Some Things I Learned in the San Mateo County (BayREN) Study (and afterwards)

How Programs, Utilities and Contractors can work together for smoother electrification

BayREN Fall Forum

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Slides Courtesy of: Josie Gaillard, Tom, HEA and 3-C REN

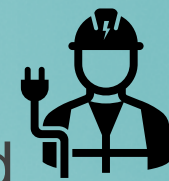
What I Learned

- Panels Have Lots of Amperage Space (to deliver more energy services)
- There are lots of ways of fitting circuit functions onto panels
- Some appliances recently became much more efficient at using power
- Overpowering things '*solves*' imaginary problems while causing real ones
- There are split incentives in the fragmented value chain that can be addressed with program design and education
- Some people are starting to get it. (Leading researchers, policy makers, program designers, engineers, manufacturers, contractors, concierge services, etc.).

Problem:

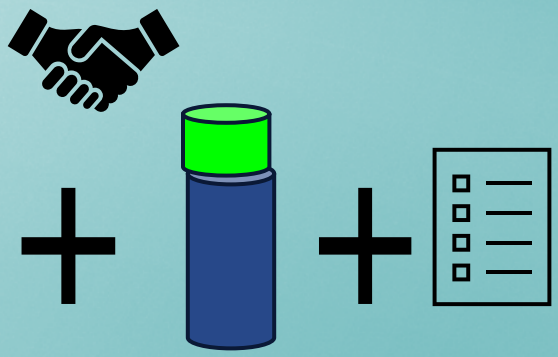
Split Incentives

- If we are bad stewards of the panel:
  - We would accidentally paint the customer into a corner (from high Amps)
  - They would need a panel upsizing before they can finish full electrification
  - Oversized loads would jam up the neighborhood transformers and wires
  - Utility staff and utility supply chain are backlogged. Electricians backlogged too
  - Projects take too long waiting for utility permission
  - Utilities yank the program support and wait until they can upgrade each neighborhood. Customers get resentful.
- All this is bad for everyone's business and the climate



Solution

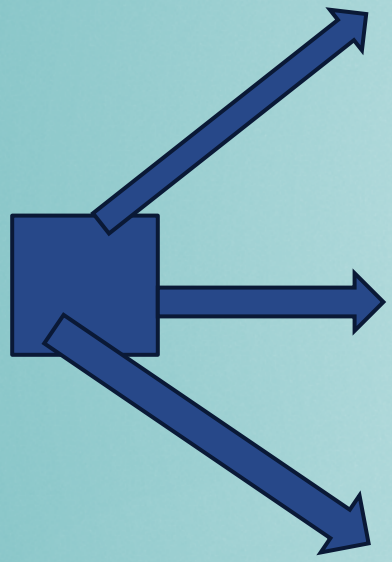
- **Programs and Contractors being good stewards of the panel.**
- Contractors right sizing high performance inverter-driven heat pumps etc.
- Avoiding resistor strips in HVAC.
- Putting in stout wire and smaller nameplate machines on right sized breaker
  - e.g. a 17 Amp machine on a 40 Amp capable wire connected to a 20 Amp breaker. (Breakers list the wire sizes that fit breaker jaw)
- Contractors getting the job based on being good stewards
- Branching into HPWHs and Electrification Plans for customers



Panel Optimization aka. “Watt Diet design” (Making equipment choices to fit on the panel)

- **Societal Benefits**
  - Preserves workforce for more rapid electrification
    - Electricians, Utility line crews, Utility project planners, Distribution engineers
  - Leaves more neighborhood space for electrification on distribution wires
  - Keeps electric rates low by reducing and delaying transformer upsizing etc.
  - Starts a virtuous cycle of rate reduction and electrification
  - Long steady inverter duty cycles help support solar power usage
  - Reduces use of fossil peaking plants

Our Choices:



- **Make a Plan (so we do it right and tell the customer)**
  - Talk about it. Make a copy for the customer. Then:
    - Use good, inverter driven, high COP, right sized equipment without resistor strips
- **Do it right without a plan (strong silent type, or lucky)**
    - Use good, inverter driven, high COP, right sized equipment without resistor strips
- **Do it wrong**
    - Use cheaper one speed or two speed, lower COP, oversized equipment and maybe with resistor strips (contractor shifting risk & cost onto customer & utility)

Problems of Electrifying WITHOUT a Plan

- Homeowner's 1st electrification projects use up too many panel amps
- Advised by contractor who is not thinking about whole-home electrification
- Worst offenders:
  - 50-amp car chargers
  - 50-amp HVAC systems

Problems of Electrifying WITHOUT a Plan

- Electric panel is poorly filled!
- Panel and service line need to be UPSIZED
- Utility gets involved
- Long wait times (several months)
- Could cost $4,000 (overhead service line) or $20,000 (underground)

Single Family Homes
Lessons Learned for Staying on the Panel

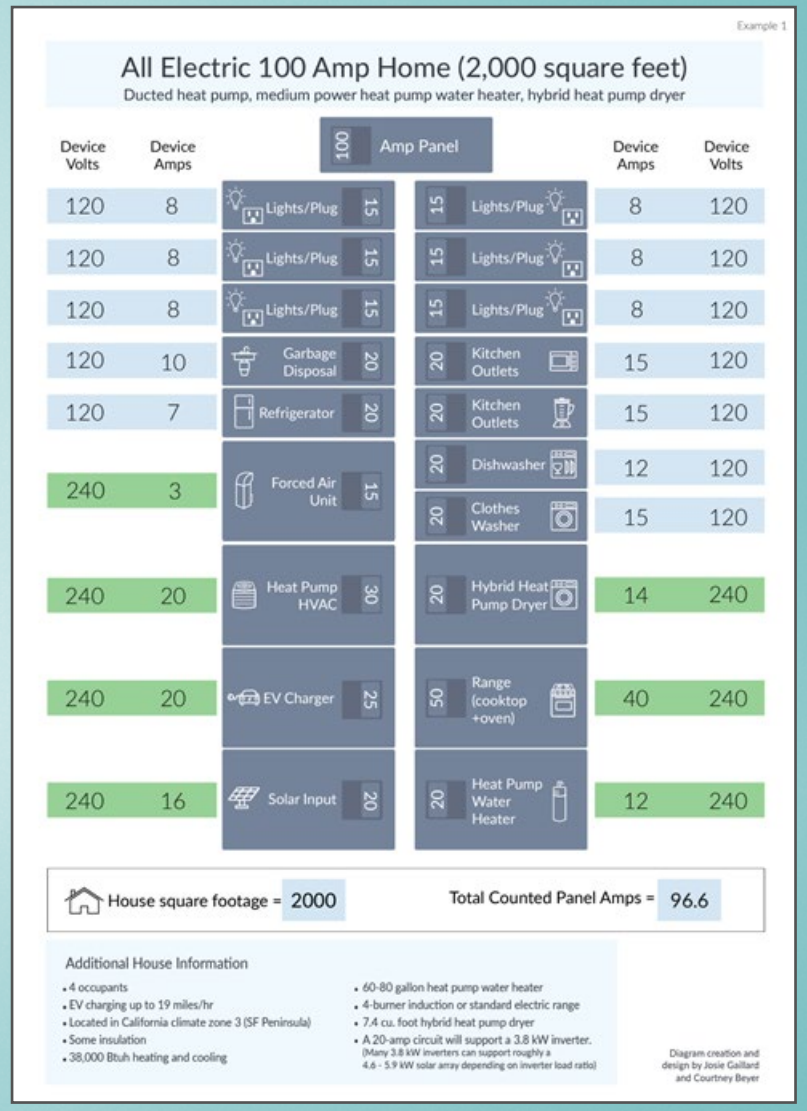
- Panels have lots of unused Capacity and lots of lightly used spaces
- Homes up to 3,000 square feet can easily fit All-Electric on 100A panels
  - By making good choices or making plans to make them
  - Be careful not to let any trade paint you into a corner.
  - Programs often don't yet encourage (or sometimes allow) smooth design.
- Homes above 3,000 square feet or below 80 Amps need to apply more solutions (if underground service wires) or choose upsize (if overhead service) .

