How to Electrify A Residence Without A Panel Upgrade



Sean Armstrong Redwood Energy



Sean Armstrong

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- 1995-2019 The Campus Center for Appropriate Technology
- 2002-2005 High School Science Teacher
- 2005-2011 Affordable Housing Project Manager, Pacific West Communities
- 2011-Today Redwood Energy's Managing Principal. ZNE Design and Research.









1935: The Rural Electrification Administration



1950s: Com Edison Funds a Hit TV Show and Reagan's Demonstration Home



"You can live better—electrically." Gov. Ronald Reagan's catchphrase 1954-1963

"The biggest evil is fossil fuels: it's coal, it's gasoline, it's the natural gas." -Gov. Arnold Schwarzenegger 12/3/18

"This [Adobe] tower represents one of the cleanest investments that's ever been made...an all-electric tower."

-Gov. Gavin Newsom 7/16/2

The NEC Code Has Changed Over Time

- 1947: In the 1947 through 1959 National Electrical Codes, a <u>60 Amp, 240</u>
 <u>Volt</u> service was the norm totaling 14,400 Watts:
- 1962: The 1962 update to the National Electrical Code (NEC) was the first to require <u>100 Amp, 240V service</u> of almost all homes, totaling 24,000 Watts



Q: How Many CA Houses Have 100 Amp Services? A: About 9.5M of about 13M



The National Electric Code has formulas (e.g. 3 W/sf for plug/lighting circuits) and mandates (e.g. two 20 Amp kitchen appliance circuits) that determines a panel and service capacity



Founded in 1896!



Consider Avoiding a Panel Upgrade

200 Amp 48,000 Watt Panel

1)

400 Amp, 96,000 Watt Panel



50 Amp 12,000 Watt Panel



100 Amp 24,000 Watt Panel



High Power Efficient Appliances (240V)

Product Type	Electric Dryer-Energy Star	Heat Pump Water Heater	Split Heat Pump 2-4 Tons
Maximum Rating	30A, 7,200W	19A, 4,500W	18-29 Amps, 4,300W- 7,000W
Make and Model	Whirlpool WED5620HW	Rheem Prestige	York YZH060 Series
Image			

Power Efficient Appliances (120V)

Power at the panel is the limiting factor, but reducing appliance voltage can be another strategy

Product Type	4.5 cu ft Condensing Washer/Dryer Combo	Heat Pump Water Heater	Through-Wall Heat Pump	Mini-Split Heat Pump
Maximum Rating (Amps, Watts)	10A, 1200W	8.3A, 1000W	6.3-15A, ~ 1400W	10.4A, 1090W
Make and Model	LG WM3998HBA	GE GeoSpring	Innova HPAC 2.0	LG LS-120HXV
Image				

The Range of Power Efficiency in HVAC Heat Pumps

Seasonal Energy Efficiency Rating (SEER)



Heating Seasonal Performance Factor (HSPF)

The Role of Air Leakage in Power Demand



Design Temperature (°F)

Plug-In Cooktops

These 120V cooktops can plug into any outlet in your home. Countertop resistance ranges cost less than \$20 for one burner and \$30 for two burners. A countertop induction range can cost as little as \$50 for one burner and \$140 for two burners.

Brentwood	Brentwood	IKEA	DrinkPod
resistance plate	resistance plates	induction	True Induction
\$18	\$30	\$50	\$140

Plug-In Cooking Appliances

These 120V models can plug into any outlet in your home and can fry, stew, bake, roast, rotisserie, steam and air fry, using the versatility and controllability of electricity to provide more services than larger, standard ovens. The largest models can accommodate a small-medium size turkey.

Constant Con				
Crockpot 2 Quart Insulated Slow Cooker	Instant Pot 3 Quart Insulated Multi-Function Cooker	Presto Stainless Steel Electric Wok	Elite Combination Oven/Griddle/ Steamer	Oster French Doors, XL Capacity Convection Oven (Staff Favorite)
\$10	\$60	\$80	\$40	\$160
Insulated cookware uses 1/4 th as much electricity to get the same job done, regardless of whether it's slow or fast.	This insulated multi-function vessel can slowly make yogurt, pressure cook beans and rice, steam vegetables and stew meats.	Electric woks can steam, bake and stir- fry, spreading heat evenly through the wok.	Many small oven appliances are multi-function—this one is unusual in having a griddle/steamer on top.	This oven can bake a modest Thanksgiving turkey and is controllable for high performance baking.

