Building Electrification Case Studies: Update for C/CAG RMCP Committee

October 20, 2021

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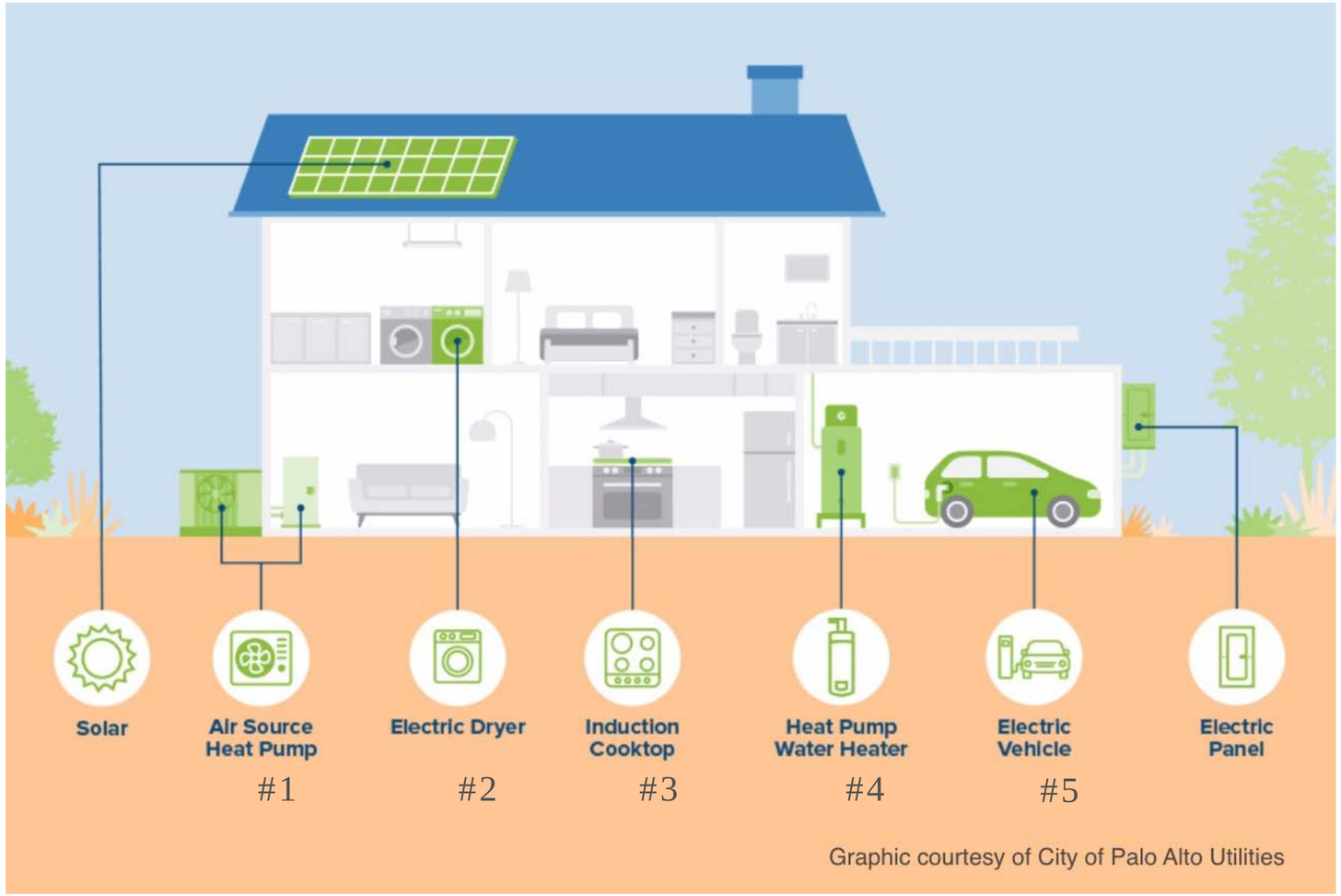
WHAT IS BUILDING ELECTRIFICATION?



Replacing all fossil fuel appliances in the building:

#1 gas furnace
#2 gas dryer
#3 gas range
#4 gas water heater
#5 gasoline for car

...with high efficiency electric alternatives

- Rooftop solar (at $0.05–0.10 per kWh) makes all-electric home conversions affordable

- Battery backup systems make all-electric homes reliable during grid outages

STUDY GOALS

- Learn about costs and strategies for decarbonizing existing homes in San Mateo County
  - What does is cost to decarbonize a home?
  - Does a plan help homeowners?
  - What can we learn from assisting homeowners in electrifying?

