

Some Things I've Learned For Fast Affordable Electrification

Process for smoother electrification

City of Oakland

5/1/2024 in person & 5/9/2024 virtual

Tom Kabat, Energy Engineer

tomgkabat@gmail.com

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 more usefulness onto panels
(Getting more from your existing panel)
- Some appliances recently became super efficient, using much less power
- Overpowering things 'so/ves' imaginary problems while causing real ones
- Power Efficient Design choices can solve a lot of problems

Power Efficient Design (PED)

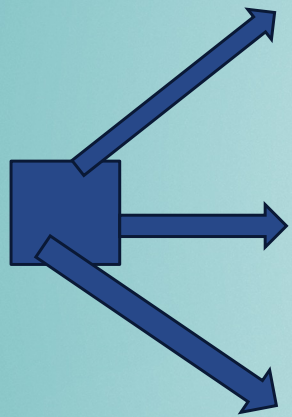
= “Watt Diet design”

= (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)

The
“Split Incentive Problem”

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
 - Followed by 30 amp Water Heaters
 - and 30 amp Dryers

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)



Glossary:

Volt	Electric pressure
Kilowatt-hour	kWh Electric energy (Ability to do work) \$0.40*
Watt	W Electric power (Speed of working)
Kilowatt	kW 1,000W Electric power (Speed of working)
Amp	Electric Current (speed of flow)
COP	Energy delivered / energy bought

* Or a person working @ 150 Watts for 6.5 hours = 1 kWh... \$97 @ \$15 min wage

Single Family Homes Lessons Learned for Staying on the Panel

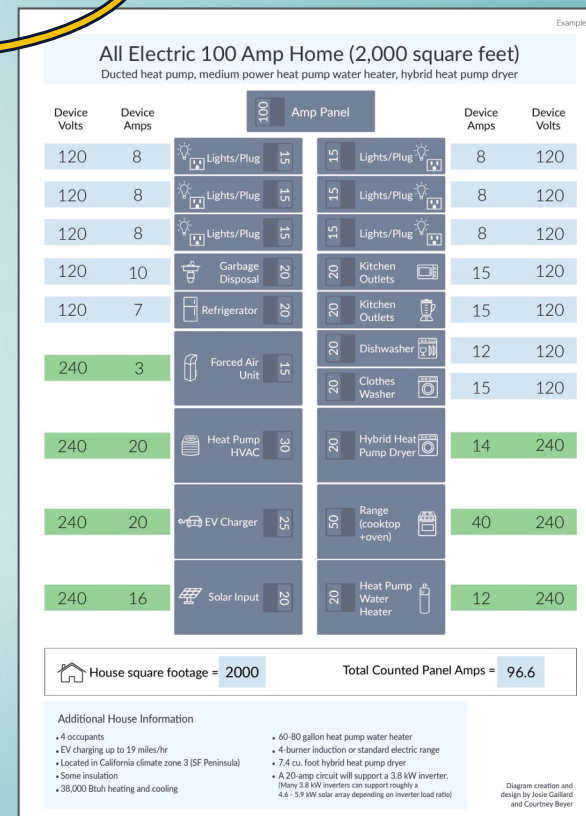
- Panels have lots of unused Capacity and lots of lightly used spaces
- Homes up to 3,000 square feet can easily fit All-Electric on 100A panels
 - By making good choices or making plans to make them
 - Be careful not to let any trade paint you into a corner.
 - Programs often don't yet encourage (or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

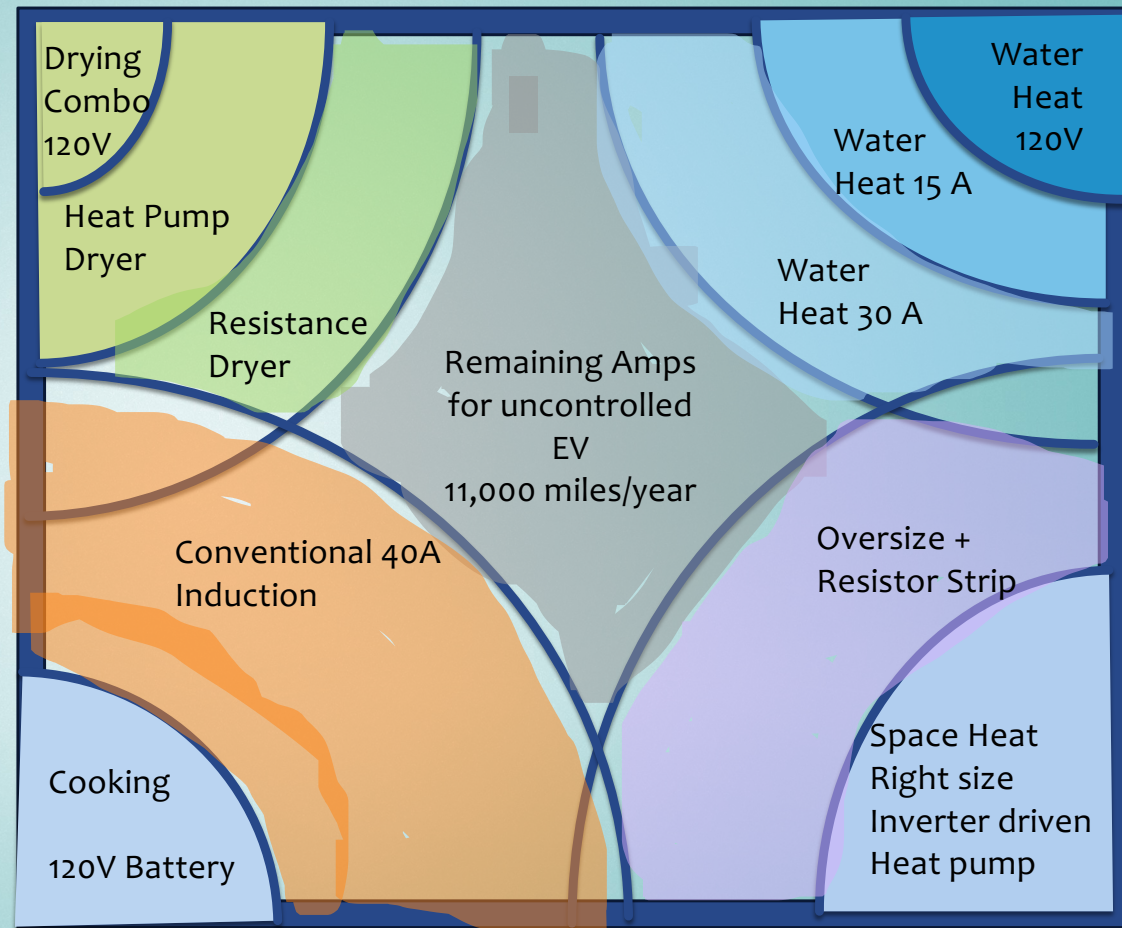
Wayne Szeto Home								
Equipment List								
Appliance	Image	Model Number	Retail Price	Type	Volts	Nameplate Amps	Breaker Size	Notes
Frigidaire gallery 30" front control induction range with air fry		FGIH3047VF	\$1299	Replace Link	Kitchen	240	42	50
Whirlpool 7.4 cu ft hybrid heat pump dryer		WHD560CHW	\$1400	Replace Link	Laundry	240	14	30
Mitsubishi 3 ton centrally ducted heat pump HVAC system		SVZ-KFS30AA/SUZ-KAS30A2	\$4800	Replace Link	HVAC Heating	240	17	20
Rheem 15 amp 65-gallon heat pump water heater		PROPH65 T2 RH375-15	\$2215	Replace Link	Water Heating	240	12	15
Wallbox Pulsar EV charger w/ adjustable current (with circuit paasing)		Pulsar	\$700	Replace Link	EV Charger	240	16	20

