RESNET® 2021
RESIDENTIAL ENERGY SERVICES NETWORK
VIRTUAL CONFERENCE 2.22-2.24

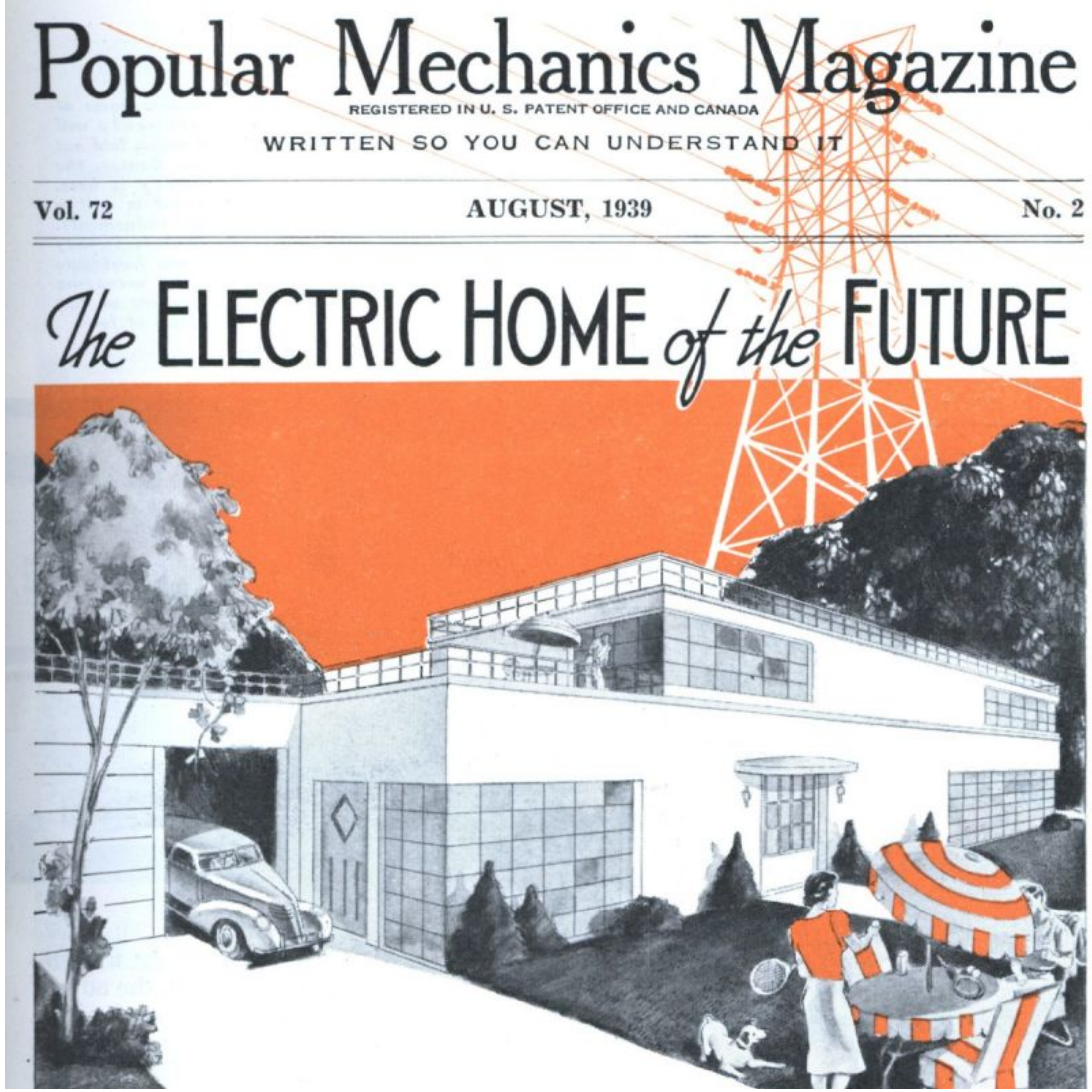
The Future of All-Electric Homes

Sean Armstrong, Redwood Energy

Iain Walker LBNL

Why Electrification of Homes?

- Need to stop emitting CO_2
- Need low/zero CO_2 energy – electricity the only viable option
  - Allows use of low/zero carbon renewable energy
- "*We can't efficiency our way to zero carbon emissions*"
  - Very limited efficiency gains remain for fossil-fule heating and DHW
- Gas leaks typically about 2-3% but higher GWP makes this a 20-30% increase in greenhouse gas emissions
  - 0.5% leakage in homes



Popular Mechanics Magazine

REGISTERED IN U. S. PATENT OFFICE AND CANADA

WRITTEN SO YOU CAN UNDERSTAND IT

Vol. 72 AUGUST, 1939 No. 2

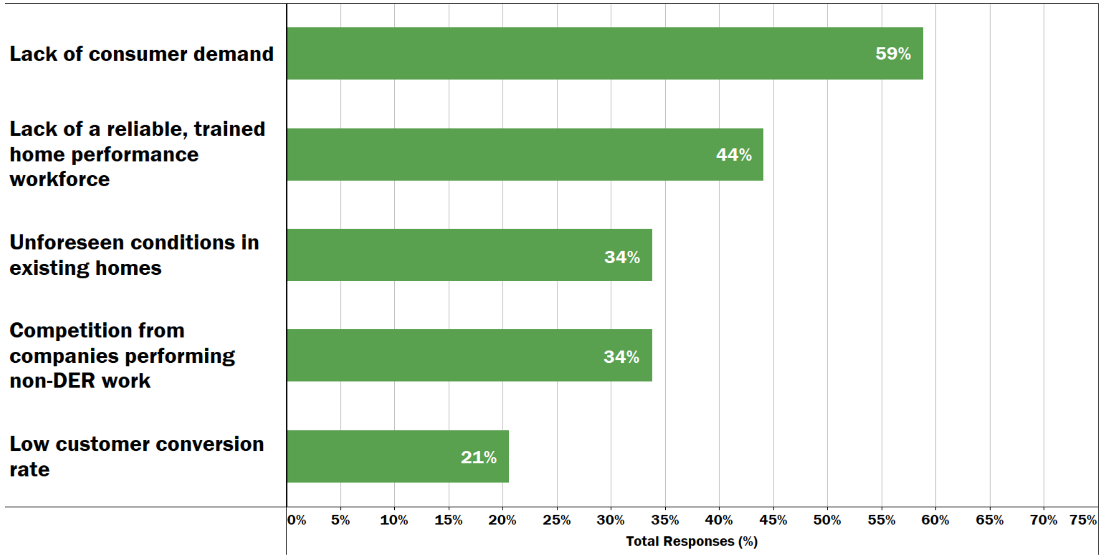
The ELECTRIC HOME of the FUTURE

Why Electrification of Homes?