TEN HOMES SELECTED FOR STUDY

Key selection criteria:

- Location
- Home vintage
- Home size
- Electrical panel size
- Income level

Locations

- Belmont
- Brisbane
- East Palo Alto
- Half Moon Bay
- Pescadero
- Redwood City (2)
- San Bruno
- San Carlos
- San Mateo

STEPS IN COUNTY STUDY

- On-line survey(s) - 78 homeowners applied
- Intro call - 45 mins
- Site visit - 2 hours
- Develop contractor bid packet
- Solicit bids from contractors
- Review bids and run financial projections
- Present plan w/ costs to homeowner
- Write up case study

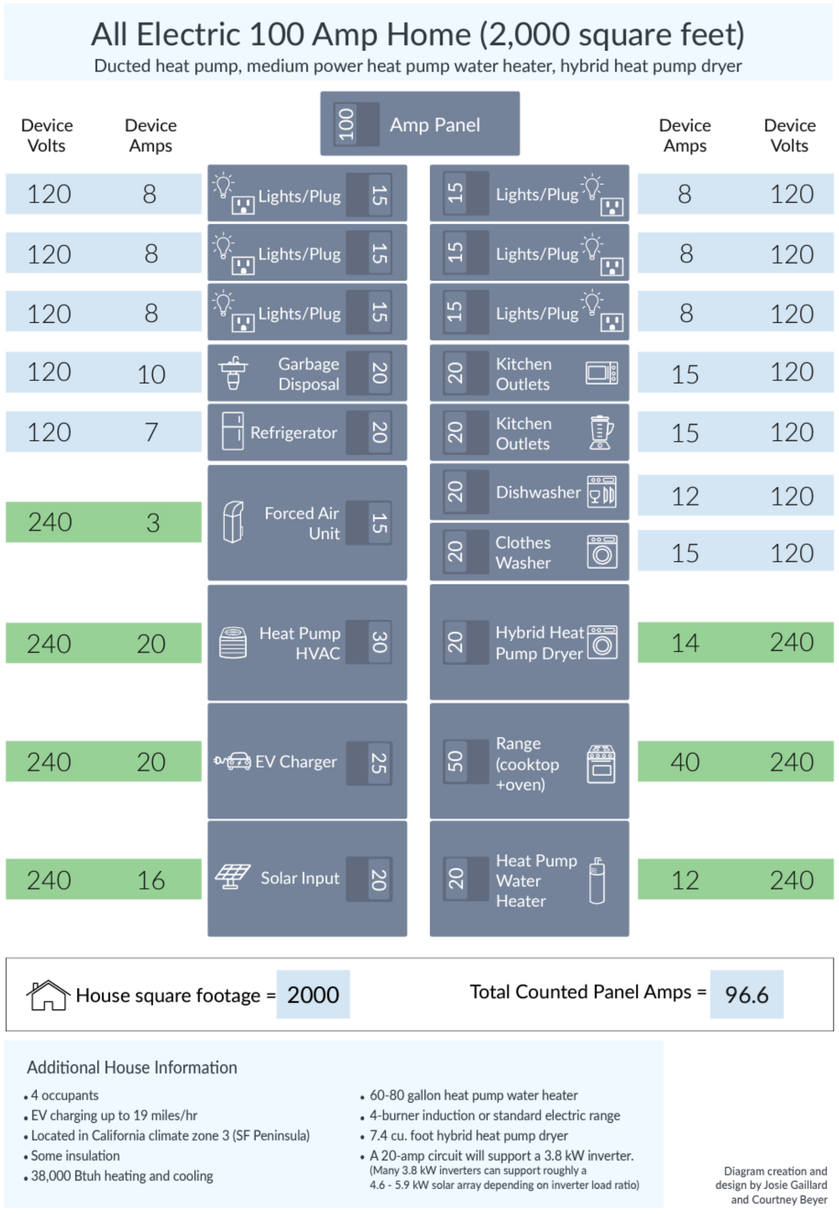
WOLF HOME

Location: Redwood City, CA
Square footage: 1,900
Occupants: 4
Main panel size: 100 amps
Vintage: 1960's

“AMP DIET” for 2,000 sq ft home

- For homes with 100 amp electrical panels
- Helps avoid ~$3,000 electric panel upgrade
- Favors efficient devices w/ low rated amps
- Provides roadmap for building owner
- Helps guide tradespeople

Example 1

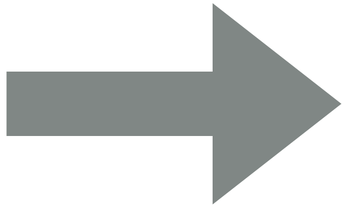


WATER HEATER

Today: 50-gallon gas tank WH in garage

Recommended: 80-gallon, 15-amp heat pump tank WH in garage

SPACE HEATING/COOLING



Today: A/C + Bryant gas furnace

Recommended: Mitsubishi 3-ton inverter-driven heat pump HVAC system w/ central air handler

COOKING

Today: 48" gas Jenn-Air range

Recommended: 48" AGA induction range

CLOTHES DRYING

Today: Samsung 7.5 cu ft <u>resistance electric</u> dryer **22.5-amps** / 240 volts

Recommended: Whirlpool 7.4 cu ft hybrid heat pump dryer **14 amps** / 240 volts

EV CHARGING

Recommended: NEMA 14-30 outlet with 30-amp / 240-volt circuit for outside of garage