[illegible]

Project List for Wayne Sze-to Home	
Component Type	Description
Electronics	<ol style="list-style-type: none"> 1. Use existing 100A service line. 2. Install main electrical panel as specified in Electrical Panels Table.  <p>Main 100A service entrance panel.</p> <ol style="list-style-type: none"> 3. Install 1 new subpanel as specified in Electrical Panels Table.

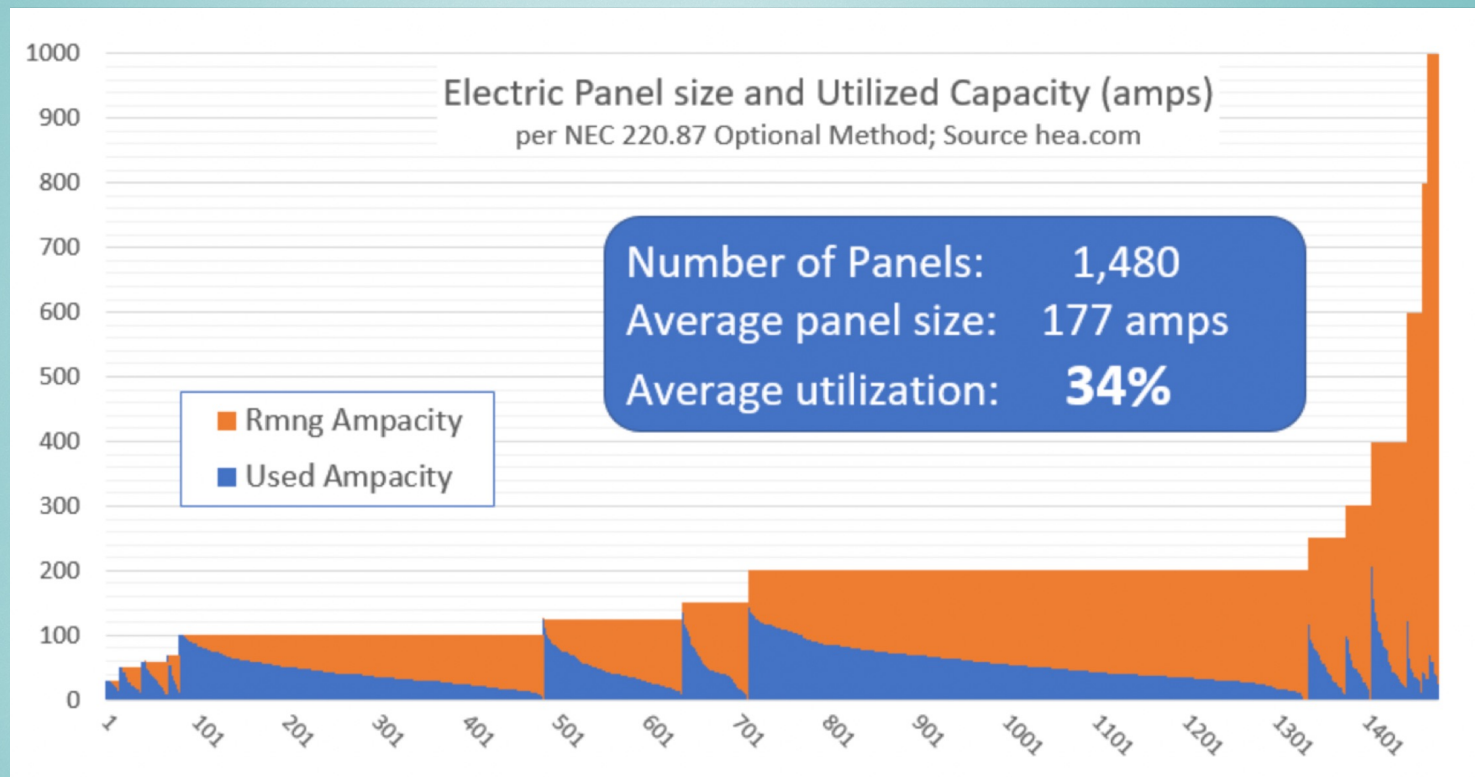
Conceptual View

- **Four Corners** occupied by
- 1 Water heat
- 2 Space heat
- 3 Cooking
- 4 Drying
- 5 Center is for EV