We have to fix all the homes in the country and electrification is easier than other retrofit approaches

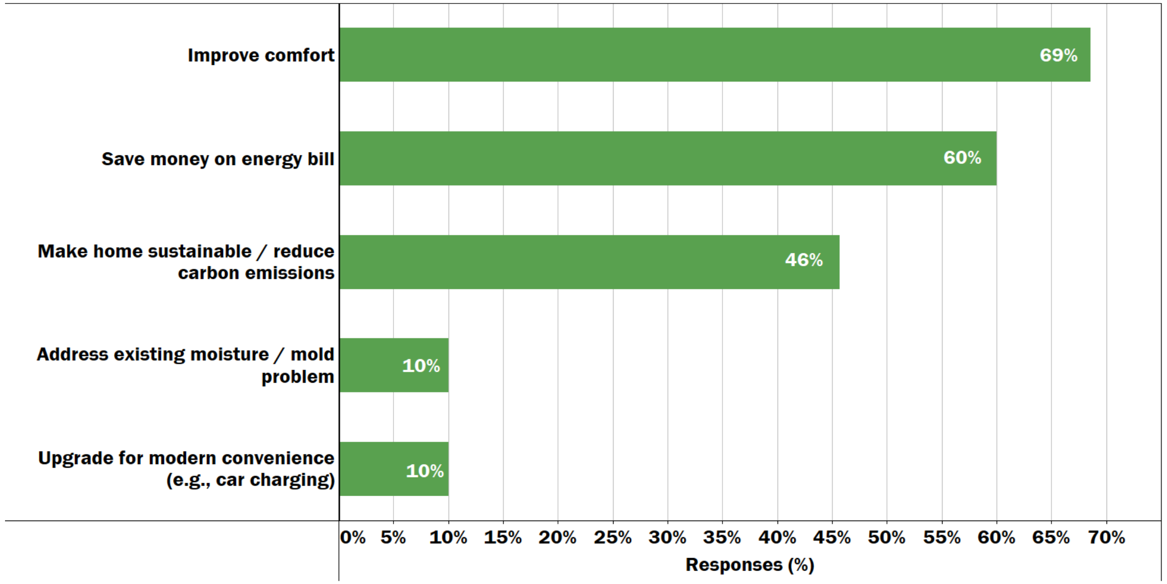
- Less home disturbance
- Better cost control
- Easier financing
- Easier work for contractors c/w envelope/window upgrades
- **Easier to sell – give people what they want**

Aside from costs, what are the biggest barriers when performing DER projects?



Sum of Responses Q3% for each List - Q33. The marks are labeled by sum of Responses Q3%.

What are main motivation of homeowners / building owners when seeking to perform a DER project?

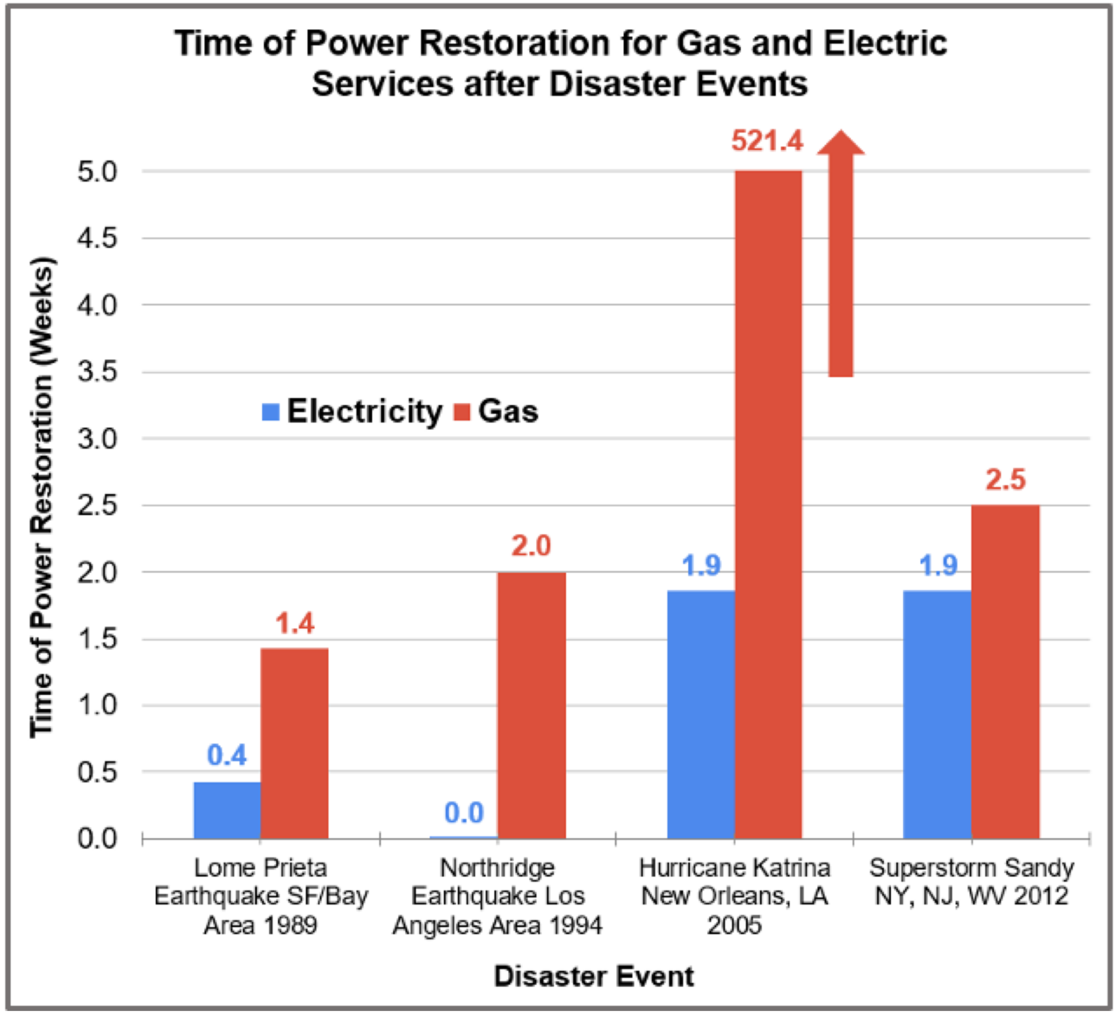


Sum of Mot 1% for each Motivation. The marks are labeled by sum of Mot 1%.

Why Electrification of Homes?