Benefits of Electrifying WITH a Plan

- Helps avoid ~$5,000+ electric panel upgrade
- Provides roadmap for homeowner
- Helps guide tradespeople
- Helps avoid unnecessary work and costly mistakes
- Facilitates right sizing equipment (vs. oversizing)
- Home more likely to be power efficient and grid-friendly

Panel optimization works:

- If house is <3000 sq ft and located in mild climate, 100 Amp panel is usually sufficient
- **Caveat:** Homes with <60 Amp panels maybe should upsize panel and service line



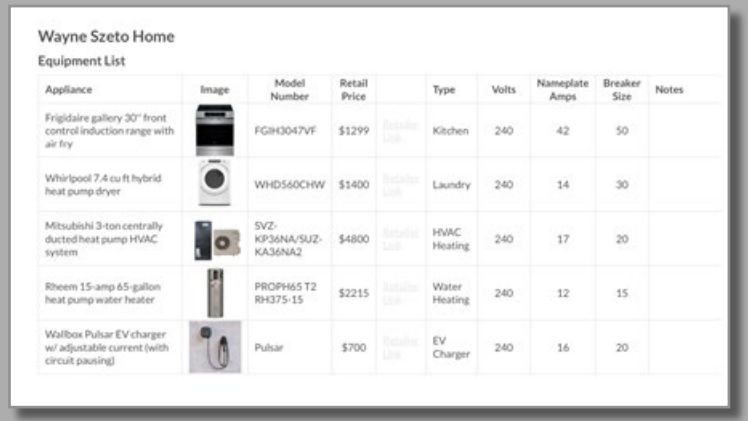
Components of an Electrification Plan

1. Recommended equipment list
2. Electrical load calculations per NEC 220.83(B) or 220.87
3. Wiring plan (optional but helpful)
4. Project list for contractors with photos of existing equipment and locations

Note:

- Homeowners can do their own or get help from an expert
- Plan takes expert ~30 minutes, or homeowner can do it in ~3 hours

Electrification Plan



Wayne Szeto Home

Equipment List

Appliance	Image	Model Number	Retail Price		Type	Volts	Nameplate Amps	Breaker Size	Notes
Frigidaire gallery 30" front control induction range with air fry		FGIH3047VF	$1299	Retailer Link	Kitchen	240	42	50	
Whirlpool 7.4 cu ft hybrid heat pump dryer		WHD560CHW	$1400	Retailer Link	Laundry	240	14	30	
Mitsubishi 3-ton centrally ducted heat pump HVAC system		SVZ-KP36NA/SUZ-KA36NA2	$4800	Retailer Link	HVAC Heating	240	17	20	
Rheem 15-amp 65-gallon heat pump water heater		PROPH65 T2 RH375-15	$2215	Retailer Link	Water Heating	240	12	15	
Wallbox Pulsar EV charger w/ adjustable current (with circuit pausing)		Pulsar	$700	Retailer Link	EV Charger	240	16	20	

Electrical Service Load Calculation

performed according to NEC Optional Method 220.83(B)

General Information:

Permit Applicant: _____ Phone Number: _____

Project Address: _____

Contractor: _____ License #: _____

Certification:

I certify that the information in the calculations below is accurate and complete.

Signature: _____ Date: _____

Printed Name: _____

Phone Number: _____ Email Address: _____

General Light and Plug Loads					Volt-Amps
Dwelling	2,350 sq. ft.	×	3 VA/ft²	=	7,050
Kitchen Small Appliance Circuits	2 (min. 2)	×	1,500 VA each	=	3,000
Laundry (Washing Machine) Circuit	1 (min. 1)	×	1,500 VA each	=	1,500

Appliance Loads (nameplate value)	Volts		Amps		Volt-Amps
Built-in Microwave (not countertop model)	120	×	10	=	1,200
Dishwasher	120	×	15	=	1,800
Garbage Disposal	120	×	9.5	=	1,140
Refrigerator (on dedicated circuit)	120	×	5	=	600
Stove hood	120	×	1	=	120
NEW: Frigidaire gallery 30" front control induction range with air fry	240	×	42	=	10,080
NEW: Whirlpool 7.4 cu ft hybrid heat pump dryer	240	×	14	=	3,360
NEW: Rheem 15-amp 65-gallon heat pump water heater	240	×	12	=	2,880

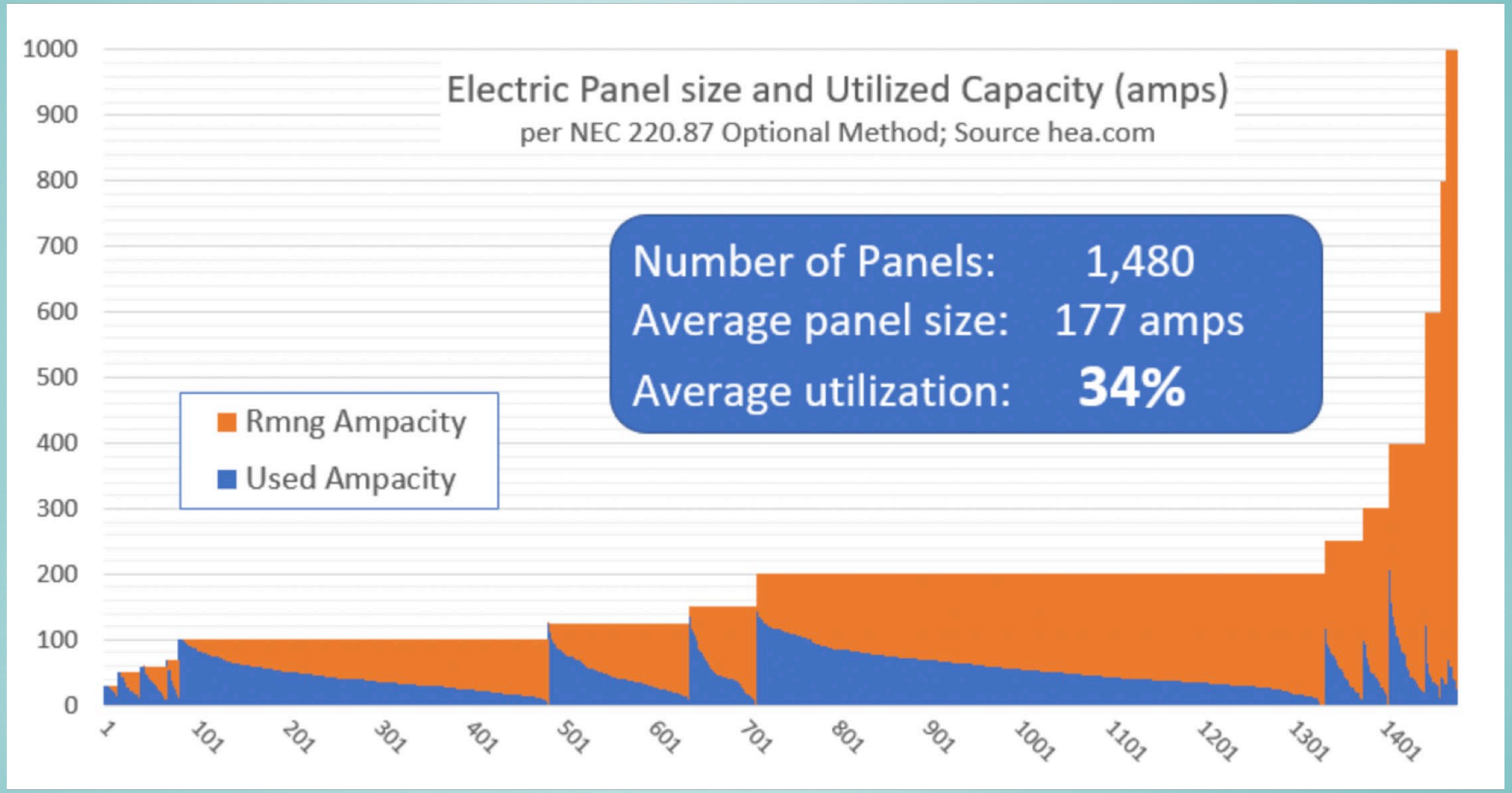
Project List for Wayne Szeto Home

Contractor Type	Description
Electrician	1. Use existing 100A service line. 2. Modify main electrical panel as specified in Electrical Panels Table. Main 100A electrical panel 3. Install 1 new subpanel as specified in Electrical Panels Table.