1
2

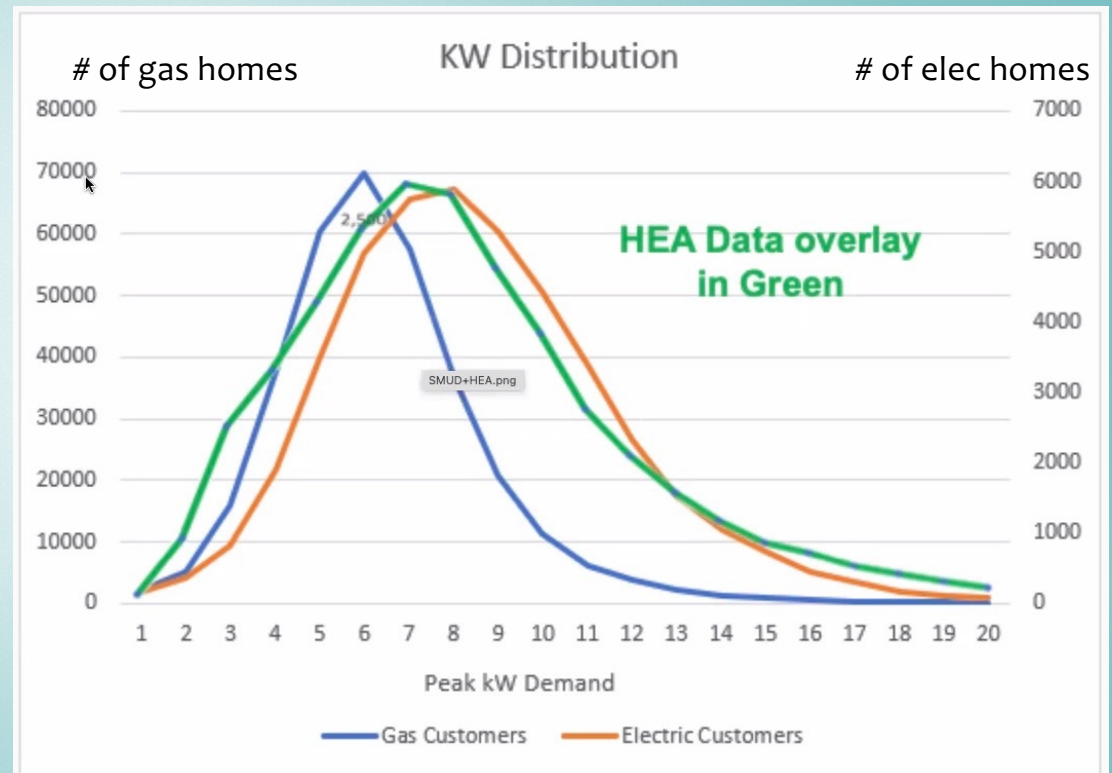
Panels have lots of Capacity



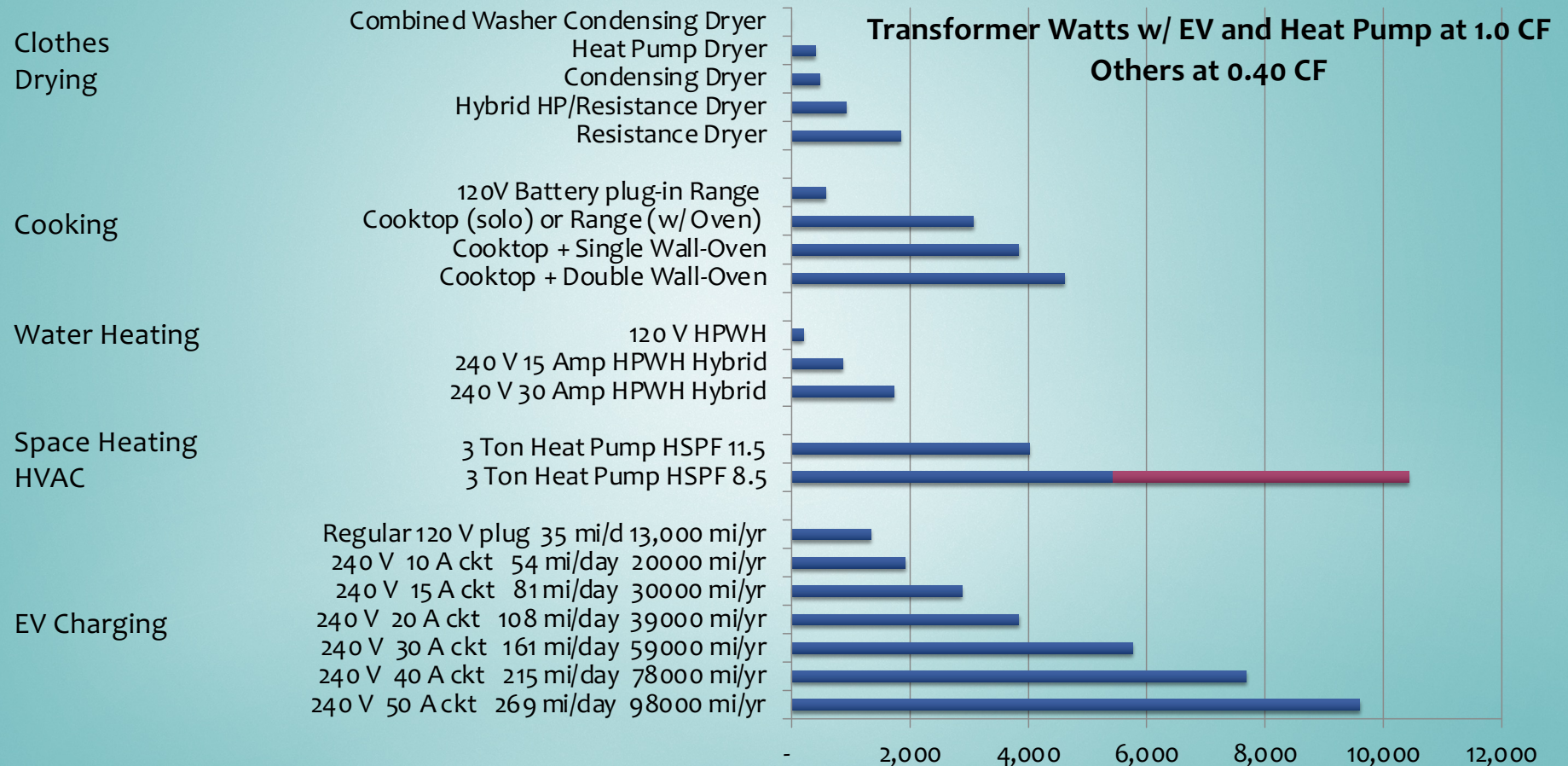
Slide Courtesy of HEA

Whole Home electrification does not add much to the peak

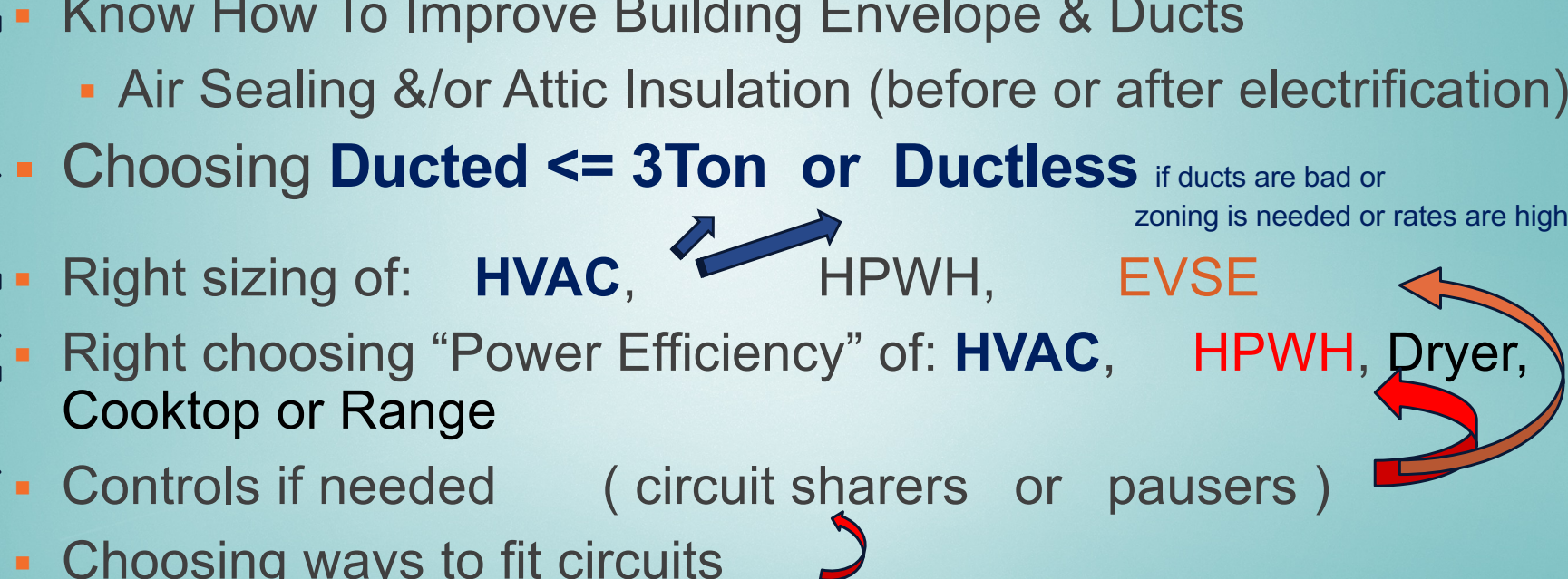
- This graph goes from 1 to 20 kW (up to 83 amps)
- Very few houses peak at 100 Amps 24 kW
- **Orange** minus **Blue** shows electrification adds about 2-4 kW of peak load to most gas homes.



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 electrification)
 - Choosing **Ducted \leq 3Ton or Ductless** if ducts are bad or zoning is needed or rates are high
 - Right sizing of: **HVAC**, **HPWH**, **EVSE**
 - Right choosing “Power Efficiency” of: **HVAC**, **HPWH**, Dryer, Cooktop or Range