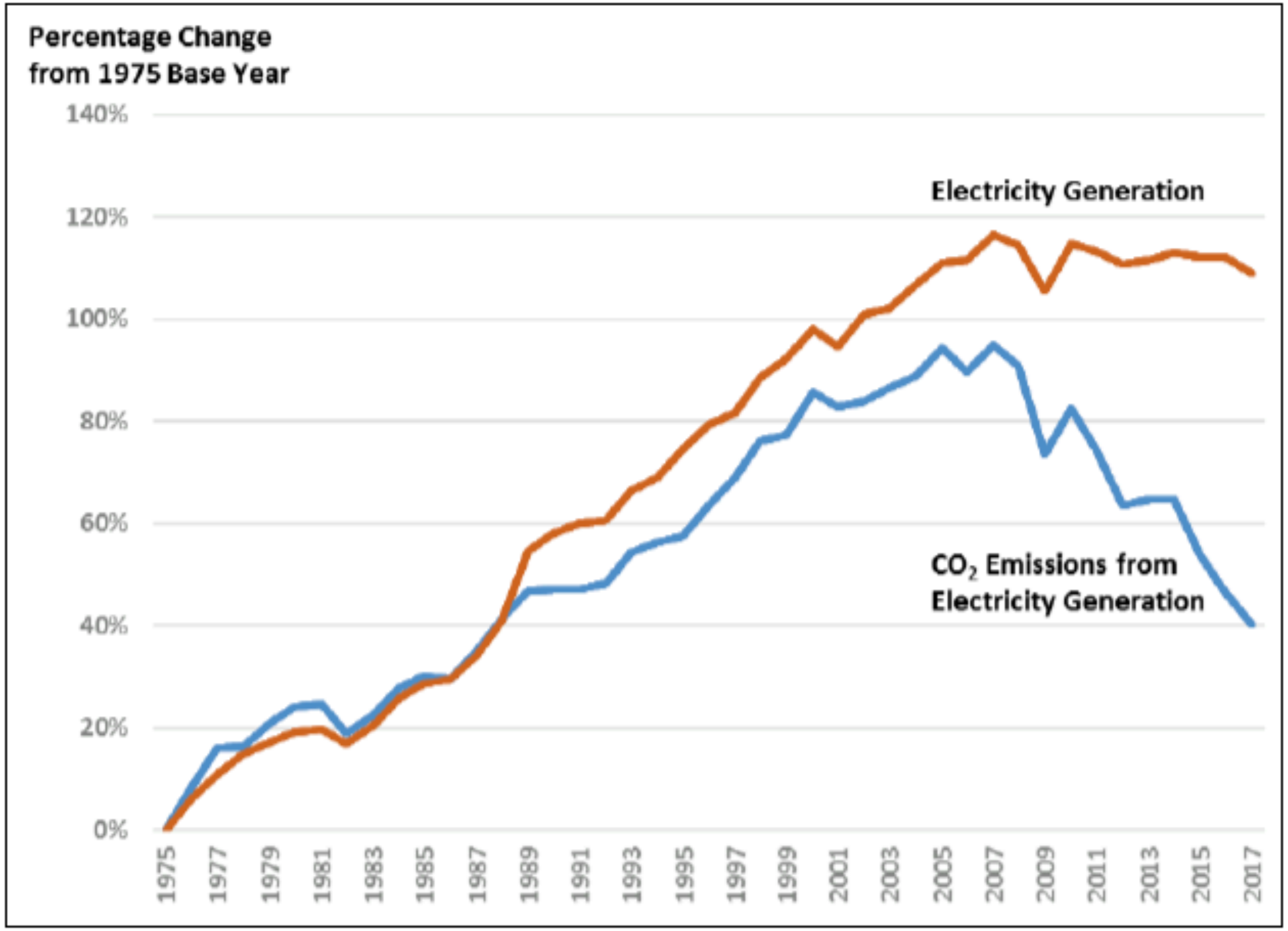
Resiliency

- on-site storage allows basic home operation during emergencies
- about half of natural gas processing is along the gulf coast and highly vulnerable to hurricanes and storm surges



Think about it as the completion of the electrification program begun in the US 100 years ago