	3000 >		
Electric	Whynter ARC-122DHP	Mr. Cool	Innova HPAC 2.0
Resistance Heaters	Mobile Heat Pump	DIY-12-HP-115B Ductless Minisplit	Through-wall heat pump via two 6" ducts
\$50+	\$440	\$1450	\$2000
For one room.	10,000 BTUs/Hr is	12,000 BTUs/Hr heat pump works	10,000 BTUs/Hr heat pump works
Enclosed	enough for a big living	down to 5F. 120V, quiet, designed	down to -5F, has supplemental
heating	room down to ~20F.	for self-installation, but needs	resistance heating. 120V, can plug
elements are	120V, audible fan, for	dedicated circuit. (Note that the	into any circuit (doesn't require a
safest.	a warmer climate.	ugly fan coil box sits outside, just	dedicated circuit), quiet, designed for
		like an A/C unit.)	self-installation.

Water Heaters

An electric resistance model can come in smaller sizes and fits the smallest construction budgets. Heat pump water heaters start at 40 gallons (although 20-gallon models in Eurasia are coming to the U.S. market), cost 3x as much to buy but use only 1/3rd as much electricity as a resistance water heater.



Smart Circuit Splitters and Sharing

- For expanding capacity for EV charging and avoiding expensive charger installs
- These are best used for non-EV appliances when one load is a short interruption of the other
- For extremely small electrical panels, these will be crucial, especially 120V devices

	BSA Electronics ^{xii}	Neo Charge ^{xlii}	EV-PowerShare ^{xliii}	SimpleSwitch ^{xiv}
	Dryer Buddy	Smart Splitter	EV-PS Smart	240V / EV Circuit Switch
				e e e e e e e e e e e e e e e e e e e
Cost	\$200 - 365	\$450 (smart splitter) \$500 (dual car splitter)	\$375	\$575 / \$675
Description	 Plugs into a 30A circuit (common dryer plug) and allows for vehicle charging while dryer is not in use. It has a digital display that shows the draw of each load. 	 Level 2 charging without rewiring or panel upgrade Pauses EV charging for other large loads then resumes charging Also have a "dual car" option – charge two EVS at half power, or fully charge one then the other 	 Plug into a NEMA 10-30 or NEMA 14-30 high voltage wall socket. Set EV service equipment to 24 Amps. (24 amps max recommended continuous load for 30- amp circuit) Plug high voltage appliance into left socket, plug your EVSE into the right. 	 One load is the "primary" load and the other is the "auxiliary" - if the primary load comes on, the auxiliary load will shut off. EV version is EVSE Useful for short- load/long-load sharing such as electric baseboard heating with overnight EV charging

Power Efficiency Options



All Electric 100 Amp Home (2,000 square feet)

Ducted heat pump, medium power heat pump water heater, hybrid heat pump dryer



2000sf on 100 Amps



Additional House Information

- 4 occupants
- EV charging up to 19 miles/hr
- Located in California climate zone 3 (SF Peninsula)
- Some insulation
- 38,000 Btuh heating and cooling
- Diagram creation and design by Josie Gaillard and Courtney Beyer

- 60-80 gallon heat pump water heater
- 4-burner induction or standard electric range
- 7.4 cu. foot hybrid heat pump dryer
- A 20-amp circuit will support a 3.8 kW inverter. (Many 3.8 kW inverters can support roughly a 4.6 - 5.9 kW solar array depending on inverter load ratio)

All Electric 100 Amp Home (3,000 square feet)

Two "automatic sharing" circuits, ductless mini split heat pump, resistance dryer, high power heat pump water heater

3000sf on 100 Amps





Additional House Information

- . EV charging up to 38 miles/hr
- Located in California climate zone 3 (SF Peninsula)
- Some insulation
- . 48.000 BTU heating and cooling

- 40-80 gallon heat pump water heater
- 4-burner induction or standard electric range
- 7.4 cu. foot standard resistance dryer
- A 20-amp circuit will support a 3.8 kW inverter. (Many 3.8 kW inverters can support roughly a 4.6 - 5.9 kW solar array depending on inverter load ratio)

A Classic California **Tiny House** Built to RV Code. 30 Amps at **240**V. ≡≡ Total





Tiny Veterans Housing in Santa Rosa. 60 Amps at

Cottages at Cypress in Fort Bragg. 100 Amps at 240V











The DIY Electrification for \$6500 at Tom Kabat's "Modest Manor"



Figure 37: The Modest Manor's Mr. Cool Minisplits heat pump and induction cooktop.