 - 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.

First

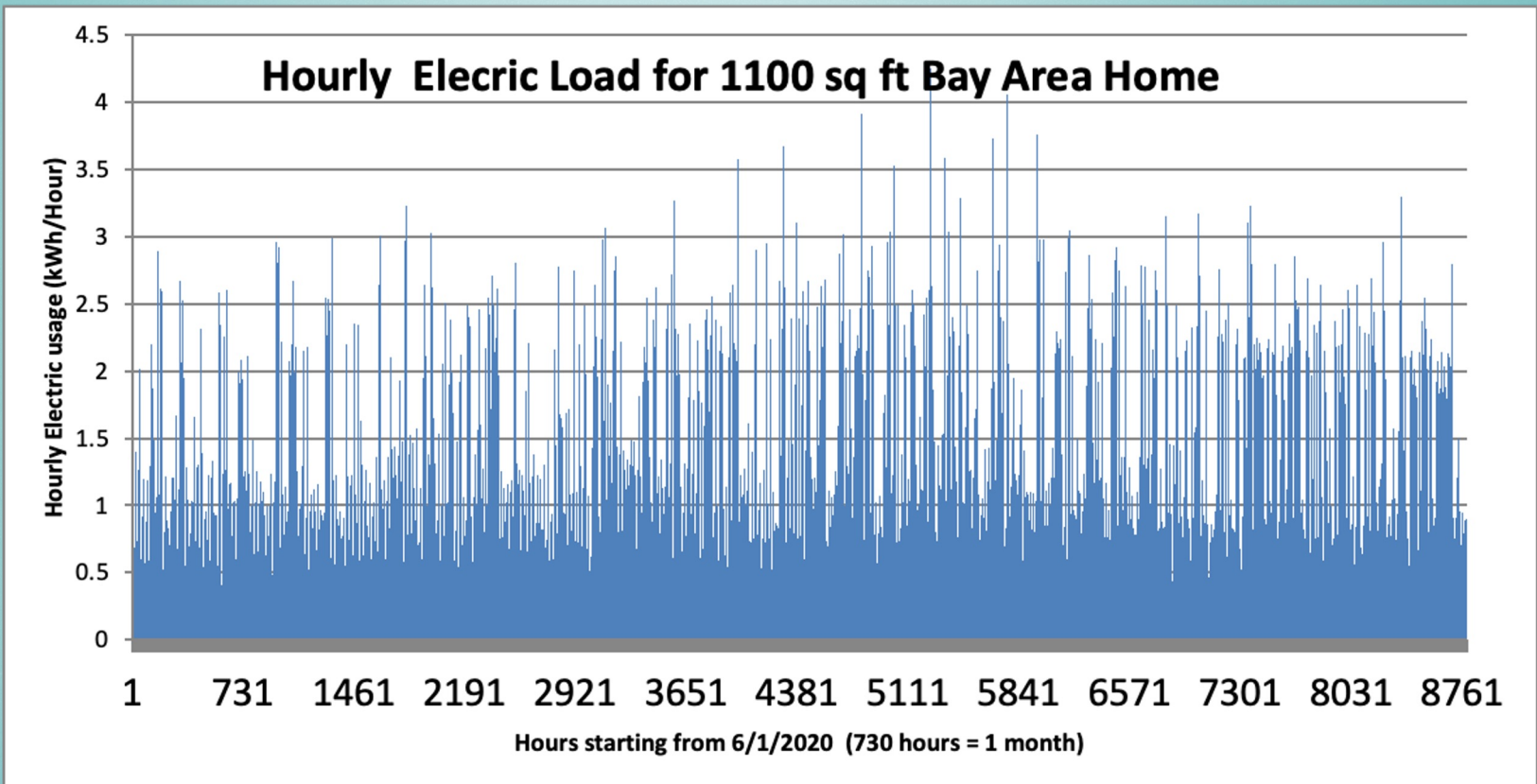
**Lets look at the Top-down Metered Method.
NEC Article 220.87**

Good for adding 1 to 3 new loads

Load Calculation with 220.87

- Top-down load history approach
- Good for adding 1-2 items at a time because it counts them as 100% on-the-peak)
- Starts with power capacity of the smaller of **main breaker disconnect Amps** or **panel rating Amps**
= Amperage rating X 240 Volts = **Wattage Rating**
- Then calculate occupied wattage on main disconnect or feeder from meter readings
= 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 peakiness safety factor = **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