Electricity is rapidly lowering its CO_2 content

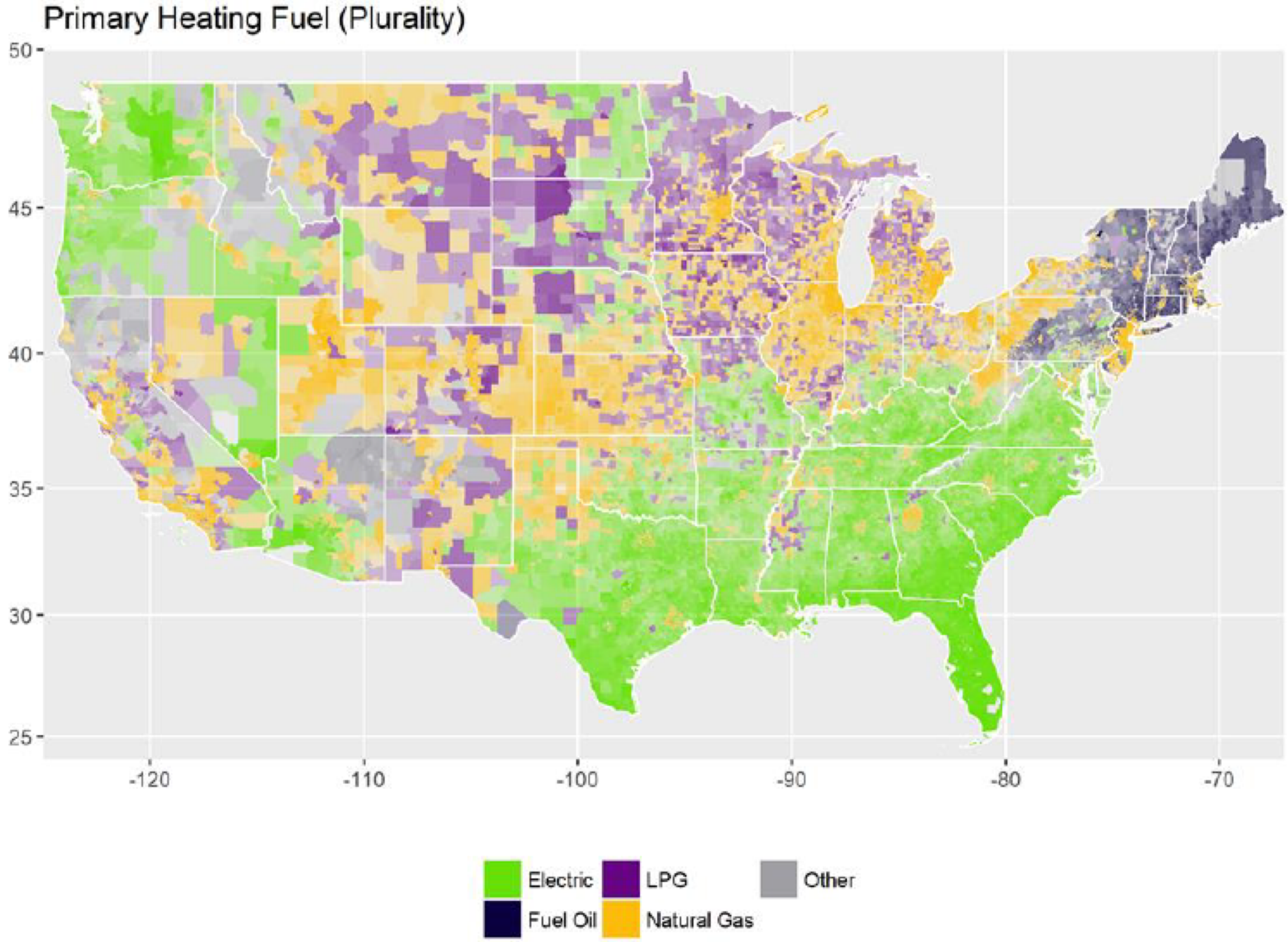


1975 - 2017

Source: Prepared by CRS; data from EIA, *Monthly Energy Review*, net electricity generation from Table 7.2 and emissions from Table 12.6, http://www.eia.gov/totalenergy/data/monthly/.

Figure from : US Carbon Dioxide Emissions in the Electricity Sector: Factors, Trends and Projections, 2029. Congressional Research Service.

Current Distribution Of Electric heating

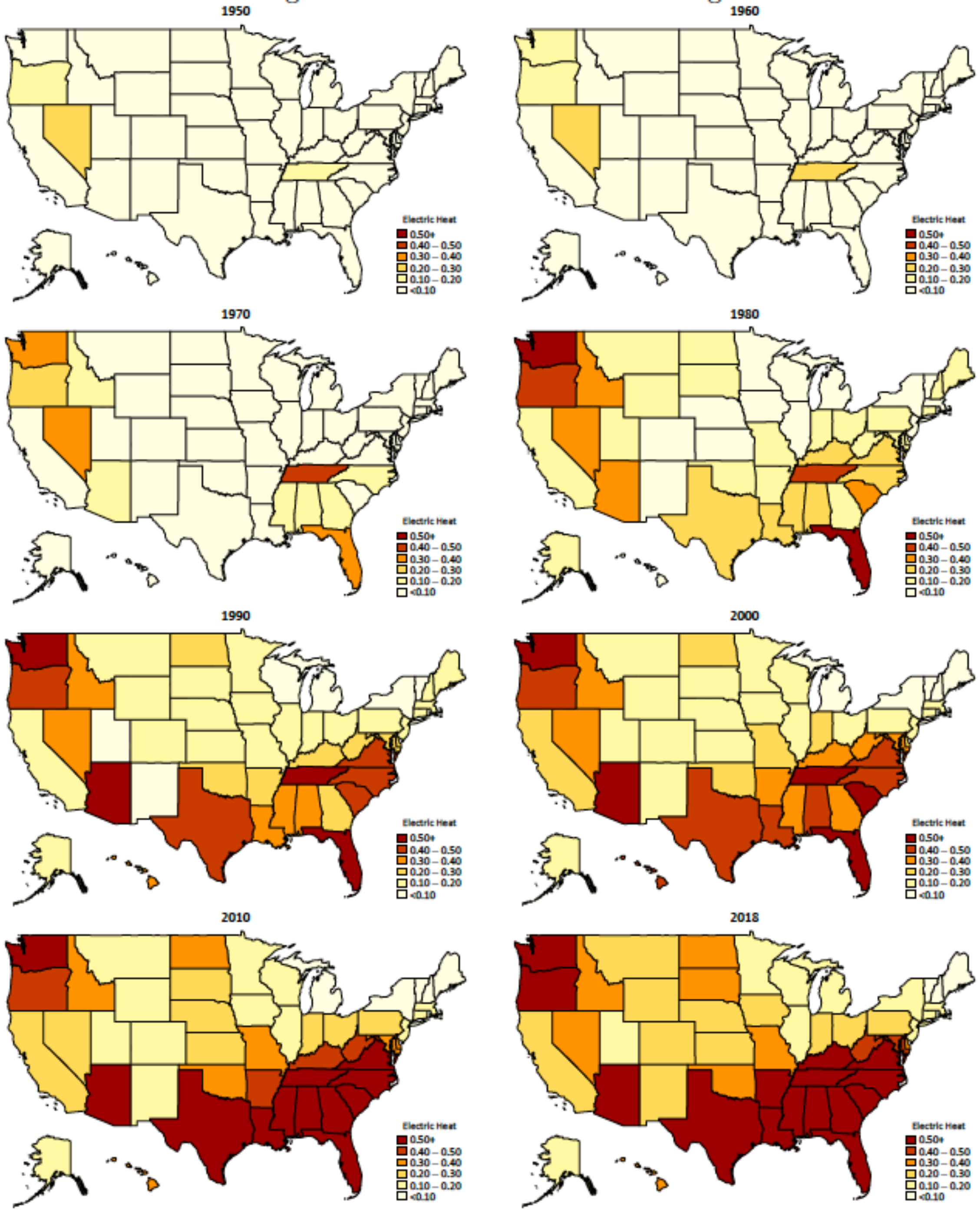


>25% of homes are already all-electric

40% of homes have electric primary heating

Data from the American Community Survey (2016).