Why pick efficient solutions to start with?

- Isn’t there only one way to electrify?
  - (e.g. Aren’t all electric water heaters the same ?)
- Aren’t most panels already full anyway?
  - (They look full at first glance)

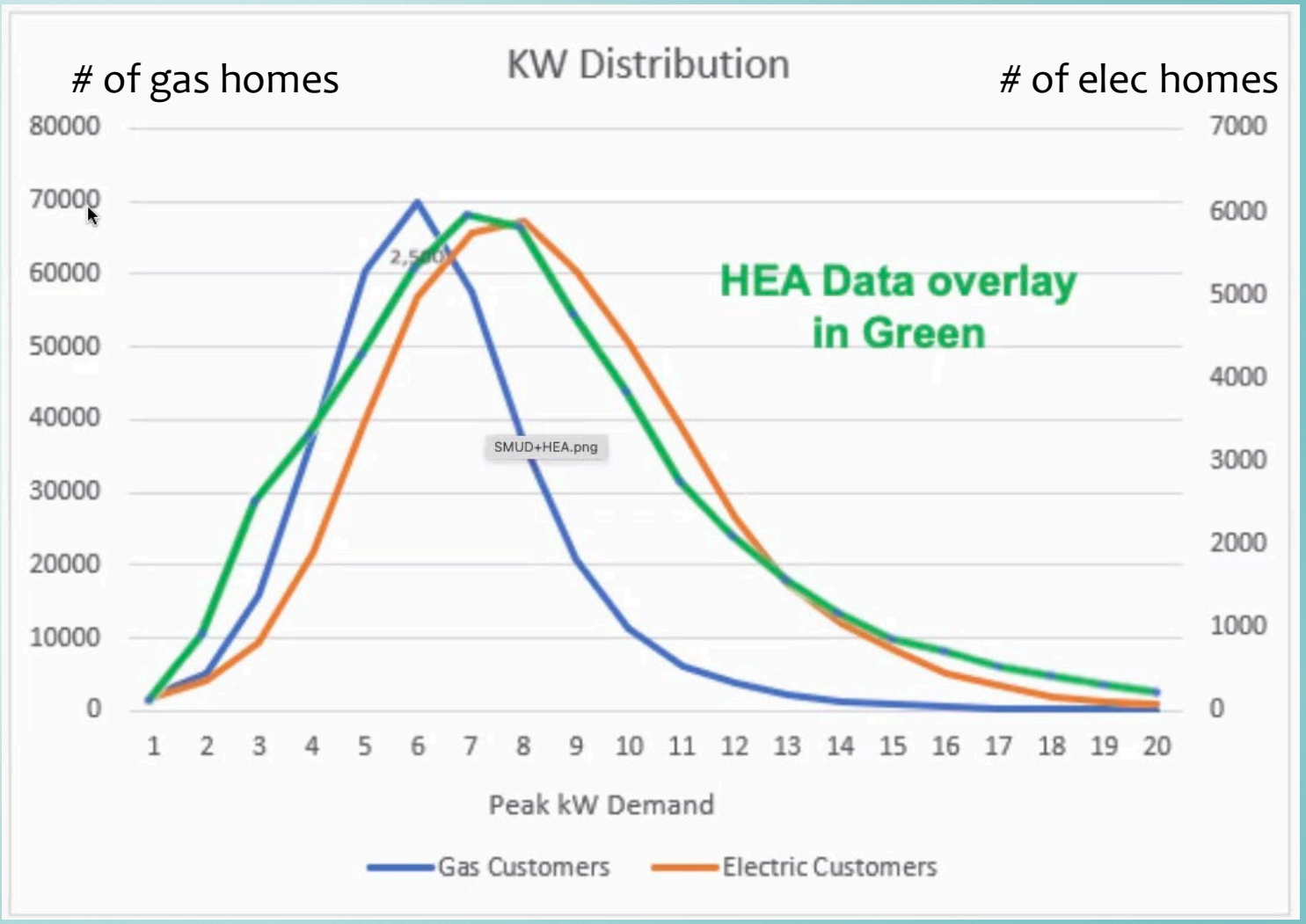
Panels have lots of Capacity



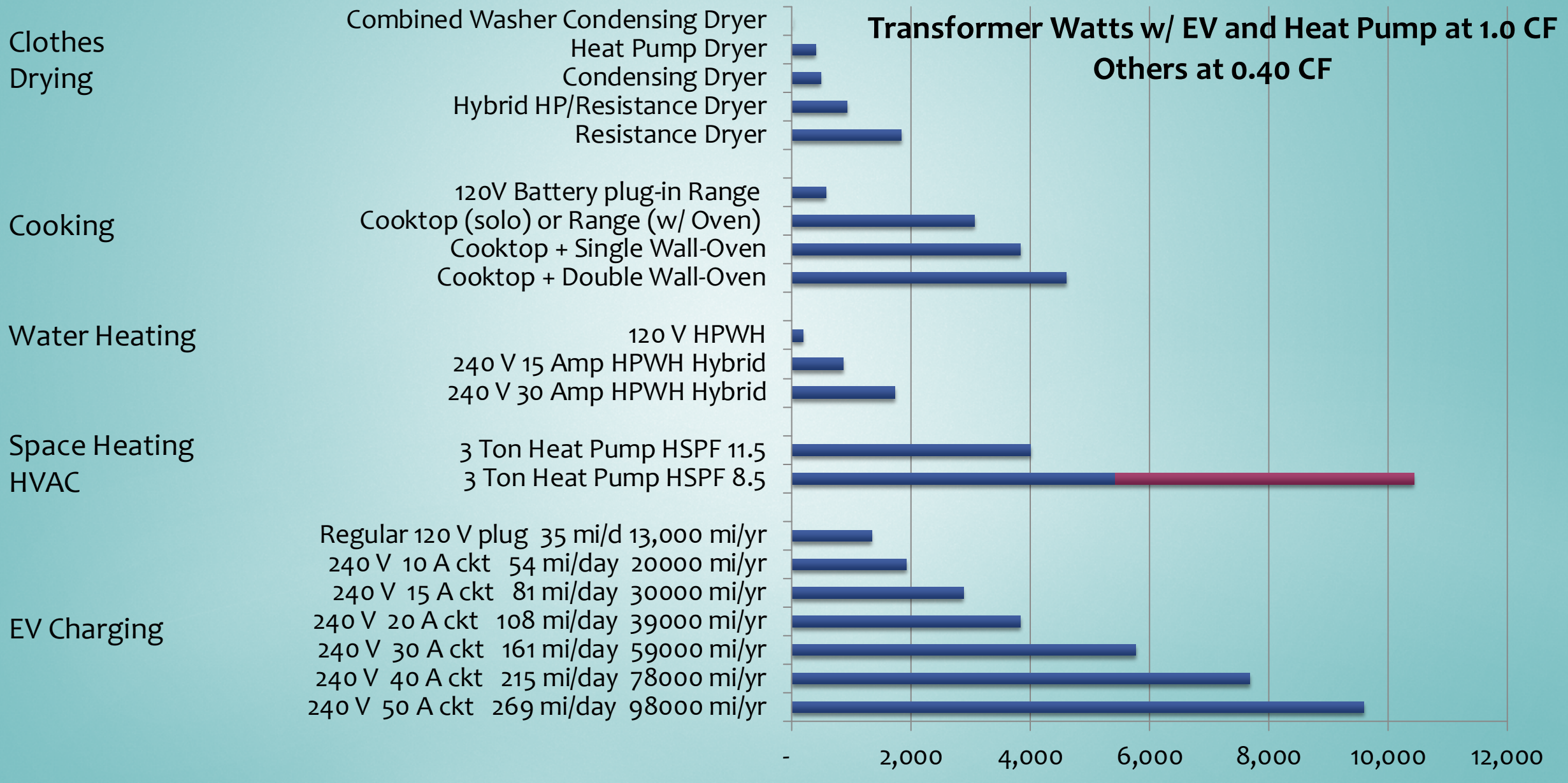
Slide Courtesy of HEA

Whole Home electrification does not add much to the peak

- This graph goes from 1 to 20 kW (up to 83 amps)
- Very few houses peak at 100 Amps 24 kW
- Orange minus Blue shows electrification adds about 2-4 kW of peak load to most gas homes.