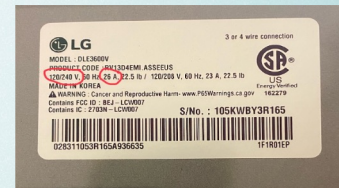
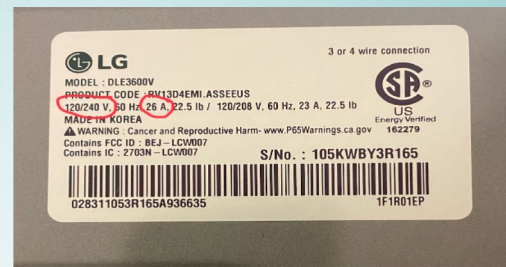
100 A 24 kW



4,000 W
peak usage
measured

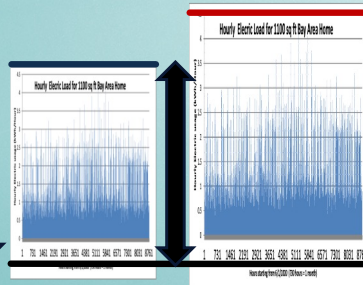
4,000 W
peak usage
X 1.25 =

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

Second in case we need it...

**Lets look at the Bottom-up Calculated Load
of All Attached Devices Method.
NEC Article 220.83 (B)**

Good for adding 3 or more new loads

**Or when you're not allowed to use the easier
method**

Bottom-up Method NEC 220.83 (B)

220.83 (B)

Good for When:

- you lack history data...

or

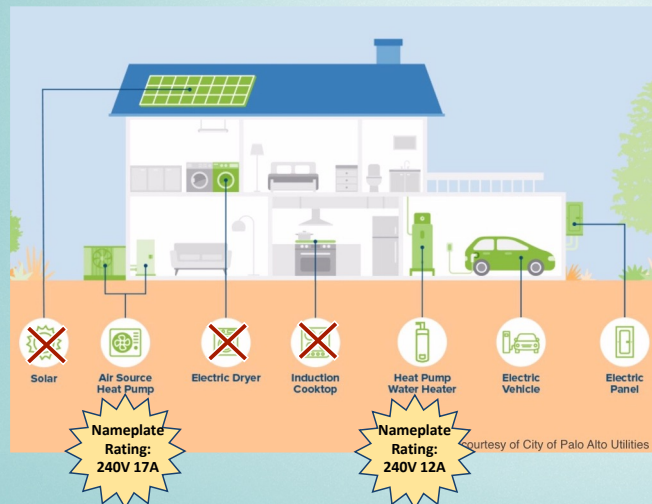
- you want to add 3 or more loads now

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

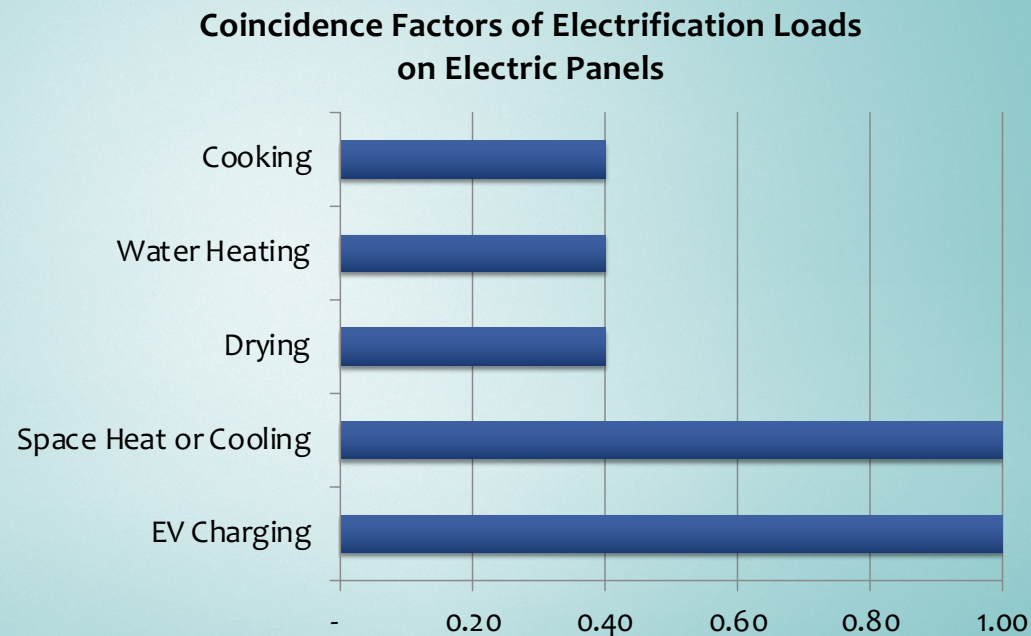
HVAC 4,080 watts @ 1.0 coincidence factor = 4,080
 HPWH 2,880 watts @ 0.4 coincidence factor = 1,152
 Total = 15,432

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

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

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]

Power Savings

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, combo W/D, Combo S/W
3. Avoid oversizing (HP 2-3 tons for most homes, EVSE 20Amps = 39k miles)
4. Pick multifunction devices (e.g. combo washer/dryer, range, combo Space/H2O)
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)

Space Savings

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)

Post Card Plan (2 years for taxes, any order is fine)

- 120 Volt GE HP Combo Washer/Dryer
- 120 Volt A.O. Smith 65 gallon HPWH (This year)
- 2-3 ton inverter driven mini split Heat Pump (early 2025)
- Look at PG&E green button home peak and pick either \$1600 240V induction range (and \$1500 Circuit) or \$6000 120V battery resilience induction range
- 20 Amp breaker 40Amp wire 16 Amp flow EVSE for 39,000 mi/yr or Emporia Smart charger for 100,000 mi/year (final move)

What may be needed re: Building Departments

■ Situation now

- Most replacement gas tank water heaters go in with a 3-4 hour install like for like in the same place **only 5% with permits.** (remodels and additions get permits 95%)

■ Soon

- The higher cost and incentives for HPWHs lead to much more permit compliance. **90% with permits.** % Might drop if incentives shrink
- The difference results needing to process and inspect about 65 more water heater permits per year per 1,000 single family homes. E.g. 5,000 more zero NOx WH permits per year in a 77,000 SFD city like Oakland.

(added 20 more /wday). + Multi family + Commercial

What may be needed re: Building Departments

Ideas to accommodate

Macro Safety

Streamline permitting of HPWHs to eliminate plan checking and calculations on some or all HPWHs.

Publish installation min requirements to meet code

Final inspection assures conformance

Cities hold and group up inspections by firm to allow more inspections in tighter grouped schedules.