Growth in Electric Heating



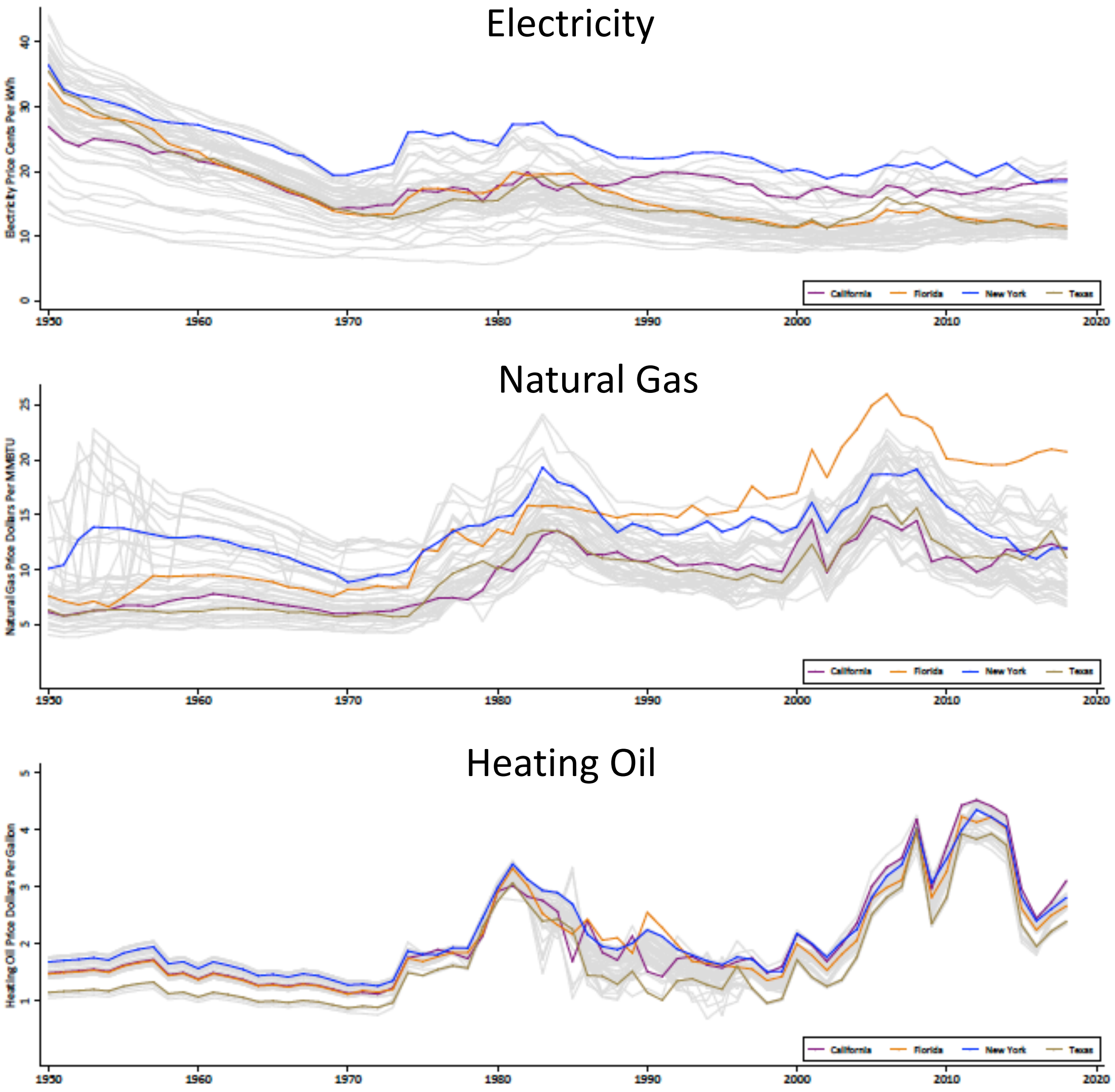
Electrification of largest end-use has been increasing for years

We are just going to accelerate this trend

Most new-home growth in areas where homes are electrified for heating/cooling

Figure from Davis, L. 2020. What Matters for Electrification? Evidence from 70 years of US Home Heating Choices. Energy Institute at Haas, WP 309.

Historic Fuel Prices



Notes: This figure plots average annual revenue from residential sales of electricity, natural gas, and heating oil, respectively. Prices are plotted for all U.S. states except for Alaska and Hawaii. Data series are labeled for the four largest U.S. states by population (California, Texas, Florida, and New York). Data before 1970 come from Edison Electric Institute (1950-1969), American Gas Association (1950-1969), and Platts Oil (1950-1969), respectively. Data after 1970 come from U.S. Department of Energy, Energy Information Administration (1970-2018b). Prices have been normalized to reflect year 2020 dollars.