Efficiency Varies Widely in each usage category



Approaches to staying on the panel

- Know How To Improve Building Envelope & Ducts
  - Air Sealing &/or Attic Insulation (before or after electrif)
- Choosing **Ducted <= 3Ton or Ductless** if ducts are bad or zoning is needed
- Right sizing of: **HVAC**, HPWH, EVSE
- Right choosing "Power Efficiency" of: **HVAC**, HPWH, Dryer
- Controls if needed (circuit sharers or pausers)
- Choosing ways to fit circuits

Two ways of getting…
Permission to add load to the panel

- **Top-down History Method: NEC 220.87**
  - Use metered or billing historic peak multiplied by 1.25 (spikey factor) + Full name plate load of new equipment (As though it's fully coincident with the old peak
- **Bottom-up Method: NEC 220.83 (B)**
  - Calculating the panel loads from nameplate loads X Demand Factors
    - Where: Demand Factor should be called Coincidence Factor.
    - It's an assumption about how fractionally coincident the device peak is with the building annual peak.

Load Calculation with 220.87

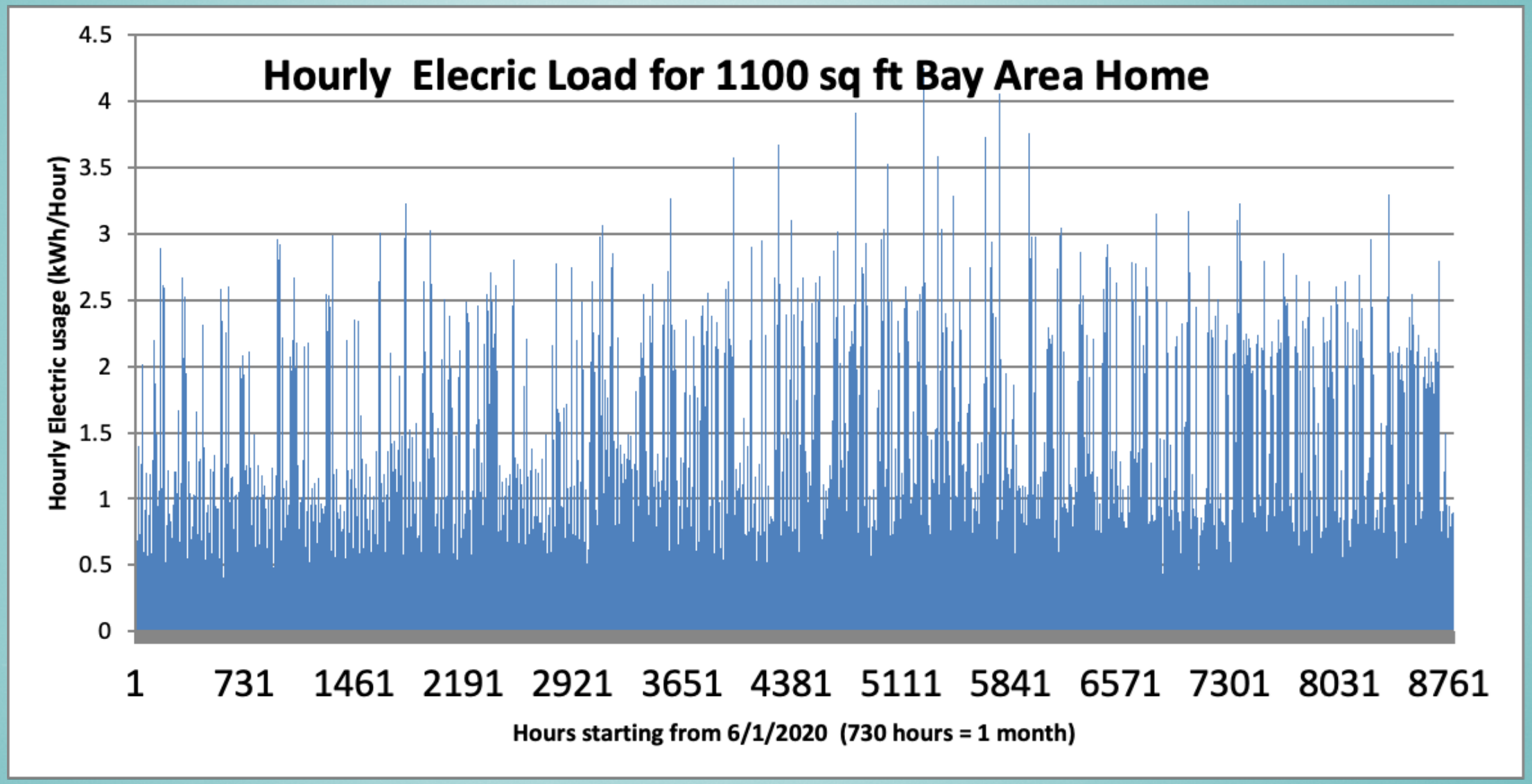
- Top-down history approach. (Good for adding 1-2 items)
- Starts with power capacity of the smaller of **main disconnect** or **panel rating**

  = Amperage rating X 240 Volts = **Wattage Rating**
- Then calculate occupied wattage on main disconnect or feeder

  = peak usage interval last year (highest 1-hr usage) in peak Watts

  Or = peak usage 15 minute interval in recent 30 days in peak Watts
- Peak Load * 1.25 = **Wattage Already Occupied**
- **Remaining Wattage Space** = **Wattage Rating** minus **Wattage Already Occupied**
- New devices are allowed
  - if their full nameplate wattage fits within **Remaining Wattage Space**
- Good for adding 1-2 new devices per year

Determining How Much Electrification a Panel can Accommodate



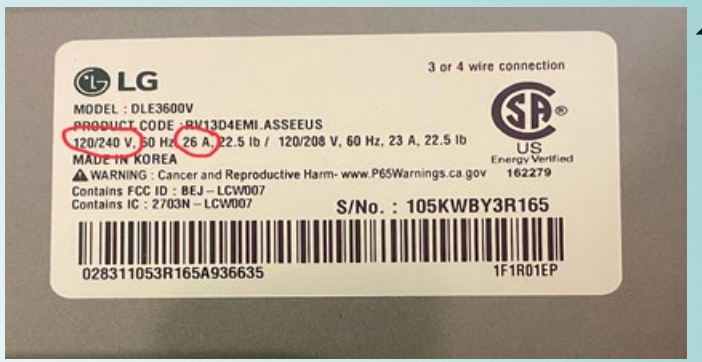
Example Load Calculation with 220.87

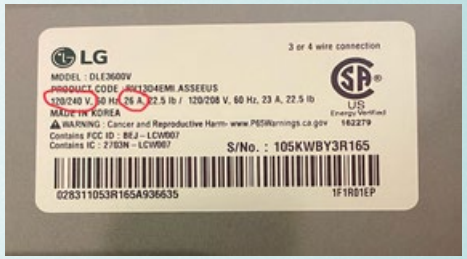
Panel Capacity: 100 Amps X 240 V = 24,000 W Rating