(avoiding a 6 hour window per inspection, reducing from 15 FTEs added in waiting windows) =
(5,000/yr X 6 hours/install / 2,000 hours/FTE)

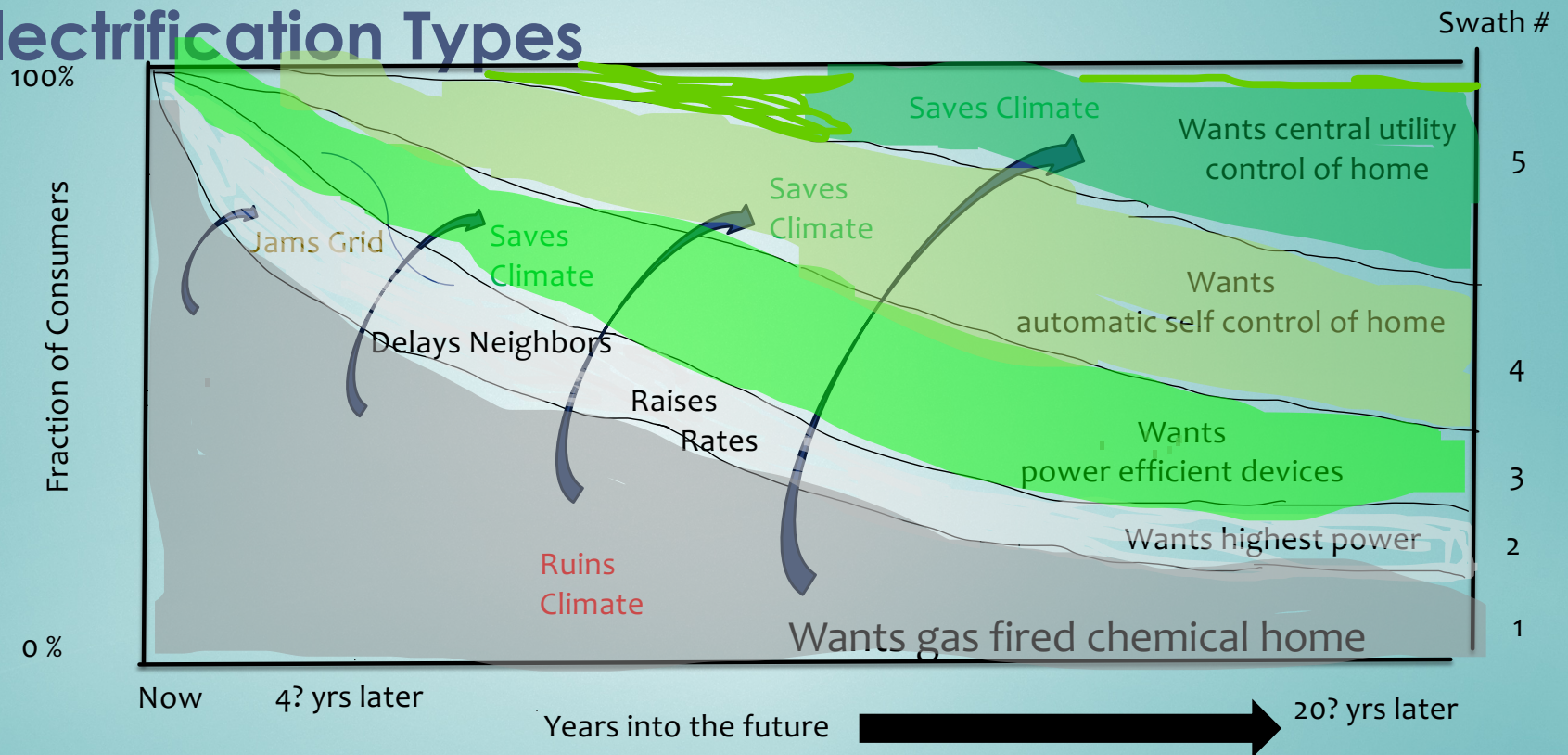
By zone and contractor: 5 of ACME's installs in NW section on Tues w/ Inspector A, 6 more in SW on Wed. Z

Carpooling to sites? Random inspections? Treat like washing machines? (same connections)