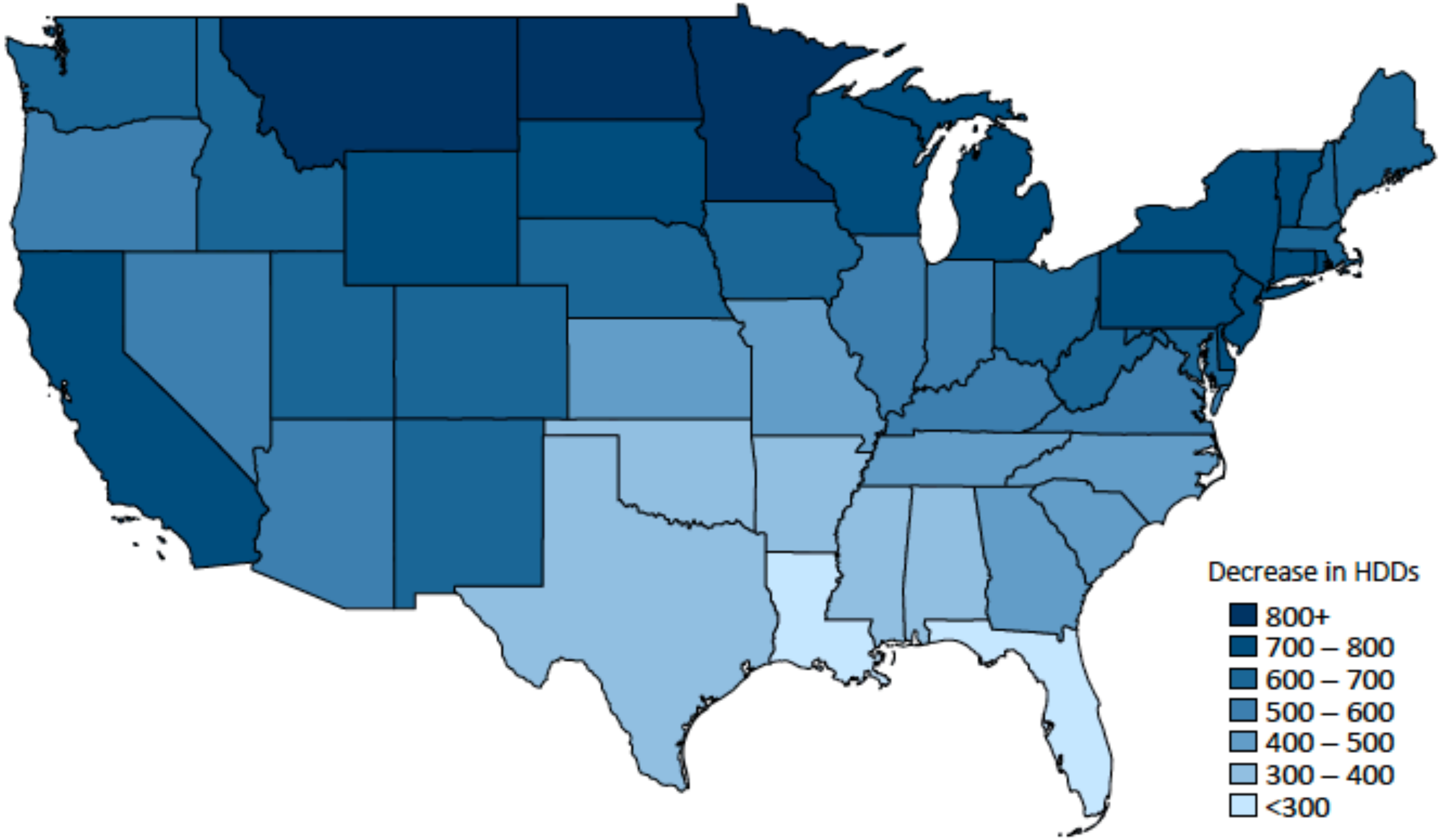
Electricity getting cheaper

Renewables the cheapest new source of electricity

Figure from Davis, L. 2020. What Matters for Electrification? Evidence from 70 years of US Home Heating Choices. Energy Institute at Haas, WP 309.

We need less heat!

Figure 3: Decrease in Heating Degree Days Since 1950



Notes: This figure describes the change in annual heating degree days (HDDs) between 1950 and 2019. For example, Minnesota had 9,300 HDDs in 1950 and 8,400 HDDs in 2019, for a decrease of 900 HDDs. Florida, in contrast, had 800 HDDs in 1950 and 600 HDDs in 2019, for a decrease of 200 HDDs. This is based on annual state-level data from NOAA National Centers for Environmental information (2020). However, rather than use the raw data which reflect a large amount of year-to-year variation, these calculates are based on fitted values from a linear time trend estimated separately by state. See Appendix Figure A1 for maps showing HDDs for each decade separately.

Figure from Davis, L. 2020. What Matters for Electrification? Evidence from 70 years of US Home Heating Choices. Energy Institute at Haas, WP 309.

