas: https://www.socalgas.com/save-money-and-energy/energy-saving-tips-tools/hiring-a-contractor, Finding a Contractor, https://www.youtube.com/watch?v=nQuwkcZPdLY, and https://docs.google.com/forms/d/e/1FAIpQLSdqkjs2joY2XVtu89gRu8PtQ7BU9l21c1IU6pguiPOlmTNiPA/viewform

36 https://neep.org/guide-sizing-selecting-ashps-cold-climates and https://neep.org/installing-air-source-heat-pumps-cold-climates

37 https://ashp.neep.org/

38 Watch two entertaining videos to learn more about heat pumps: "Heat Pumps: The Future of Home Heating" and "The Future of Heat Pumps is Underground (and other places, too!): https://www.youtube.com/watch?v=7J52mDjZzto and https://www.youtube.com/watch?v=7zrx-b2sLUs

39 From https://www.switchison.org/how-it-works

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41 "One ton" of cooling capacity, historically, referred to the amount of heat energy absorbed in the melting of one ton of ice over 24 hours, which is 288,000 British Thermal Units (BTU), or 12,000 BTU/hour. From https://inspectapedia.com/heat/Tons-Cooling-Capacity.php

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50 https://www.contractormag.com/management/article/20874577/hp-water-heaters-where-the-rubber-meets-the-road

51 https://www.energy.gov/articles/new-infographic-and-projects-keep-your-energy-bills-out-hot-water

52 https://www.eco2waterheater.com/product-info

53 https://www.heat2o.com/

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55 From BayREN's FAQ: https://www.bayren.org/residentialhpwh

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About Rewiring America

Rewiring America is a growing nonprofit, working to launch a movement that electrifies everything, starting with our 121 million households. Through accurate, accessible, and actionable data and storytelling tools that power smart, inclusive advocacy and market-transforming partnerships, Rewiring America aims to achieve national emissions goals, improve our health, lower monthly bills, and create millions of clean energy jobs. Join us at **rewiringamerica.org** and **@rewiringamerica**.

Feedback Welcome

This guide is our best effort to help you make a plan to electrify everything. If you have any feedback on its contents, including corrections, suggestions, improvements, and your own electrification stories of what you've done and challenges you've encountered, please don't hesitate to reach out at **electrifyhomeguide@rewiringamerica.org**. We plan to update this guide as technology changes and electrification becomes easier.

Electrifying everything in your home — whether you're a renter, owner, or landlord — can be a big undertaking. But it's worthwhile for your home's comfort and health, your energy resiliency, and the future of the planet's climate. Thanks for taking on the challenge.