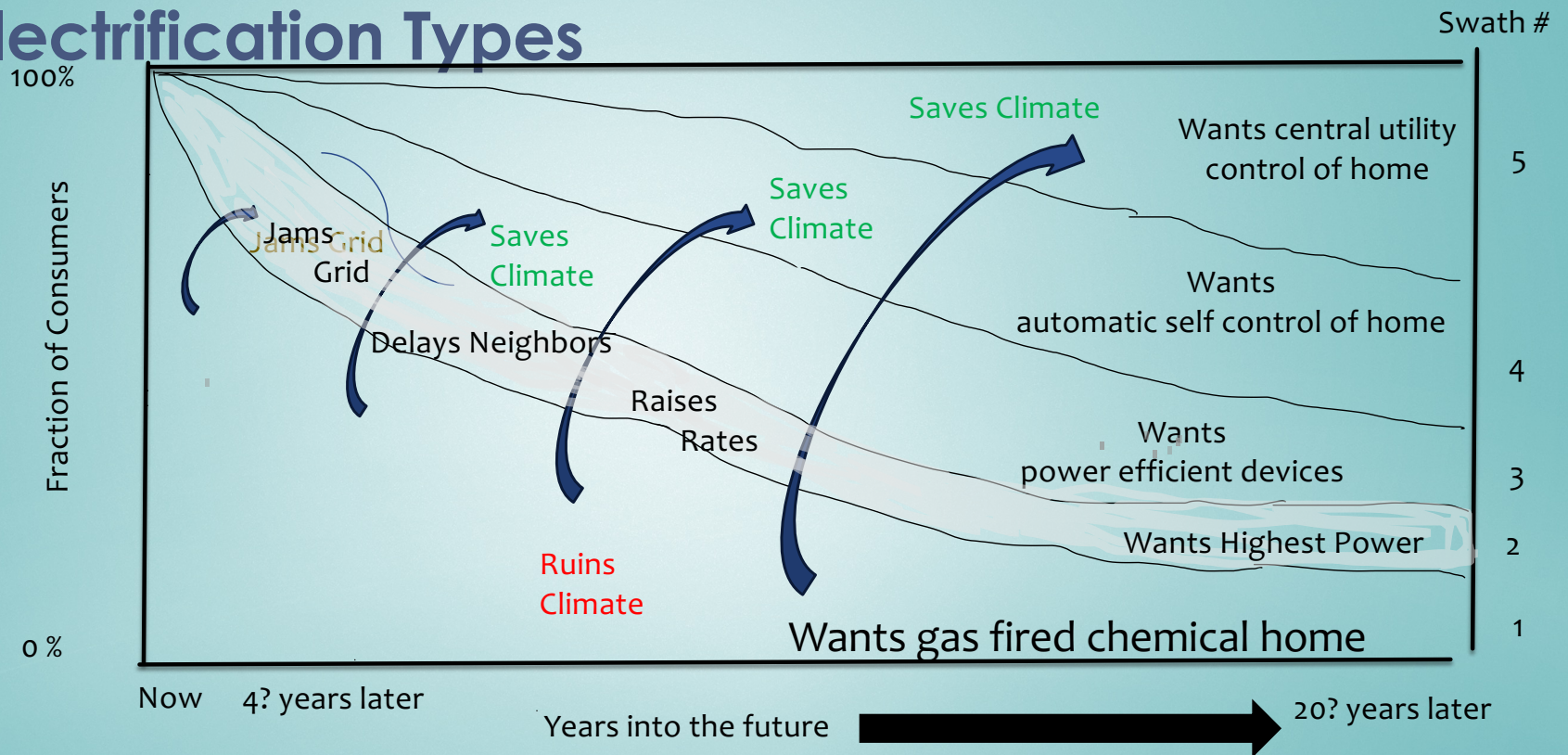
When to require electric panel calcs

- Maybe not on water heaters
- Maybe not on < 30 Amp Water heaters
- Maybe not on 120V Water heaters
- Maybe always on 40-50 and larger EV chargers to be sure they have enough panel capacity remaining for a water heater
- Maybe encourage 240V 16A Chargers with 20A breakers (39,000 miles per year at 8 hours) and 40A wire for future proofing)

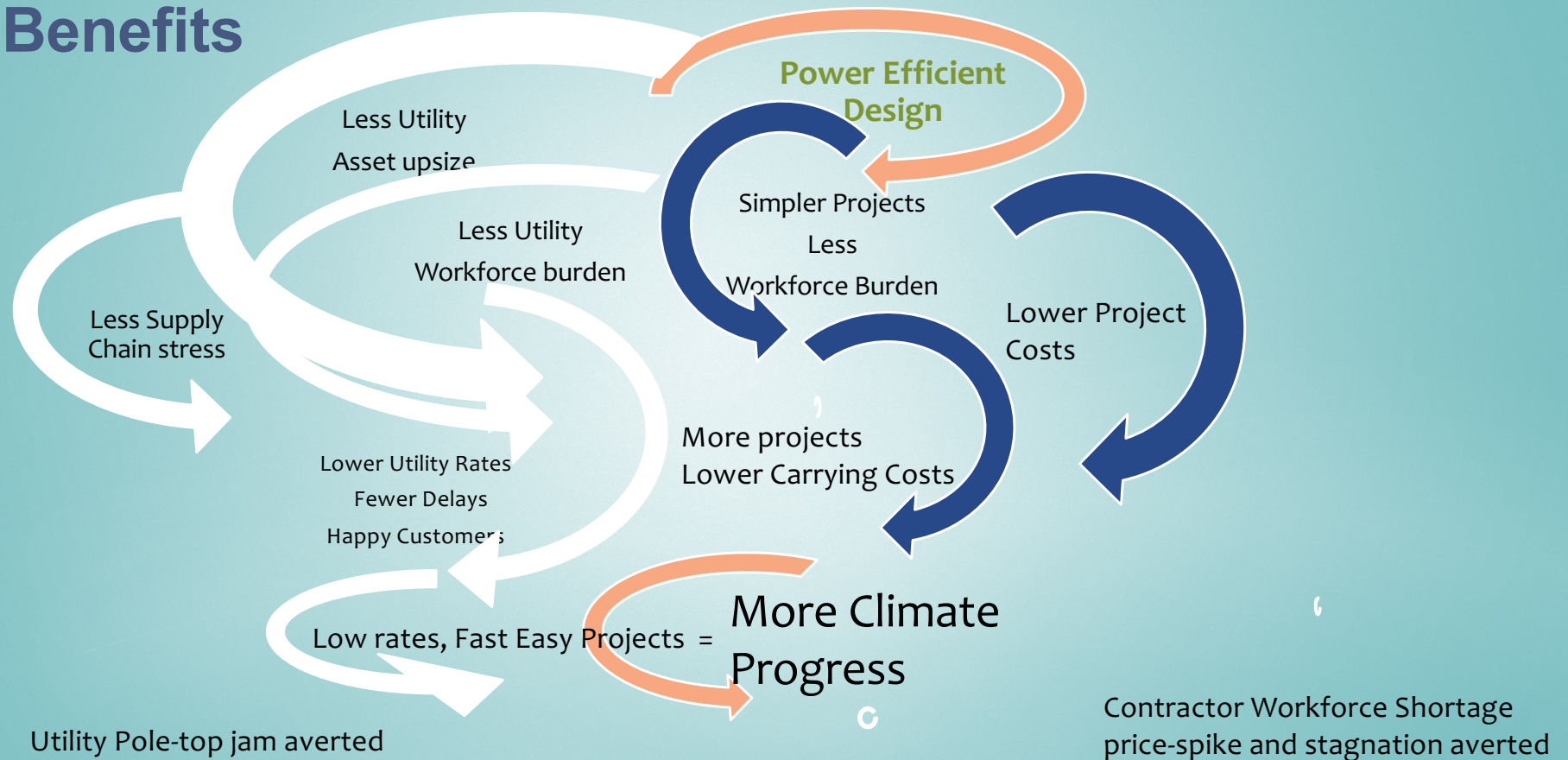
Possible market shares of Home+EV Electrification Types