100 A 24 kW

4,000 W peak usage measured

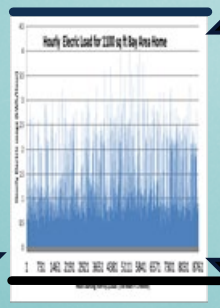
4,000 W peak usage X 1.25 = 5,000 W occupied

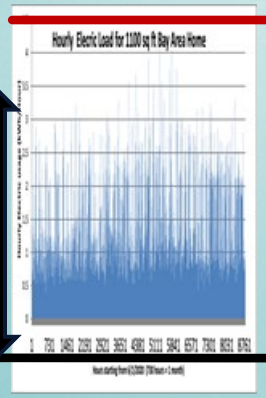




Remaining space available for full nameplates of new equipment:

19,000 Nameplate Watts (24,000-5,000 - 19 kW





5,000 W occupied

History not allowed if modified by solar or batteries or by load control devices

0

Bottom-up Method NEC 220.83 (B)

220.83 (B)

Good for When:

you lack history data…

or

you want to add 3 or more loads now

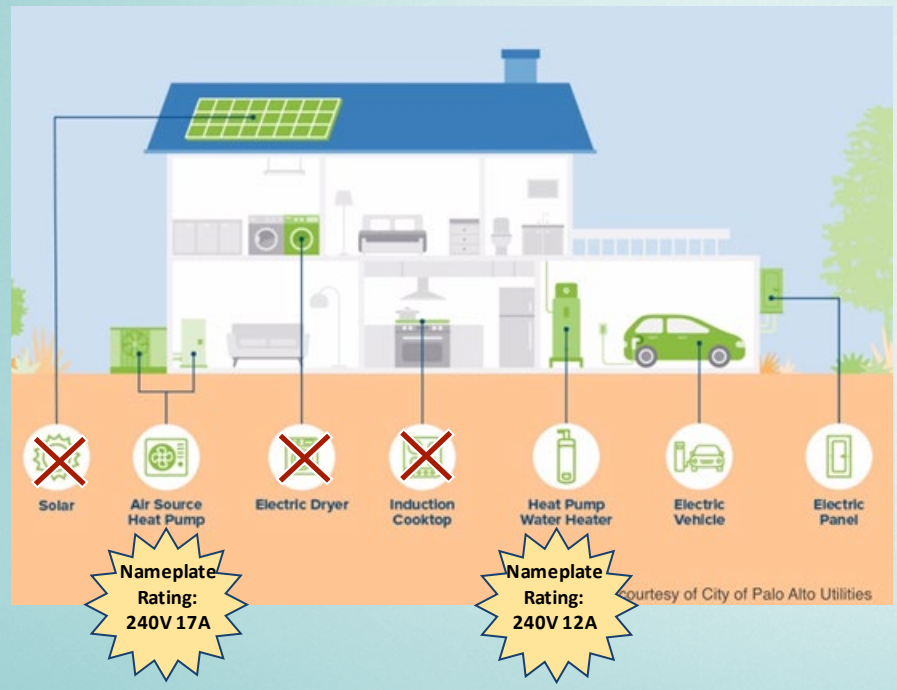
or

you already have solar or batteries

Load Calculation: Adding Electric HVAC, HPWH

Home B

Total floor area:	**2,000 sq ft**
Main service capacity:	**100 amps**
No. of gas appliances:	**2**



Load Type	Amps	Volts	Watts
Kitchen Circuit	12.5	x 120	= 1500
Kitchen Circuit	12.5	x 120	= 1500
Laundry Circuit	12.5	x 120	= 1500
Refrigerator	10	x 120	= 1200
Dishwasher	10	x 120	= 1200
Garbage Disposal	5	x 120	= 600
Lights + Plugs	(3 watts / sq foot)		= 6000

First 8,000 watts @ 1.0 coincidence factor = 8,000
Remaining 5,500 watts @ 0.4 coinc. Factor = 2,200

HVAC 4,080 watts @ 1.0 coincidence factor = 4,080
HPWH 2,880 watts @ 0.4 coincidence factor = 1,152
Total = 15,432

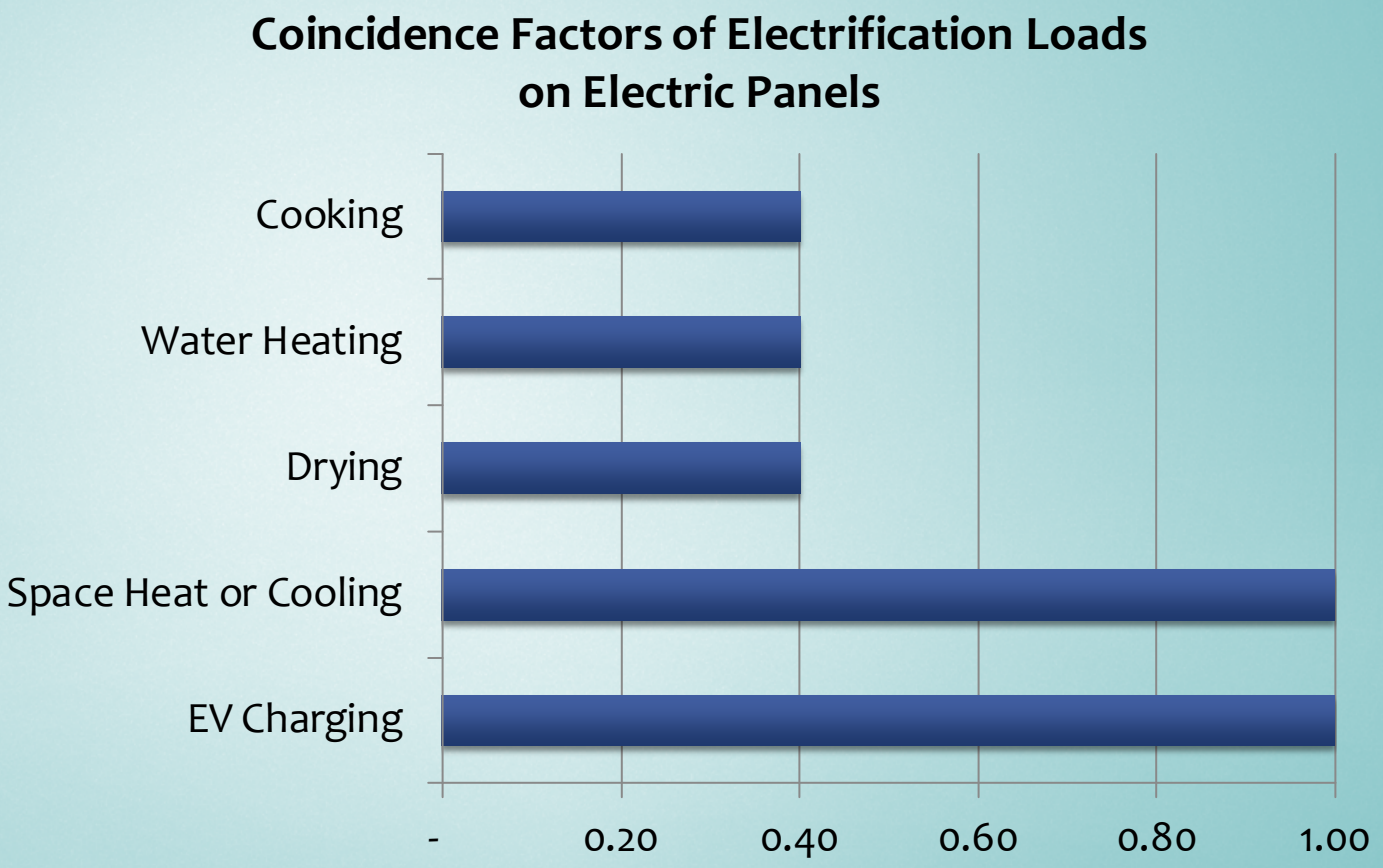
In this example, we use NEC code sections: 220.83 (B)