SOLAR + BATTERY

Recommended: 5.8 kW rooftop solar system + 20 kWh battery system

BUILDING SHELL IMPROVEMENTS

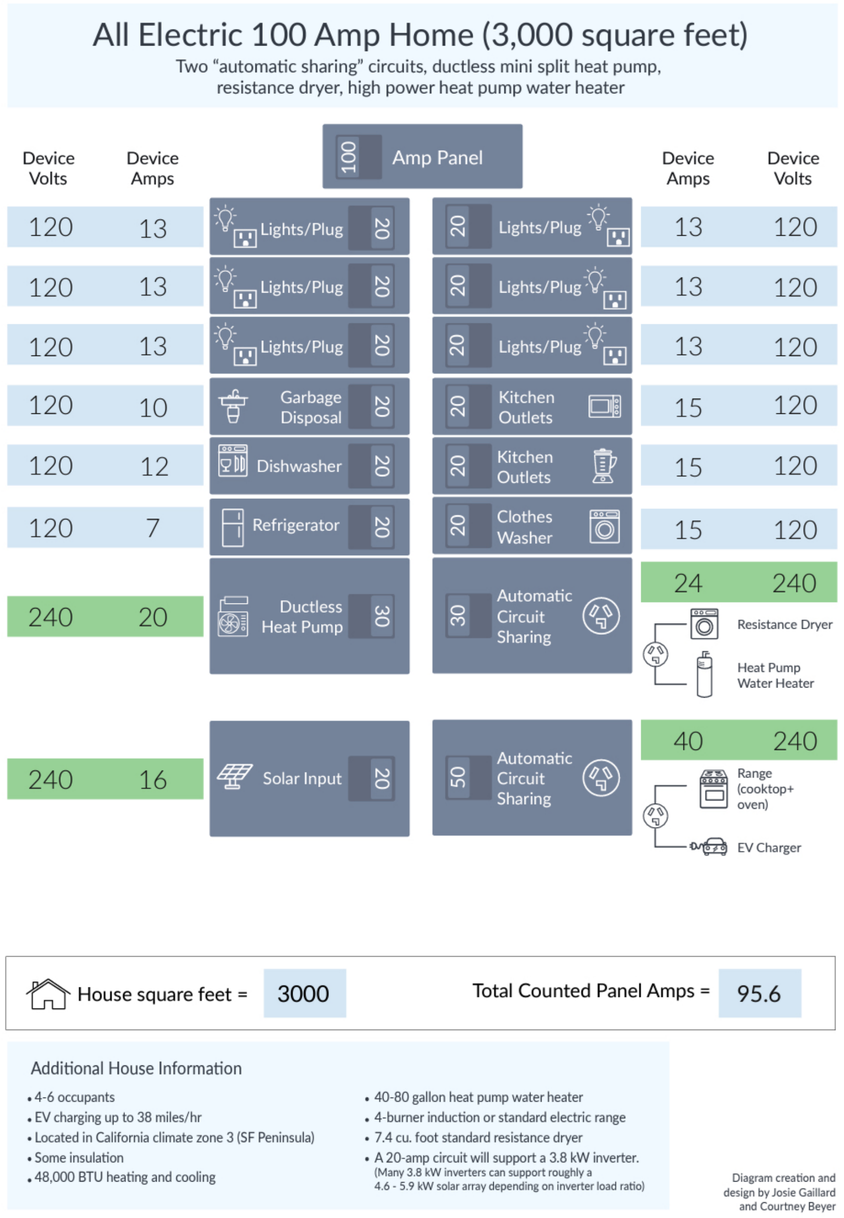
Today: Attic, R-19 insulation
Recommend: R-38

Today: Crawlspace, no insulation, poorly insulated ducts
Recommend: R-19 or R-30 for floors, repair ducts

“AMP DIET” for 3,000 sq ft home

- For homes with 100 amp electrical panels
- Uses “circuit sharing” devices like plug-in smart splitter *Neocharge* or hard-wired version *SimpleSwitch*
- Still easy to avoid ~$3,000 electric panel upgrade