Possible market shares of Home+EV Electrification Types



Cascade of Benefits



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

Q&A

- tongkabat@gmail.com

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

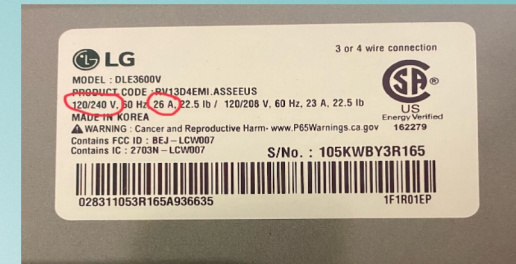
Feeder breaker capacity of subpanels



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

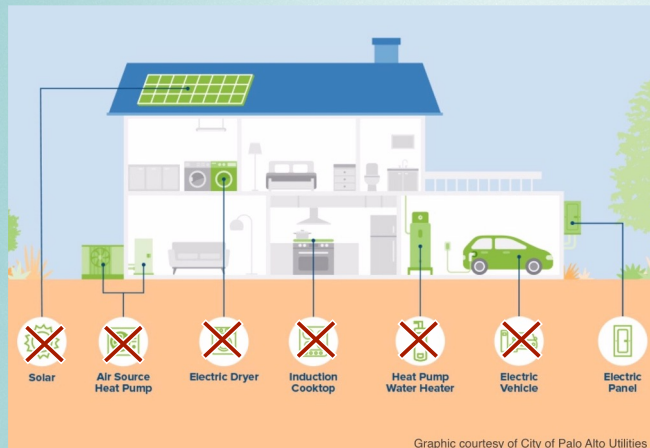






Electric Panels



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

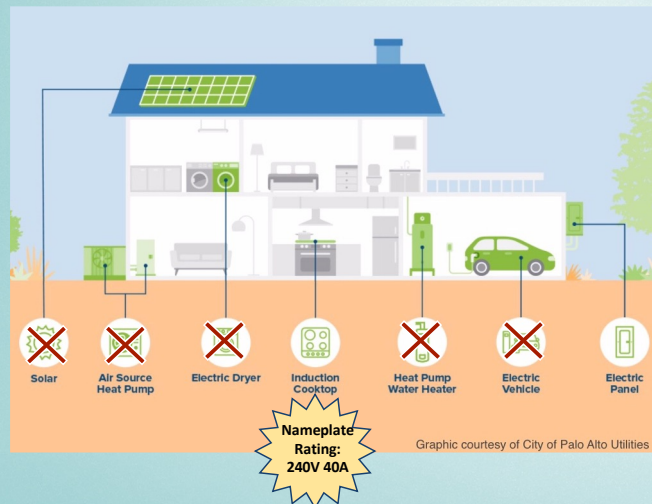


Load Type	Amps	Volts	Watts
 Kitchen Circuit	12.5	x 120	= 1500
 Kitchen Circuit	12.5	x 120	= 1500
 Laundry Circuit	12.5	x 120	= 1500
 Refrigerator	5	x 120	= 600
 Dishwasher	10	x 120	= 1200
 Garbage Disposal	5	x 120	= 600
 Lights + Plugs	(3 watts / sq foot)		= 4500
Subtotal			= 11,600

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

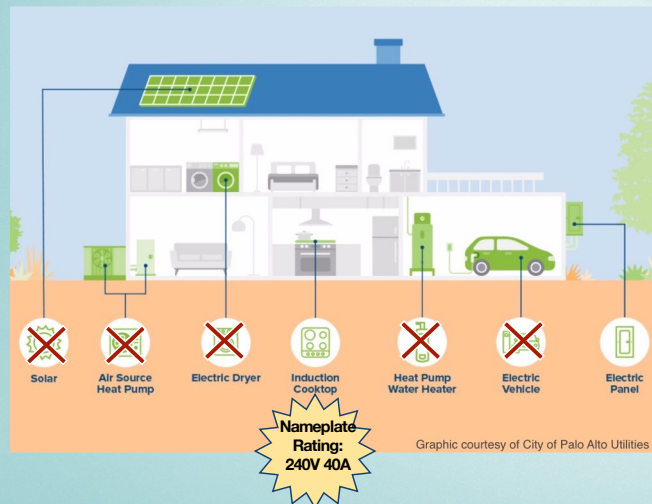


Load Type	Amps	Volts	Watts
Kitchen Circuit	12.5	x 120	= 1500
Kitchen Circuit	12.5	x 120	= 1500
Laundry Circuit	12.5	x 120	= 1500
Refrigerator	5	x 120	= 600
Dishwasher	10	x 120	= 1200
Garbage Disposal	5	x 120	= 600
Lights + Plugs	(3 watts / sq foot)		= 4500
Induct. Range	40	x 240	= 9600
Subtotal			= 21,000

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



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

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
First 8,000 watts @ 1.0 coincidence factor			= 8,000
Remaining 13,000 watts @ 0.4 coinc. factor			= 5,200

Total = 13,200

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

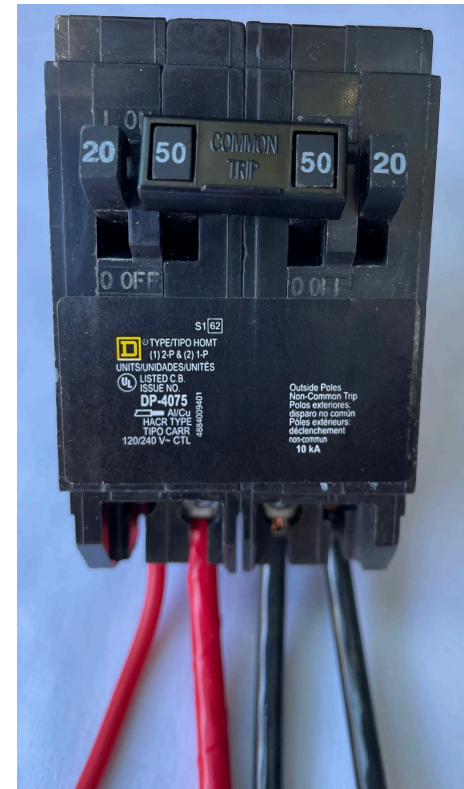
- Combined slide-in range has oven and cooktop on one circuit
- Combined (All in one) Washer/Dryer has both washing and drying performed by the same machine
- Combined Space heat pump and water heat pump provide both space heating and cooling on the same circuit
- Umbilical fed mini splits and ductless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



Example 1 Electrification Plan from HVAC Contractor

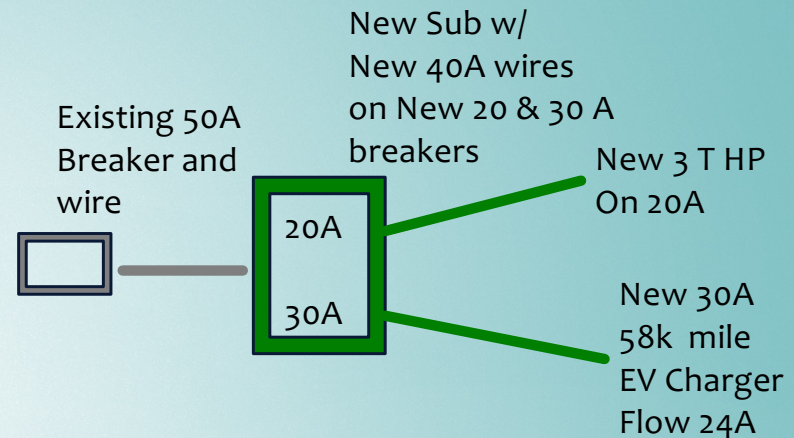
- ▶ You Started with 100 amp Panel and No AC
- ▶ We put in power efficient 3 ton HP using 17A on 20 Amp Quad breaker freeing up space to move two of your other 20 Amp 120V circuits to the quad in the same space.
- ▶ We freed up your old 15 amp 120V furnace circuit for a 120V HPWH near HP Air handler. 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



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