Different paths to electrification

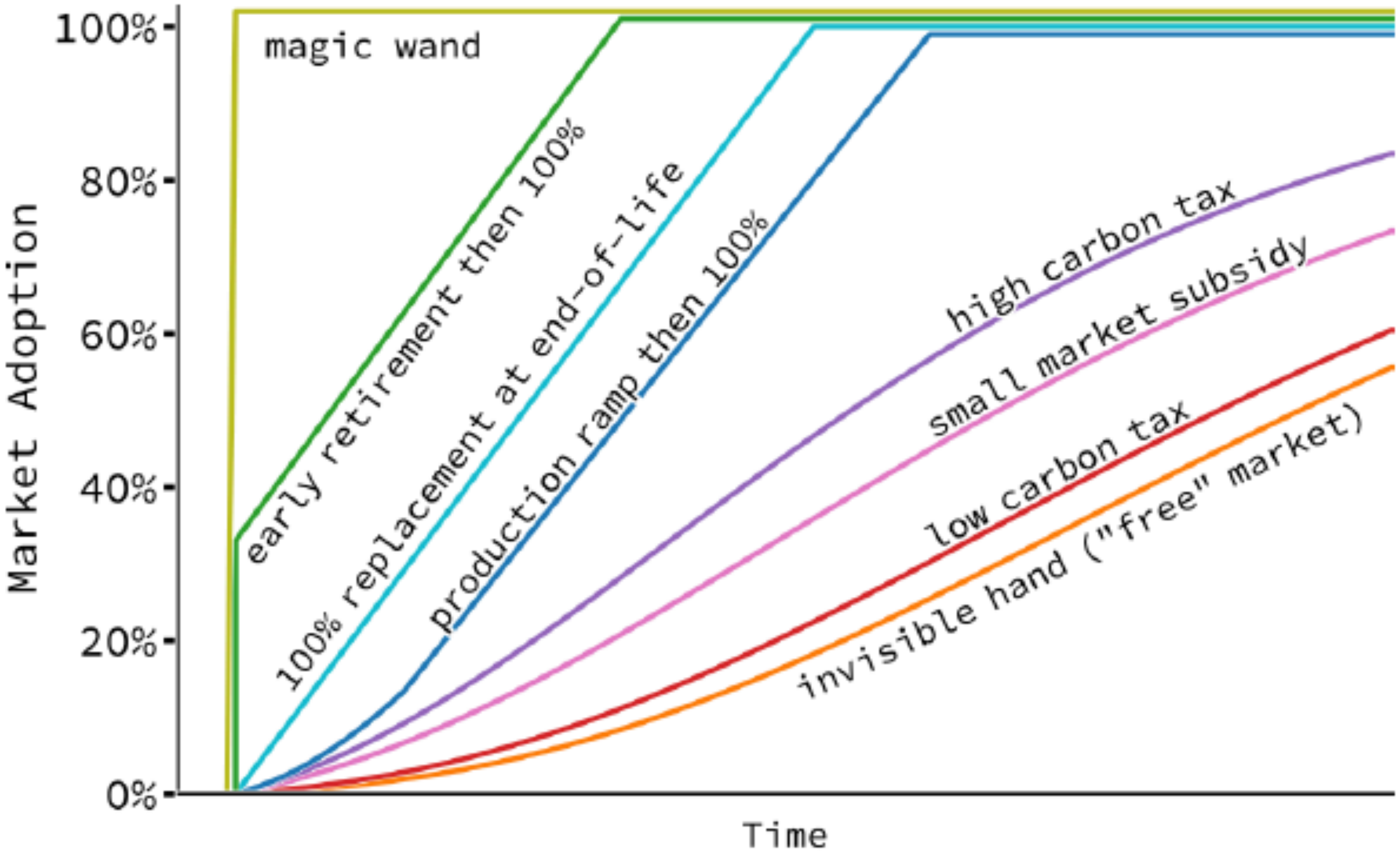


Figure from Rewiring America by Saul Griffith, Sam Calisch and Laura Fraser

Different Consequences

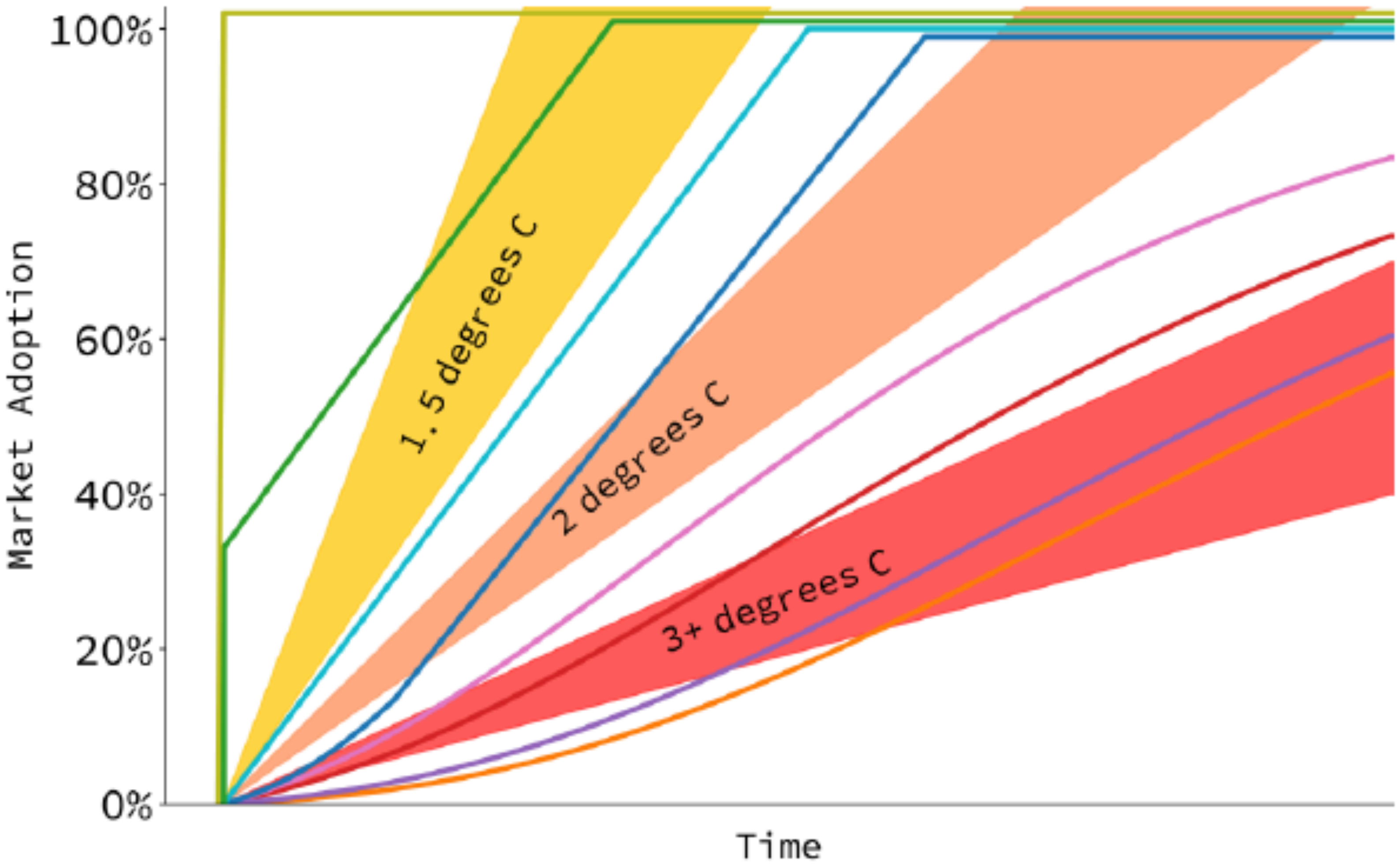
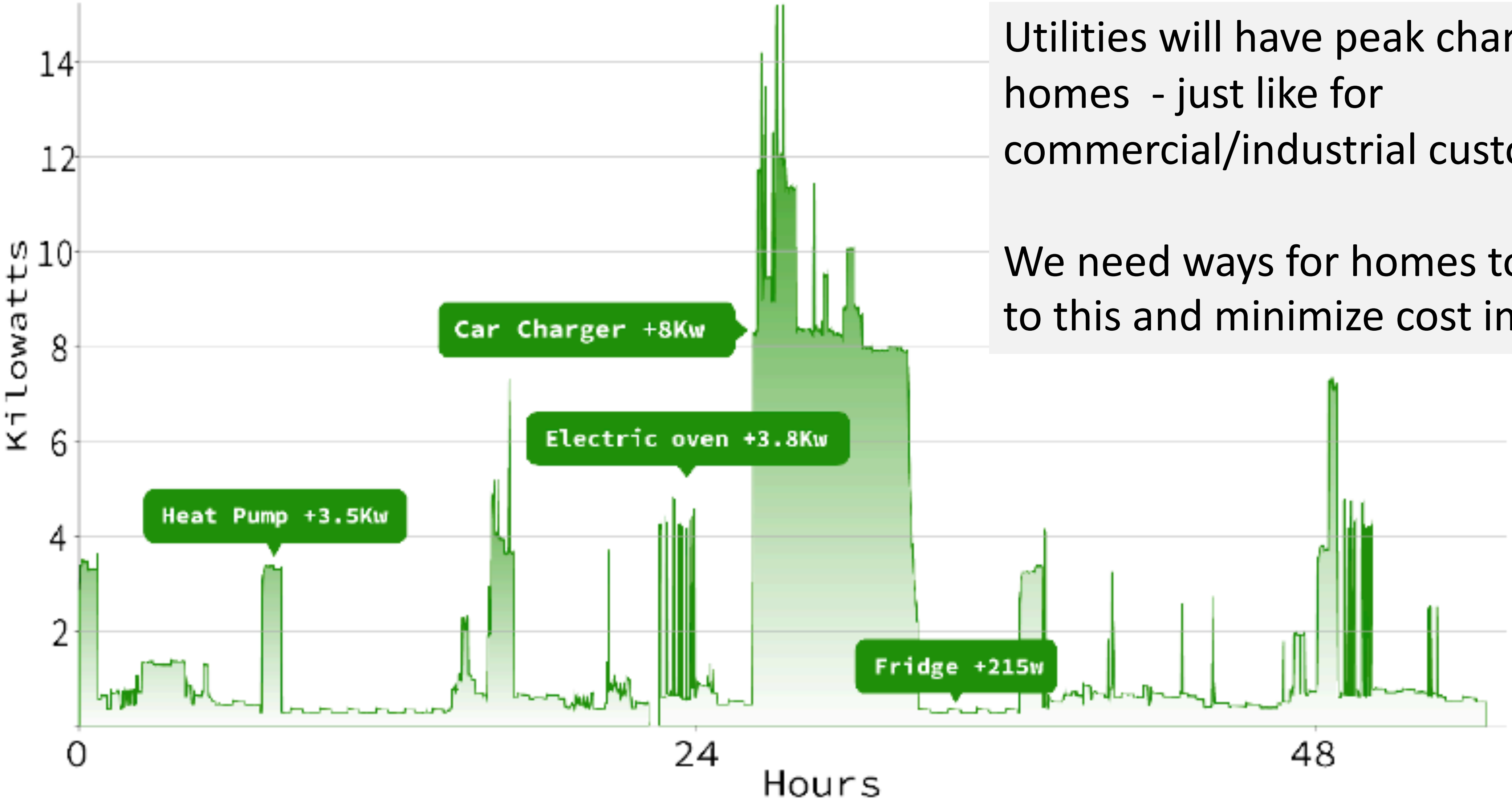