Amperage = 15,432 W/ 240V = 65 Amps

2
3

NEC Article 220.83(B) Coincidence Factors

- When using NEC 220.83(B), these are the electrification coincidence factors for adding equipment
- When using NEC 220.87, the factors are all 100% for adding equipment



Optimizing the Panel:

Electrically (Amps) [power to meet needs]

&

Physically (Spaces) [fitting new needs on]

7 ways to lower your panel amp requirements

1. Pick high efficiency equipment (Heat Pump HSPF > 10)
2. Pick power efficient versions of: heat, water heater, dryer, cooking
   e.g. HPs without backup resistance, low Amp HPWHs
3. Avoid oversizing (HP 2-3 tons for most homes, EVSE 20Amps = 39k miles)
4. Pick multifunction devices (e.g. combo washer/dryer, range)
5. Consider circuit sharing devices (e.g. alternate dryer & EV charger)
6. Consider circuit pausing devices (e.g. pauses charger or HPWH)
7. Decrease your loads (e.g. add air sealing, insulation and duct sealing) (go ductless)

11 ways to free up physical panel space

1. Pick multi-function appliances
2. Free up furnace circuit
3. Choose shared circuit version 120V HPWH
4. Use tandem or slim breakers
5. Automatic circuit sharing devices (two appliances share one circuit)
6. Junction box (join two low-load circuits)
7. Square D breakers can hold 2 circuits
8. Pig Tail breaker can hold 2 circuits
9. Add subpanel for ~9 circuits
10. Line tap solar
11. Use a meter collar (bypasses the main panel and connects to the meter)

2
7

Resources

- SwitchIsOn.org rebate finder https://incentives.switchison.org/?_ga=2.167415294.1341690265.1699243126-1608017970.1698895045&_gl=1*yxyda4*_ga*MTYwODAxNzk3MC4xNjk4ODk1MDQ1*_ga_8NM1W0PLNN*MTY5OTI0MzEyNi4zLjAuMTY5OTI0MzEyNi42MC4wLjA.

- Ashp.neep.org (Air source product guide to performance) https://ashp.neep.org/#!/product_list/
- PG&E Electrification Staying on the Panel Class: https://pge.docebosaas.com/learn/course/external/view/elearning/1206/home-electrification-retrofits-without-upsizing-the-electric-panel-previously-recorded

- Retrofit Guide for Homes https://www.redwoodenergy.net/research/a-pocket-guide-to-all-electric-retrofits-of-single-family-homes

- Watt Diet Site https://www.redwoodenergy.net/watt-diet-calculator

- PCE Electrifcation Guide https://www.peninsulacleanenergy.com/wp-content/uploads/2023/02/Design-guidelines-for-home-electrification-v021023.pdf

Q&A

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Bonus slides below

Circuit Sharing Devices

- Examples:
  - NeoCharge, Dryer Buddy and SplitVolt let your dryer and EV charger share the existing dryer outlet (and circuit).
  - SimpleSwitch 240 is a hardwired circuit sharing device to let two 240V items share the same circuit and take turns.
- General:
  - They let two devices share, giving priority to one, and letting the other start when the priority device finishes.
- Code counting: Lets you not count the smaller of the two loads
- Bonus: Saves two poles in the electric panel by sharing one circuit

Circuit Pausing Devices

- Examples:
  - Thermelec DCC9 and SimpleSwitch 240M pause the car charger if the load on the electric panel goes over the 80% full level
  - Emporia Smart Charger with Emporia Vu also pauses the car charger if the load on the electric panel goes over the 80% full level
  - Lumin Smart Panel and Lumin Smart Breakers will do the same
- General: Circuit Pausing devices pause the controlled load when needed to keep panel load below a target level.
- Code counting: Lets you not count the controlled load

Using Circuit Controls for Spaces and Amps

Case		Breaker(s)	Controller(s)	Amps Counted / Saved
No Controls		30 A for Dryer 30 A for EVSE	None None	12 30 42
Circuit Splitter		30 A for sharer Breaker Saved	Circuit Sharer <	Larger of two 30 **12**
One Circuit Pauser		30 A for Dryer 30 A for EVSE	None Circuit Pauser	12 0 **12** **30**
Two Circuit Pausers		30 A for Dryer 30 A for EVSE	Circuit Pauser Circuit Pauser	0 0 0 **42**

Electrical Load Calculations

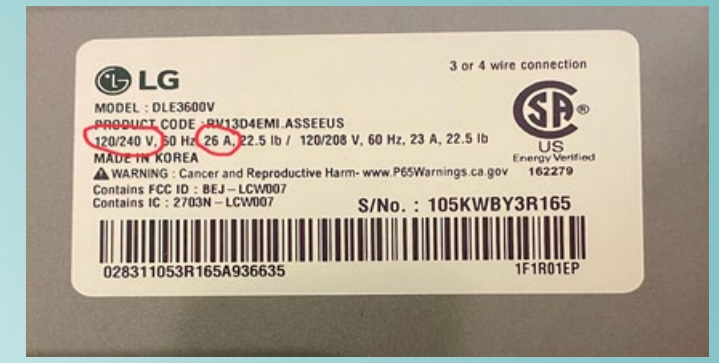
Home Visit Data: Main Panel & Subpanels

- Shut-off breaker capacity of main panel
- Open breaker spaces in main panel and subpanels
- Busbar capacity of main panel and subpanels
- Feeder breaker capacity of subpanels

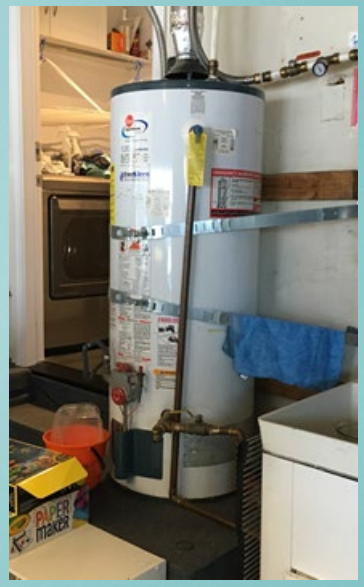
First Step: Gather Data

1. Utility interval data showing home's current energy needs
   - Best to gather before home visit
2. Homeowner preferences
3. Home visit observations, measurements and photos

Fixed Equipment Name Plates



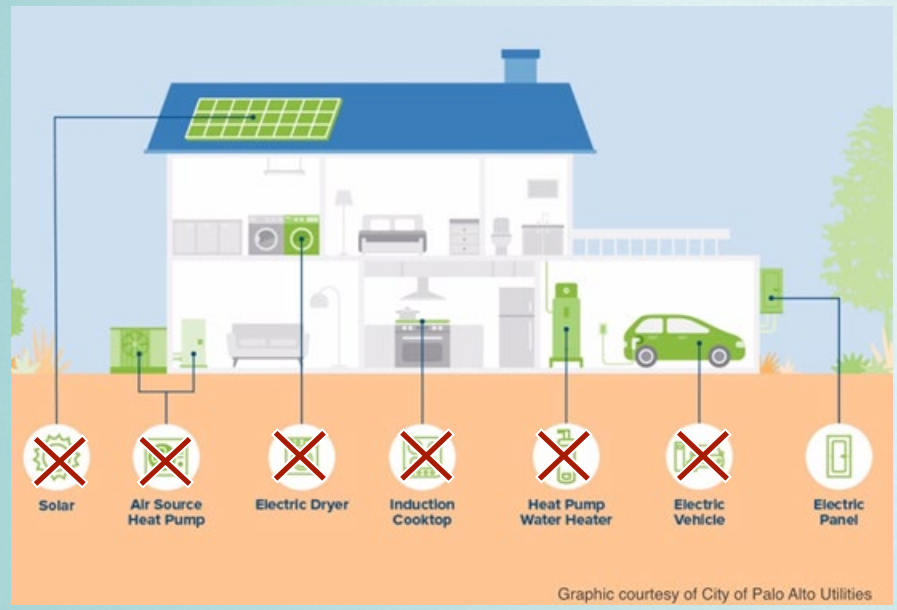
Electrification Locations



Electric Panels

Load Calculation: Step #1 Sum Existing Electric Loads

Home A
Total floor area: **1,500 sq ft**
Main service capacity: **100 amps**
No. of gas appliances: **4**