Example 2



CONTRACTOR BID PACKET

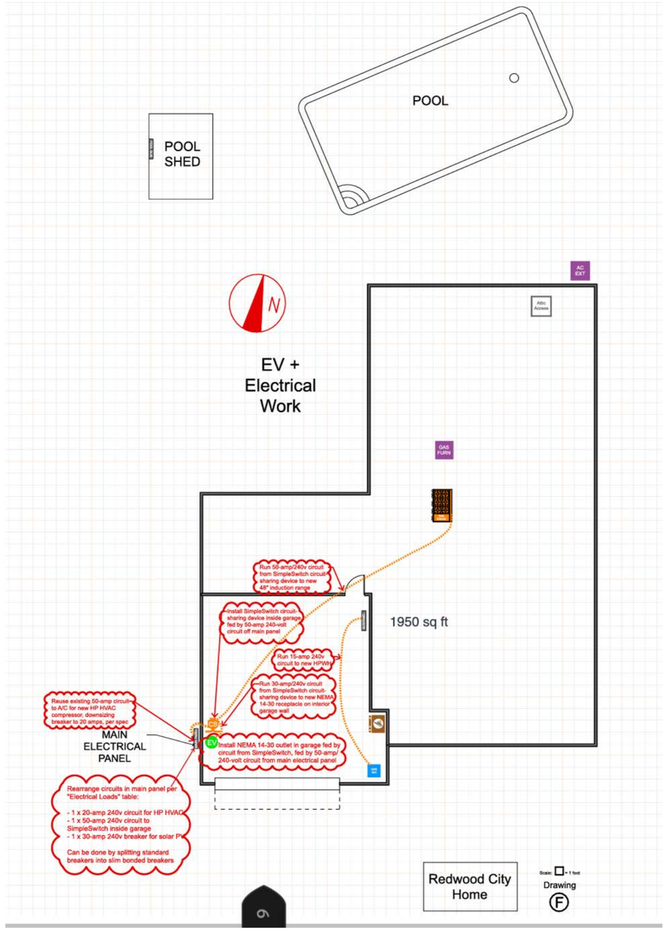
Quote Request

Please provide notional quotes (±10% of expected cost) for the following work.

Home Background Info
Single-family, detached
1,900 sq ft
1-story
Built 1966
Redwood City Emerald Hills

Please provide separate estimates for each project and a discount estimate if the electrification projects were all combined together. Please separate the $ quotes into separate cost categories of equipment, labor, permit labor

Work Type	Work Description	Price
1) HPWH	Replace existing gas-fired 50-gallon tank water heater with new 15-amp electric HPWH in same location about 25 feet from sub panel in unconditioned garage workspace. (WH location is protected from car driving area.) Code minimum sizing for 4 BR 2 BA home is 62 gallons of first hour rating. To preserve Amps for future pool equipment, JT suggest 15-amp water heater similar to Rheem or Ruud 65-gallon or 80-gallon models or Stiebel Eltron tank models. Also please quote an alternative 80-gallon 120-volt retrofit ready HPWH if information can be found for it. Price an option for adding a mixing valve (for enhancing the ability to deliver more gallons of 120°F water from any storage tank operated at a higher temperature). Please price labor, permits and materials separately. Also please price a discount if electrification projects are combined. See **Drawing B** for details Contractor reply including prices:	



Wolf Home

Redwood City Emerald Hills, 94062
Main panel size: 100 amps
Square footage: 1900

Electrical Panel Information

Circuits

Main Panel, rated amps: 100

Circuit Number	Voltage	Breaker Amps	Type	Splittable?	Notes
1 + 2	240	100	Subpanel	yes	Subpanel in garage serving most indoor loads
3 + 4	240	50	Air Conditioner	yes	Breaker can be reduced to 20 amps and circuit repurposed for heat pump
5	120	15	Unknown	yes	Assuming no load on this circuit, other than lights and plugs
6	120	20	Unknown	yes	Assuming no load on this circuit, other than lights and plugs
7 + 8	240	30	Subpanel	yes	Subpanel serving pool equipment

Subpanel 1, rated amps: 100

Circuit Number	Voltage	Breaker Amps	Type	Splittable?	Notes
1	120	20	Clothes Washer	no	Washer
3	120	20	Lights and Plugs	no	Lites + Plugs
5	120	20	Lights and Plugs	no	Lites + Plugs
7	120	20	Lights and Plugs	no	Lites + Plugs
9	120	20	Dishwasher	no	Disposal and Dishwasher
11	120	20	Lights and Plugs	no	Lites + Plugs
13	120	20	Lights and Plugs	no	Lites + Plugs
15	120	20	Lights and Plugs	no	Whole House Fan
17	120	20	Lights and Plugs	no	Dining Room Plugs
19	120	20	Kitchen Outlets	no	Kitchen Plugs
21	120	20	Microwave	no	Microwave Oven, microwave is built-in model, 1550 watts/120v
23	120	20	Unknown	no	
2 + 8	240	30	Clothes Dryer	no	Dryer
4 + 6	240	30	Oven	no	Oven 1, part of range
10 + 16	240	20	Oven	no	Oven 2, part of range
12 + 14	240	20	Griddle	no	BBQ but we think it now serves a griddle on the range
18	120	20	Lights and Plugs	no	Plug under pool, side yard light, house fan
20	120	20	Lights and Plugs	no	?
22	120	20	Garage Outlets	no	Garage refrigerator + freezer

WHAT WE LEFT OUT...FOR NOW

400,000-BTU gas pool heater

gas fireplace

TYPICAL SITE VISIT

- 2 hours long
- Replaces visits by 6+ different contractors
- 1 hour spent outside:
  - site sketch
  - building and window dimensions
  - electrical panel, potential HVAC sites
  - potential battery sites
  - rooftop solar potential
  - viewing crawlspace for insulation condition, key measurements duct condition and accessibility assessment
- 1 hour spent inside:
  - viewing key appliances to replace
  - recording energy ratings for other major electrical loads
  - viewing attic for insulation condition, key measurements, duct condition and accessibility assessment