Appliance	Type of Cost	Cost	DIY Labor Hours	Specifications
	Appliance	\$1,200	4	50 Gal. HPWH from Lowe's
Heat Pump	Electrical	\$150	5	New 240V 30A circuit in flexible armored conduit
Water Heater	Pipes and fittings	\$190 for materials & lunch for my buddy	10	Connectors and ball valves for future hydronic heating coil plus condensate pump and line
Window Heat Pump	Appliance	\$390	1/2	Frigidaire 8,000 BTU/h 120V plug-in window heat pump. # FFRH0822R1
	Appliance + shipping	\$1,600	1	Mr. Cool DIY 12,000 BTU/h variable speed 120V
Mini-Split	Electrical	\$120	5	New dedicated 120V 20 Amp outdoor outlet serving as "disconnecting means"
neatrump	Head Installation	Free with my buddy after we did hers	9	Watch video, mount bracket, drill hole, pass line-set through it
	Compressor Installation	\$40	3	Bolt to plastic base on gravel bed
	Appliance	\$900	1	Frigidaire Gallery "36
Induction Cooktop	Electrical	\$190	5	Crawling under house to run new 240V 40A circuit
Combined Washer/Condensing Dryer	Appliance	\$1,600	1	It just plugs in where the prior washer was and replaces washer and dryer.
Total	Gross Cost	\$6,400	45	Net Incremental Cost \$1,400 if we subtract out the cost of new gas machines.

The "Watt Diet" Calculator

- Developed by Tom Kabat and Redwood Energy
- Follows the California electrical code requirements
- General methodology:
 - Calculates building heating load based on building characteristics and location
 - Calculates the total watt diet of the home
 - Converts total watts to panel amps
 - From there you can determine your needed panel size
- Allows pinpointing of appliances that are electricity guzzlers
- Integrates EVSE and load management with your whole house

https://www.youtube.com/watch?v=XQJzoP2br1Y&t=28s&ab _channel=RedwoodEnergy

	Device	Select with Dropdown Menu	Volts	Rated Amps	Circuit Size (Amps)	Calculated Power (Watts)
	Lighting+Plugs 3W/square foot	:				6,000
aseline Loads	Kitchen Countertop Circuits					3,000
	Dryer Circuit					1,500
aundru	Washer	Washing Machine: LG	120	-	10	1,200
aunury	Dryer (or Combined	Heat Pump Dryer: Bloomberg	240	5	-	1,200
	Fridge	Fridge: Frigidaire 20.4 cuft	120	6	-	720
	Garbage Disposal	Garbage Disposal: GE	120	4	-	480
	Dishwasher	Dishwasher: Frigidaire	120	-	10	1,200
litchon	Kitchen Hood	Kitchen Hood: Broan	120	1.4	-	168
atchen	Optional: Microwave	**Select Device**	-	-	-	
	Range (oven and cooktop)	**Select Device**	-	-	-	
	Built in Oven	Oven: Built in GE	240	11.9	20	2,856
	Cooktop	Oven: Built in Whirlpool	240	11.6	20	2,784
Water Heating	Water Heater	Heat Pump Water Heater: Rheem 30 Amp	240	21	-	5,040
	User Defined Heat Pump (selec	ted above)	-	-	-	4,720
leating, Cooling and	Heat Pump	**Select Device**	-	-	-	
/entilation	Air Handler Fan (for central ducted system)	**Select Device**	-	-	-	
electric Vehicle Charging	EV Charger	EVSE Level 2 (med)	240	30	40	7,200
	selection: use the drop down m	enu to choose what strategy of power managem	nent you would like	to use. The sele	ctions are repre	esentative of real
products. An example of subtracted from the Watt Smart" Circuit Splitter	Selection: use the drop down m how it works: when selecting "car Diet. Circuit Sharing Device	enu to choose what strategy of power managerr to dryer" the EV charging will pause when the of Car to Dryer (Product Example: DryerBuddy)	hent you would like dryer runs, therefo -	to use. The select re the lesser pow	ctions are repre ver draw of the <i>Watts Saved:</i> Formula Bar	esentative of real two will be 1,200
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Step 1: Heating Load Estimate

Enter building parameters and design temperatures

Result is the heating load in BTUh with and without ducts:

Ductless Heating Demand	
Sub total (BTUh-DegF)	383
Ductless or ducted in	
thermal envelope heating	
demand (BTUh)	13,421
Duct Loss Subtotal (BTUh-Deg	96
Duct Loss Total heating	
demand (BTUh)	3,355
Ducted Heating Demand	
Sub Total (BTUh-DegF)	479
Total Ducted in Attic	
heating demand (BTUh)	16,777

aiue	UA (Btu/nrF)
0.25	48
6	10
13	67
38	12
30	-
5	135
6,163	111
	-
	'alue 0.25 6 13 38 30 5 6,163