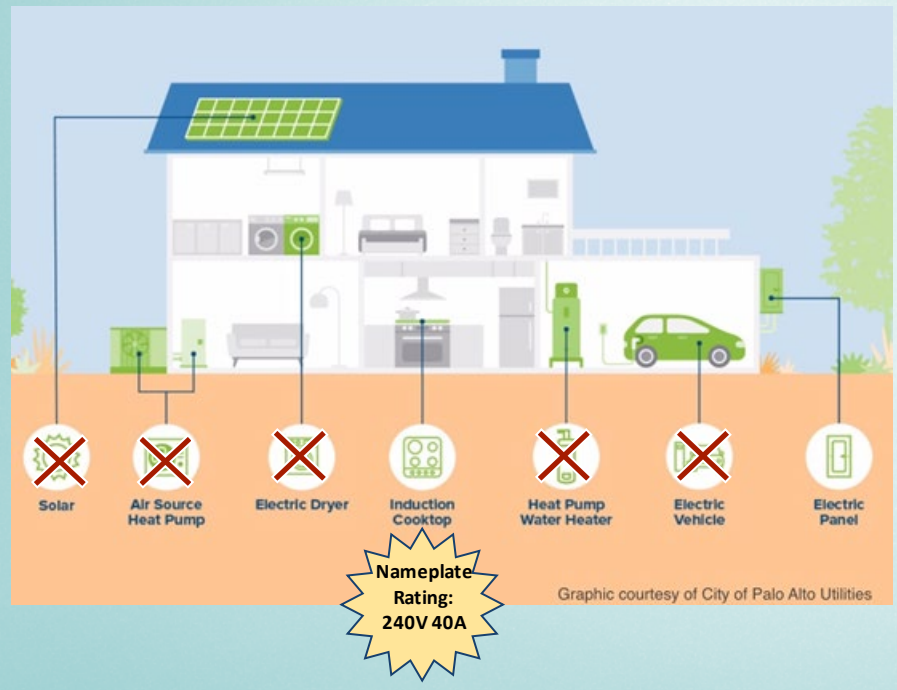
Load Type	Amps	Volts	Watts
Kitchen Circuit	12.5	x 120	= 1500
Kitchen Circuit	12.5	x 120	= 1500
Laundry Circuit	12.5	x 120	= 1500
Refrigerator	5	x 120	= 600
Dishwasher	10	x 120	= 1200
Garbage Disposal	5	x 120	= 600
Lights + Plugs	(3 watts / sq foot)		= 4500
		Subtotal	= 11,600

Here we are using NEC code section: 220.83 (B)

Load Calculation: Step #2 Add New Electric Load, an Induction Range

Home A

Total floor area:	**1,500 sq ft**
Main service capacity:	**100 amps**
No. of gas appliances:	**3**



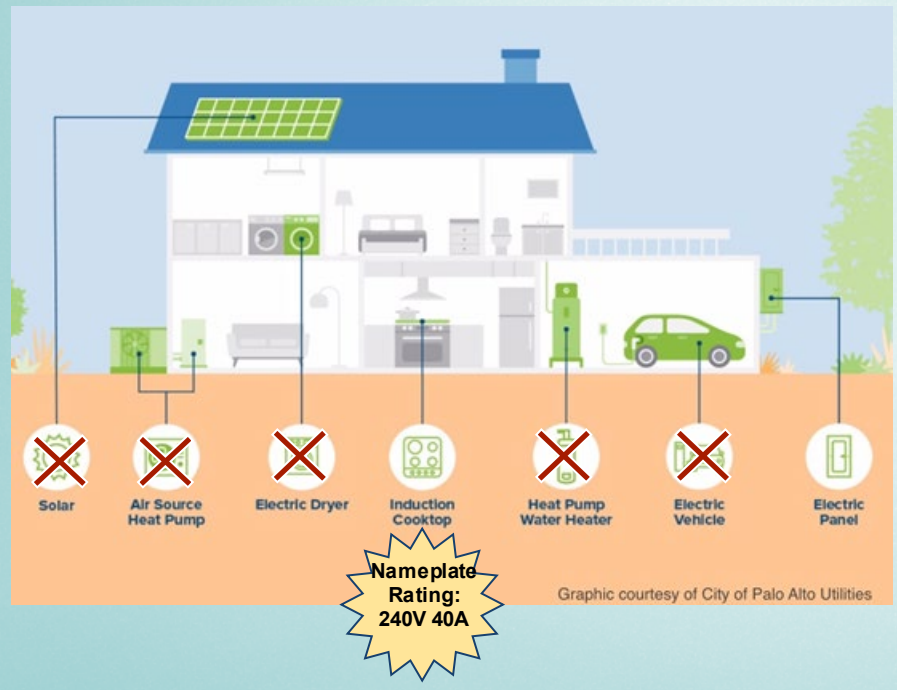
Load Type	Amps	Volts	Watts
Kitchen Circuit	12.5	x 120	= 1500
Kitchen Circuit	12.5	x 120	= 1500
Laundry Circuit	12.5	x 120	= 1500
Refrigerator	5	x 120	= 600
Dishwasher	10	x 120	= 1200
Garbage Disposal	5	x 120	= 600
Lights + Plugs	(3 watts / sq foot)		= 4500
Induct. Range	40	x 240	= 9600
		Subtotal	= 21,000

Here we are using NEC code section: 220.83 (B)

Load Calculation: Step #3 Apply Coincidence Factors

Home A

Total floor area:	**1,500 sq ft**
Main service capacity:	**100 amps**
No. of gas appliances:	**3**



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Refrigerator	5	x 120	= 600
Dishwasher	10	x 120	= 1200
Garbage Disposal	5	x 120	= 600
Lights + Plugs	(3 watts / sq foot)		= 4500
Induct. Range	40	x 240	= 9600
		Subtotal	= 21,000
First 8,000 watts @ 1.0 coincidence factor			= 8,000
Remaining 13,000 watts @ 0.4 coinc. factor			= 5,200
		Total	= 13,200

Here we are using NEC code section: 220.83 (B)

NEC code sections relevant to electrification

- 220.82 (B) New Homes 10 kW @ 1.0
- 220.82 (C) New Homes HVAC @ 1.0 with some diversity for strip heat and 4+ separate zones
- 220.83 (A) Existing Homes 8 kW @1.0
- 220.83 (B) Existing Homes adding HVAC @ 1.0 coincidence factor
  - First 8 kW of other loads also counts at 1.0 coincidence factor
- 220.54 For multifamily and laundromat dryer fleets, not single-family homes
- 220.87 To use historic hourly usage to find the remaining panel capability
- 625.40 For applying the 1.25 combination long duration factor and coincidence factor for EVSE loads on their branch, How far up?