KEY LEARNINGS..SO FAR

- Most any home can be fully electrified without upsizing the electrical panel
- A plan helps the homeowner "defend the electrical panel"
- A few key product choices make electrification really easy (and are gentle on the grid):
  - 15-amp heat pump water heaters
  - 17-amp inverter-driven heat pump HVAC systems that are super quiet
  - 15-20-amp EV chargers (provide 100 miles a night)
  - Heat pump dryers
  - Circuit-sharing devices like Neocharge and SimpleSwitch
- Electrification is not rocket science, but you can be steered down bad paths by contractors
- We need more contractors who understand amp diets and want to sell heat pumps
- There is no shortage of ways to electrify a home on its existing electrical panel

CHALLENGES

- Contractor quotes are coming in higher than expected. Possible reasons:
  - Chip shortage
  - Labor shortage in Bay Area (cost of living, housing shortage?)
  - New demand due to climate awareness
  - Rebates at point of installation supporting higher pricing (opposite of intended effect)
  - Rebate-required permits add costs (10-25% more) and delay
  - Equipment manufacturers have not ramped up production enough
  - Copy-cat high pricing by contractors
  - Special mark-up for government program

SYSTEM-LEVEL SOLUTIONS

- **Find a way to make electrification plans widely available and easily accessible**
- Streamline permitting for electrification and train building officials on relevant code
- Increase labor pool with community college grads trained in HVAC, plumbing, electrical, electrification designers
- Encouraging formation of contractor businesses focused on electrification
- Organize bulk buy of equipment and/or services
- Aquire and store rotating stock of equipment to make available on short notice (e.g. for water heater burnouts)
- Launch a direct-install program with contractors bidding through RFP
- Electrification authority run as JPA

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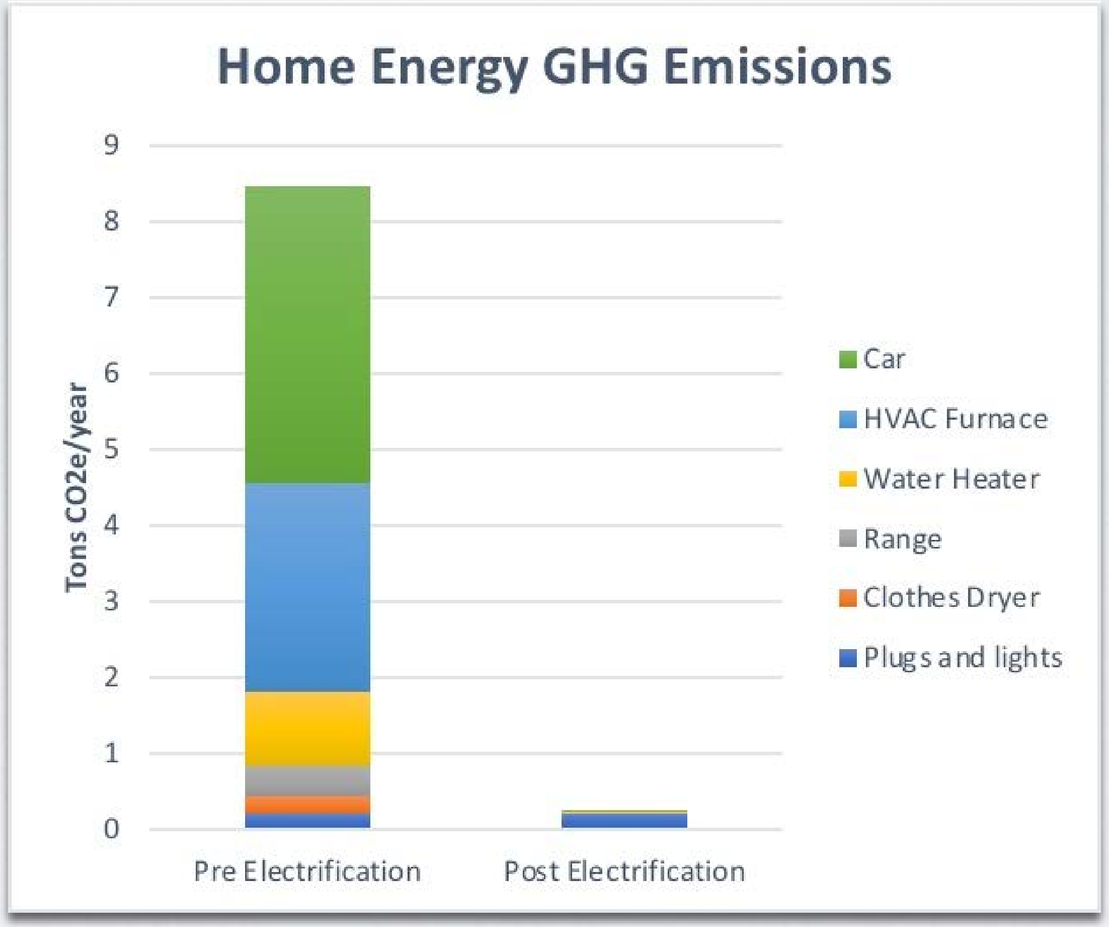
APPENDIX