Step 2: Determine your heating and cooling product

Enter product specs that roughly match your heating load

The heating capacity and power are interpolated to the specified design day



This gives us an idea how much power will be used for heating



2. Determine Heating a	nd Cooling Product		· · · · · · · · · · · · · · · · · · ·			
2a. Use NEEP's Cold Climate	e Heat Pump List to find p	roduct wi	th roughly the	same heating	capacity nee	ded
(BTUh)						
Resource: NEEA Heat Pump Li <u>h</u>	ttps://neep-ashp-prod.herok	uapp.com/	#!/product list/			
Resource: Example link to NE <u>h</u>	ttps://neep-ashp-prod.herok	uapp.com/	#!/product/2645	<u>6</u>		
2b. Type in values or copy a	nd paste heating equipn	nent data	below (make s	ure outdoor a	nd indoor	
temperatures are entered a	as numbers)					
Name/model of product (D	aikin VRF					
Heating	Outdoor Dry Bulb	Indoor Temp	Unit	Min	Rated	Max
Heating	5	70	Btu/h	14,860 -		37,900
		kW	1.1 -		4.06	
		COP	3.96 -		2.74	
Heating	70	Btu/h	16,460	25,800	42,000	
			kW	1.2	2.7	4.43
		COP	4.02	2.8	2.78	
Heating	70	Btu/h	16,460	42,000	42,000	
		kW	0.87	3.2	3.2	
			COP	5.54	3.85	3.85
Data is interpolated for hea	ting design temperature	•				
Interpolation Factor	0.60					
	Outdoor Dry Bulb	Indoor Temp	Unit	Min	Rated	Max
Heating Design Temp	35	70	Btu/h	16,460	35,520	42,000
			kW	1.00	3.00	3.69
			COP	4.93	3.43	3.42
The heating load is estimat	ed for each outdoor air te	empature	and is compare	d to equipm	ent data	
		Design Terr	p			
	5	17	35	47		
Heating Load Estimate Ducted (BTUh)	31,157	25,405	16,777	11,025		
Heating Load Estimate Ductless (BTUh)	24,925	20,324	13,421	8,820		
Equipment Heating Capacity						
Max (BTUh)	37 900	42 000	42 000	42 000		
Equipment Heating Power						
Max (kW)	4.1	4.4	3.7	3.2		
Equipment Heating COP	2.7	2.8	5.5	3.8		

Step 3: Calculated total *device* watts

- Enter in number of devices
- Enter in either volt and amps or watts for each device
- Total device watts are calculated

	Device	Number of Devices	Volts	Label Amps	Watts	Power (Watts)
	Lighting+Plugs 3W/square foot	-	-	-	-	3,000
Baseline Loads	Kitchen Countertop Circuits Washer Circuit					3,000 1,500
	Resistance Dryer		240	18	4200	-
Laundry	HP dryer		120	8	800	-
	Combined Wash/Dryer	1	120	10		1,200
	Fridge	1	120	10		1,200
Kitoboo Dlug Loods	Disposal	1	120	3		311
Kitchen Plug Loads	Dishwasher	1	120	10		1,200
	Built in Microwave	1	120	8	1200	1,200
Kitchon Bongo or Ovon	Built in Oven		240	40		-
and Coakton	Cooktop		240	40		-
and Cooktop	Range (cooktop on oven)	1	240	40		9,600
	Resistance WH		240	30	4500	-
Water Heater	Hybrid WH		240	15	2520	-
water neater	HP only WH	1	240	13		3,120
	120 V HP WH		120	9		-
	Heat Pump	1	240	10	4	2,400
Heating and Cooling	HP SC 2 tons		240	12	3,860	-
nearing and Cooling	HP SC 3 tons		240	18	4	-
	System Ducted? FAU		120		-	-
Electric Vehicle Charging	EVSE 40 Amp		240	40		-
		Total Watts (before co	incidence calculation)			26,231

Step 3: Whole total *panel* watts

- Panel watts are calculated by multiplying device watts by a coincidence factor
- The first 8,000 watts are 100% coincidence, the remaining watts are 40%
 - Heat pumps are 100% coincidence
 - Heat pump water heaters are 40% coincidence
 - EV charging is 50% coincidence

Total Watts (before coincidence calculation)		26,231
	Coincidence Factor	Panel Watts
The first 8,000 Watts	1	8,000
Heat Pump Watts	1	2,400
Remaining Watts	0.4	15,831
Total Panel Watts		16,732
Total Panel Amps		70
Minimum Panel Size		100
Allowed Watts		48,000