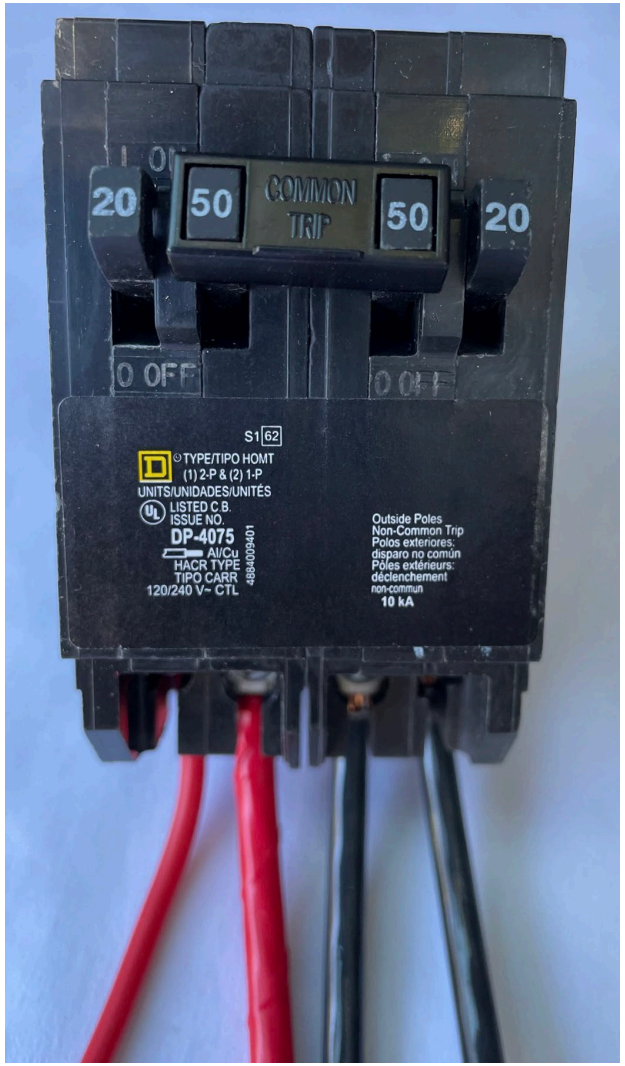
Examples of multi-function devices

- Combined slide-in range has oven and cooktop on one circuit
- Combined (All in one) Washer/Dryer has both washing and drying performed by the same machine
- Combined Space heat pump and water heat pump provide both space heating and cooling on the same circuit
- Umbilical fed mini splits and ductless mini splits power both the outdoor machine and the indoor machine from the same circuit

Example 1 Electrification Plan from HVAC Contractor

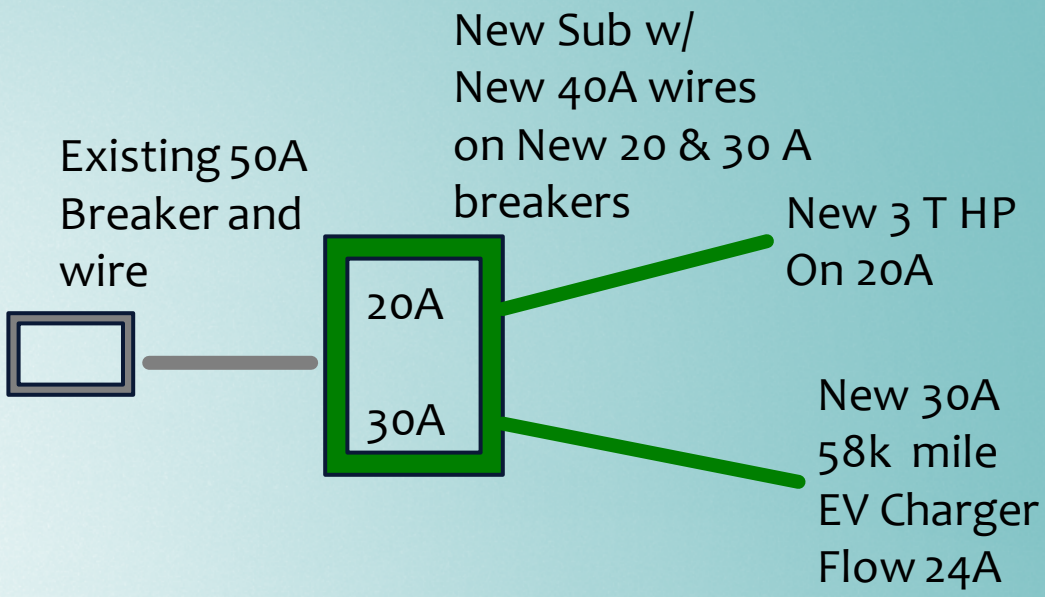
- You Started with 100 amp Panel and No AC
- We put in power efficient 3 ton HP using 17A on 20 Amp Quad breaker freeing up space to move two of your other 20 Amp 120V circuits to the quad in the same space.
- We freed up your old 15 amp 120V furnace circuit for a 120V HPWH near HP Air handler. So you are prewired and ready for dedicated or shared 120V
- You can power a combo W/D on your existing washer circuit freeing up the dryer breaker double space for quad
- Your future projects can use a quad breaker to feed a 50 Amp range and a 20 Amp EV circuit for 39,000 miles per year.

Two Quads like these replaced 2 20s and a dryer 2p breaker



Example 2 Electrification Plan from HVAC Contractor

- You Started with 100 amp Panel and 50 Amp AC circuit
- We used your 50A circuit to feed a new sub panel to power an efficient 3 ton HP using 17A on 20 Amp breaker in the sub. This left 8 more spaces for future projects.
- You can power up to a 30 Amp EV circuit for 58,000 miles per year from the sub
- We freed up your old 15 Amp 120V furnace circuit for a 120V HPWH near HP Air handler
- And use a quad breaker to feed a 50 Amp range from the main without adding spaces.
- You can power a combo W/D on your existing W circuit freeing up the dryer breaker



Free up the Furnace circuit w/ umbilical-fed central heat pump or a ductless heat pump

- Umbilical fed mini splits and ductless mini splits power both the outdoor machine and the indoor machine from the same circuit.
  - Central Examples: Mitsubishi Fujitsu, Mr. Cool
  - Any ductless heat pump.
- This frees up the typical 120V 15 Amp furnace circuit to be used as a 120V HPWH circuit, or for other use

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4

Using a few ‘tandem’ or ‘slim’ breakers

Top left breaker is normal 1” 1 pole breaker

Top two breakers on right are 2 tandem breakers filling the same sized space

Middle right 2” wide breaker has two-pole middle section for a 240V circuit and two more slim single-pole breakers on the outside

Bottom right shows 2” wide 2-pole breaker for comparison

Examples of combining old under-loaded circuits

- Junction box
  - (combines two 15 amp circuits into one 15 amp wire to a 15A breaker)
  - (combines two 20 amp circuits into one 20 amp wire to a 20A breaker)
- Square D brand has breakers allowing two wires held in double jaw
- Can use a “Pig Tail” in the panel combining two wires into one wire fed by the same amperage breaker
- Can use a Sub Panel fed by one big breaker and a feeder wire.
  - The sub panel can feed up to ~10 circuits \
  - Can use old AC wire as new sub panel feeder near compressor
  - Useful for replacing knob and tube wiring or for shortening the branch wire paths

NEW products that free up panel spaces and Amps

120V Washer/Dryer:
GE Profile 4.8 cu ft combo unit w/ heat pump dryer 11 amps / 120 volts LG has one also

120V HP Water Heater:
AO Smith Voltex 120V Plug-in Hybrid Electric Heat Pump 10 amps / 120 volts

120V HP Water Heater:
Rheem Proterra 120V Plug-in Hybrid Electric Heat Pump 4 amps / 120 volts

Equipment silver bullets

1. 120-volt heat pump water heaters or 240-volt 15-amp hybrid water heaters
2. Upsizing water heater and adding a mixing valve to accommodate slower recovery time
3. 17-amp inverter-driven heat pump HVAC systems that are not just power efficient and energy efficient but also extremely quiet
4. Centrally ducted heat pumps w/ air handlers on same circuit, or multizone ductless
5. Split heat pump water heaters for tight spaces (consider combo washer/dryer to make space)
6. Heat pump dryers or combo washer/dryers (single 120-volt machine that washes and dries)
7. Wallbox Pulsar EV charger with adjustable current (6 to 32 amps) & Emporia Smart Charger
8. Circuit-sharing devices like NeoCharge and SimpleSwitch
9. Circuit pausers like DCC9, SimpleSwitch 240M and EV Duty, Emporia Smart EV Charger
10. Smart electric panels like Span.io & Lumin Smart Panel