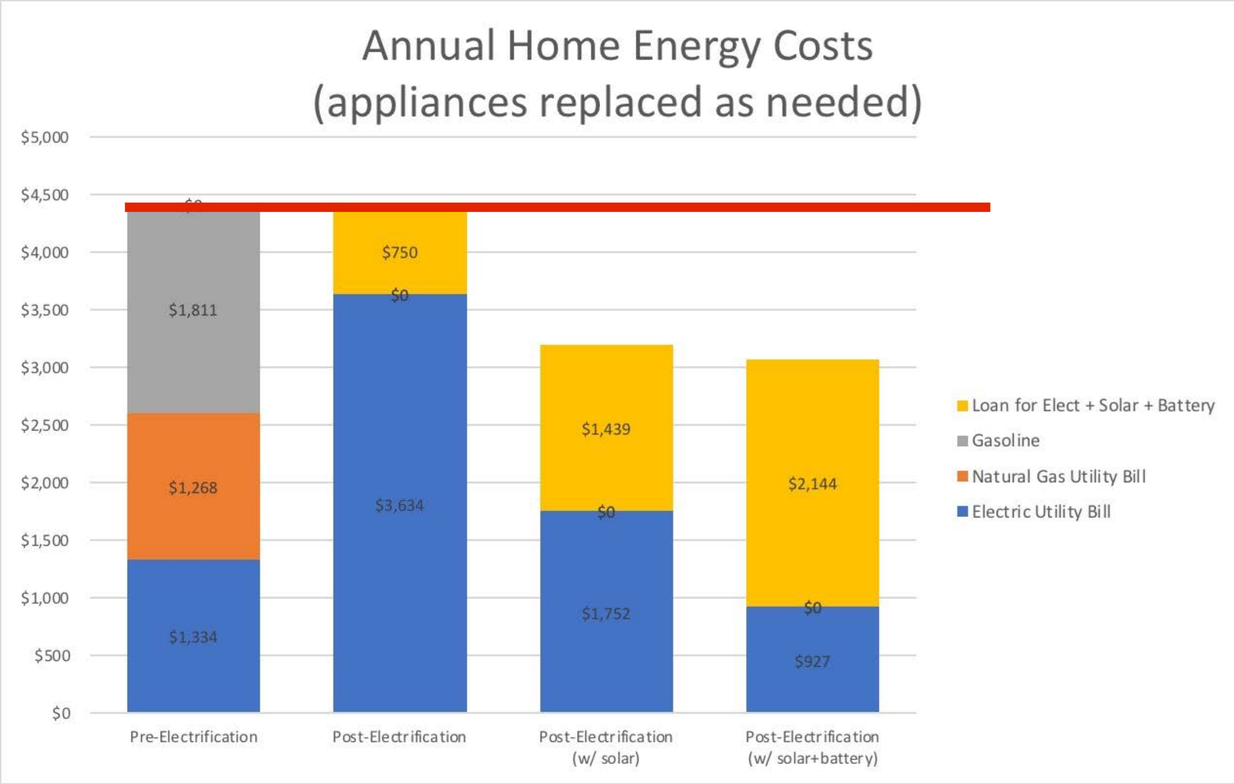
KEY LEARNINGS...SO FAR (CONT)

- You can electrify your pool heat or keep your 100-amp panel, but you can't do both
- Heating a pool for a home with a 100-amp panel will likely force a panel upsize...but don't over do it, another 50 amps of panel capacity is plenty
- Upsize the water heater when going from gas to heat pump, for homeowner satisfaction
- Old resistance dryers are energy hogs (e.g. 26 amps), use more power than a 3-ton inverter-drive heat pump HVAC system (17 amps) which can easily heat an entire house
- Insulation is just one tool in the electrification/decarbonization tool kit
- Electrification is not rocket science, but you can be steered down bad paths by contractors
- We need more contractors who understand amp diets and want to sell heat pumps

ELECTRIFICATION NEARLY ELIMINATES BUILDING GHG EMISSIONS



WHAT DOES IT COST TO ELECTRIFY?



Annual Home Energy Costs	Pre-Electrification	Post-Electrification	Post-Electrification (w/ solar)	Post-Electrification (w/ solar +battery)
Electric Utility Bill	$1,334	$3,634	$1,752	$927
Natural Gas Utility Bill	$1,268	$0	$0	$0
Gasoline	$1,811	$0	$0	$0
Loan for Elect + Solar + Battery	$0	$750	$1,439	$2,144
Total	**$4,414**	**$4,384**	**$3,191**	**$3,071**

SCENARIO APPLIANCE ASSUMPTIONS

	Starting State	End State	Conversion Yr
Water heating	gas water heater	heat pump water heater	3
Space heating	gas furnace	heat pump HVAC	5
Clothes drying	gas dryer	hybrid heat pump dryer	7
Cooking	gas range	induction range	8
Vehicle fuel	gasoline	electricity (via home EV charger)	1
Solar	0 kW	5.8 kW	1
Stationary battery	0 kWh	13.5 kWh	3
Electric service	100 amps	100 amps	n/a

A HOW TO GUIDE FOR ELECTRIFICATION

- Just released by Redwood Energy and Menlo Spark
- Electrification solutions for existing buildings
- Product lists
- Case studies from across the country
- Amp diet info
- Cost examples

- https://redwoodenergy.net/wp-content/uploads/2021/02/Pocket-Guide-to-All-Electric-Retrofits-of-Single-Family-Homes.pdf

APPLIANCE INSTALLATION COST ASSUMPTIONS

New Electrific Equipment	Capital Costs - Electrification												
	Electric Equipment Installation								Equivalent Gas Equipment Installation				
	Included in Project?	Equip Cost	Labor Cost	Wiring Cost	Permit Cost (Fee + Labor)	Installed Cost Before Incentives	Incentives	Total Cost Electric	Equip Cost	Labor Cost	Permit Cost	Total Cost Gas	Premium: Electric v. Gas
Electric service upgrade	no	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
New electric subpanel	no	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Heat pump water heater	yes	$1,300	$1,200	$400	$500	$3,400	($2,500)	$900	$600	$400	$400	$1,400	($500)
Heat pump HVAC	yes	$5,000	$4,000	$550	$1,000	$10,550	$0	$10,550	$3,000	$2,000	$500	$5,500	$5,050
Hybrid Dryer	yes	$1,500	$0	$300	$0	$1,800	$0	$1,800	$700	$100	$0	$800	$1,000
Induction Range	yes	$3,000	$0	$600	$0	$3,600	$0	$3,600	$1,200	$100	$0	$1,300	$2,300
EV charger	yes	$500	$0	$600	$400	$1,500	$0	$1,500	$0	$0	$0	$0	$1,500
TOTAL		**$11,300**	**$5,200**	**$2,450**	**$1,900**	**$20,850**	**($2,500)**	**$18,350**	**$5,500**	**$2,600**	**$900**	**$9,000**	**$9,350**

ROOFTOP SOLAR ECONOMICS

Solar System Size	5.8	kW
Solar System Price*	$2.00	per watt
Total Price of Solar System	$11,600	
Federal Tax Credit - 26%	$3,016	
Solar System Cost After Tax Credit	**$8,584**	
Average Full Sun Equiv	1,600	hours per
Average Daily Insolation	4.38	hours per day
Daily Solar Array Output	25	kWh per day
Annual Solar Array Output	9,280	kWh per year
Solar System Life	25	years
Derating Factor due to Aging	20%	
Derating Factor from Size Clipping	7%	
Derated Annual Solar Array Output	**6,922**	kWh per year
Solar Electricity Cost (ex. loan)	**$0.05**	per kWh
Annual Loan Payment on System**	**$689**	
Solar Electricity Cost (inc. loan)	**$0.10**	per kWh
Avoided PG&E Electricity Cost	**$1,661**	
Annual Savings from Solar	**$973**	

* Note: $2.00 per watt installed price taken from Tesla's website

** Assumes 5% interest rate and 20 yr term

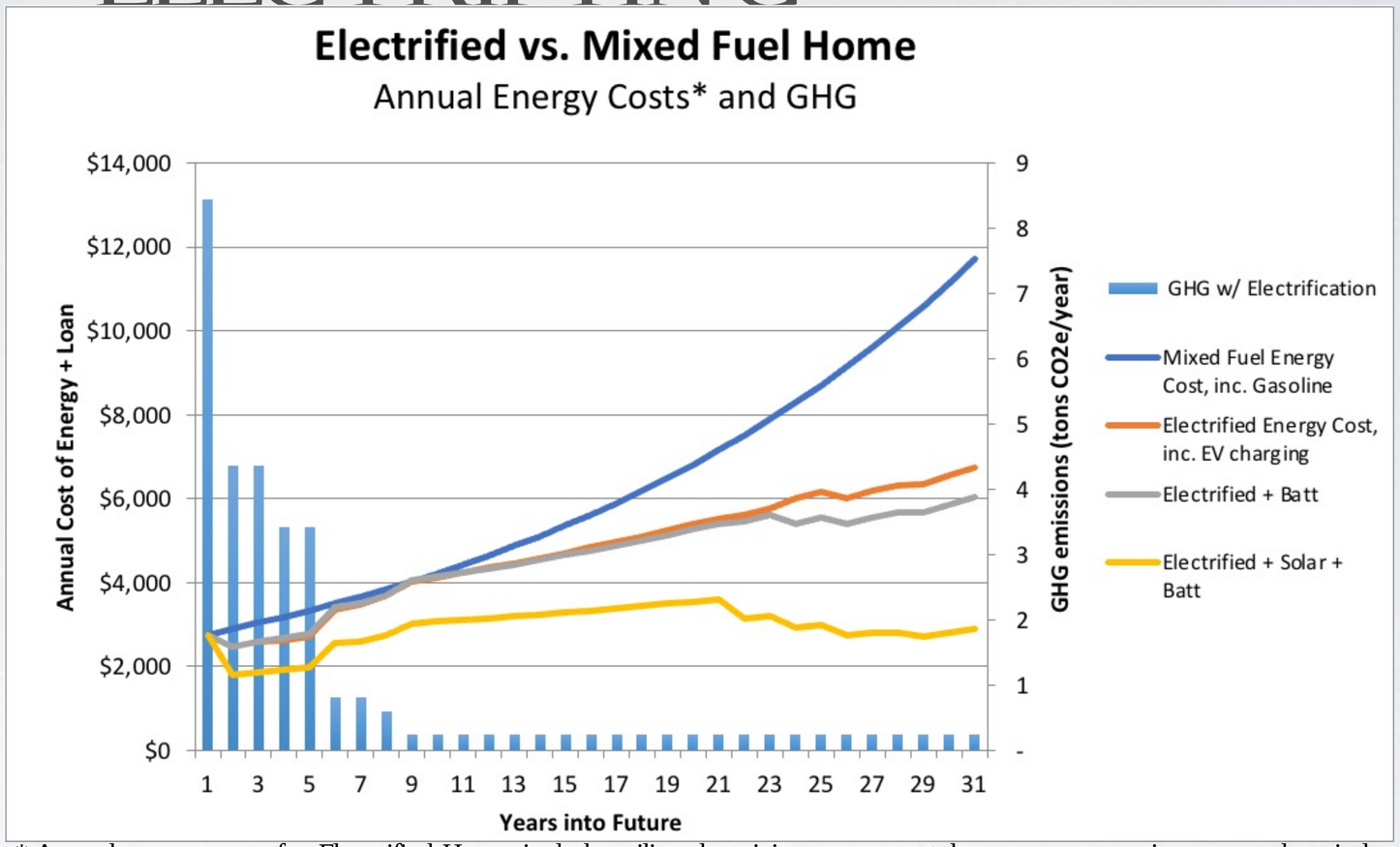
FINANCE AND OTHER KEY ASSUMPTIONS

- Loan term: 20 years
- Loan interest rate: 5% fixed
- Electrification costs reflect actual prices/quotes
- Rooftop solar installation cost = $2.00/watt
- Stationary battery installation cost = $880/kWh
- Battery capacity reserved for outages = 35%

- Federal tax credit = 26%
- CCE subsidy = $2,500 for HP water heater

HOME BUDGET IMPACT OF NOT ELECTRIFYING

Key Variables		
Interest rate	5.0%	
Loan term	20	yrs
Natural gas rate multiplier from inputs b	1.84	
Starting Electric Rate	E-1	
Starting Electricity Rate (Average)	$0.24	per kWh
New Electric Rate	EV2-A	
Include solar?	yes	
Solar system size	5.8	kW
Solar system price	$2.00	per Watt
Include battery?	yes	
Battery system size	13.5	kWh
Battery system price	$880	per kWh
Battery capacity in reserve for outage	35%	
Upgrade to main panel req'd?	no	
Permit streamlining for electrifcation?	no	
Permit cost reduction for electrification	80%	
Federal tax credit applicable?	yes	
Federal tax credit rate	26%	
Incentive for main panel upgrade	$0	
Incentive for subpanel upgrade	$0	
Incentive for HP water heater	$2,500	
Incentive for HP HVAC	$0	
Incentive for HP dryer	$0	
Incentive for electric cooking range	$0	
Incentive for EV charger	$0	



* Annual energy costs for Electrified Home include utility electricity payments + loan payment on incremental capital investments for electrification. Escalation rate assumptions for electricty and natural gas rates in PG&E territory and gasoline prices are all taken from the California Public Utilties Commission Report entitled "Utility Costs and Affordability of the Grid of the Future: an Evaluation of Electric Costs, Rates and Equity Issues, Pursuant to P.U. Code Section 913.1", February 2021, p. 73.

KEY FINDINGS

- **Electrification is cost neutral from day one to the end customer if:**
  - Financed
  - Paired with roof-top solar
  - Installation costs are competitive
  - Amount financed is “premium” for electrification over gas appliances
- Panel saving “amp diet” concept is key to avoiding $3,000+ electrical service upgrade
- Capital costs for electric appliances are currently higher than equivalent gas appliances
- Solar is so inexpensive that it floats the economics of electrification
- Adding a battery pays for itself due to “duck-head” savings on PG&E’s EV2-A rate

WHAT CAN WE LEARN FROM ROOFTOP SOLAR?

- Installation costs will come down with volume
- Installer training is key to quality and cost
- Streamlining permits is key to reducing costs
- Stepping down subsidies by volume (vs. time) creates prompt demand, injects urgency and imposes discipline on installer market
- Financing will move electrification from something only wealthy people can afford to something most people can afford

KEY LEVERS FOR POLICY MAKERS AND UTILITIES

#		Who
1	Low interest financing	private sector, PCE, County?
2	On-bill financing	PG&E, PCE
3	Extra support for low-income households	?
4	Equipment rebates	PCE
5	Installer training	PCE, County
6	Public education	PCE, County, Cities
7	Permit streamlining	Cities, County, State
8	Favorable electricity rates	PCE, PG&E, CPUC
9	City ordinances	Cities

WHAT ELSE DO WE NEED?

- Low-interest financing solutions
- Financing solutions for customers with poor credit
- On-bill utility financing
- Education on using “amp diets” to avoid panel upgrades
- Permit streamlining and fee reduction
- More developed and competitive installer market

LOAD ANALYSIS