Figure from Rewiring America by Saul Griffith, Sam Calisch and Laura Fraser

Need to manage the peaks with storage



Utilities will have peak charges for homes - just like for commercial/industrial customers

We need ways for homes to respond to this and minimize cost impacts

Figure from Rewiring America by Saul Griffith, Sam Calisch and Laura Fraser

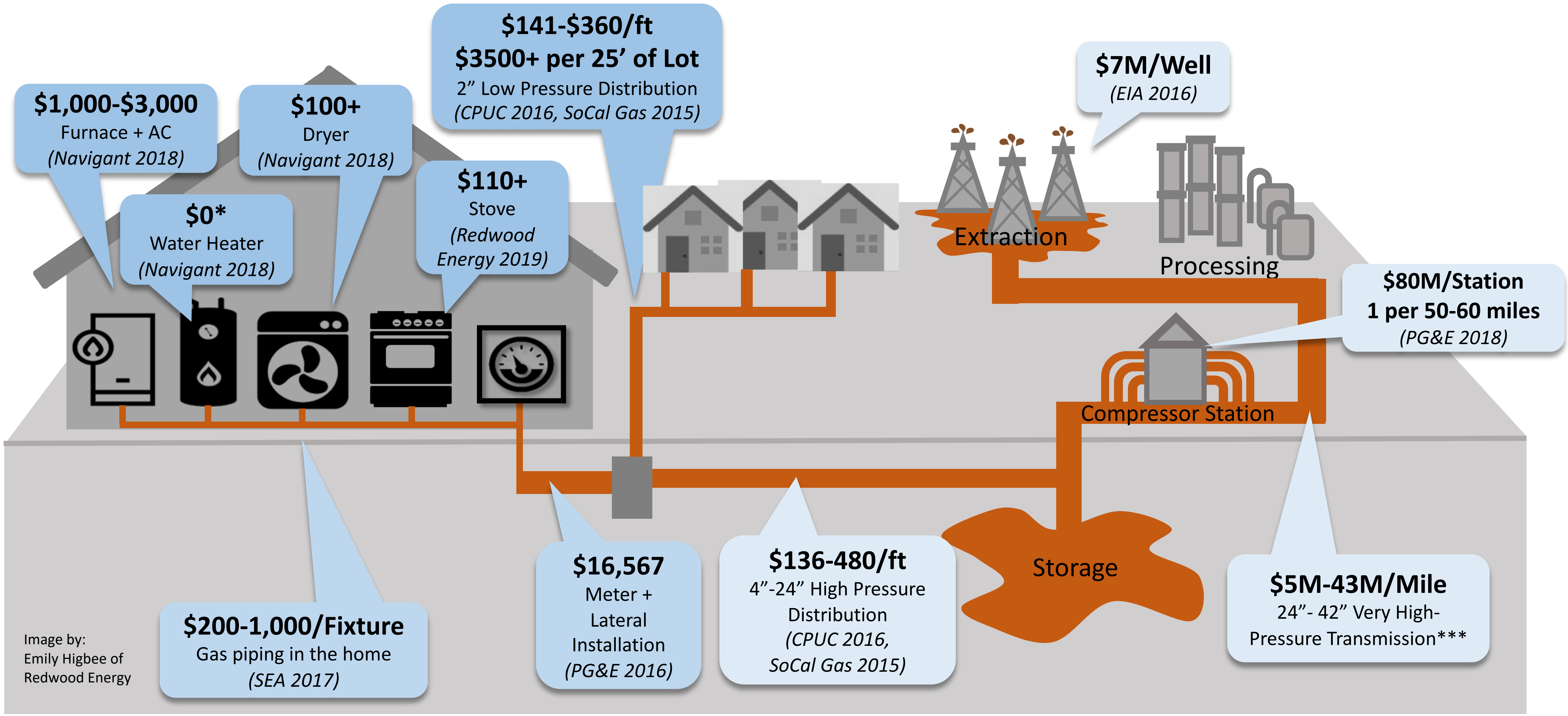
EV-ready Homes

- Major obstacle to EV purchases is lack of charging infrastructure
  - Need to be able to charge at home
- All new homes should have a circuit ready for a charger install
- Trickier in existing home – need a space circuit or new panel/rewiring
- EV can easily be the biggest home load: 7.2 kW
- Will need managing to integrate with existing distribution infrastructure

New home cost reductions – over to Sean…

Residential Natural Gas Infrastructure Costs and Methane Leakage: $25,000+ per home, 2.7%-5.2% leakage

The total methane leakage rate from California's residential natural gas infrastructure is estimated to be 4.18% (2.7 – 5.2%). Owner paid cost increases due to more expensive gas appliances and infrastructure additions are in darker blue, while "rate based" cost increases are in lighter blue.



$1,000-$3,000
Furnace + AC
(Navigant 2018)

$0*
Water Heater
(Navigant 2018)

$100+
Dryer
(Navigant 2018)

$110+
Stove
(Redwood Energy 2019)

$141-$360/ft
$3500+ per 25' of Lot
2" Low Pressure Distribution
(CPUC 2016, SoCal Gas 2015)

$7M/Well
(EIA 2016)

$80M/Station
1 per 50-60 miles
(PG&E 2018)

$200-1,000/Fixture
Gas piping in the home
(SEA 2017)

$16,567
Meter + Lateral Installation
(PG&E 2016)

$136-480/ft
4"-24" High Pressure Distribution
(CPUC 2016, SoCal Gas 2015)

$5M-43M/Mile
24"- 42" Very High-Pressure Transmission***

Image by:
Emily Higbee of
Redwood Energy

Appliance costs are the marginal cost ($) of gas over all-electric

*heat pump water heater equal in cost to on demand gas water heating

**Aliso Canyon leaked 4.62 Billion cubic feet and alone cost $1.014 billion shared by 5.6 million meters - $181/meter cost (Reuters, Aug 6, 2018)

*** Average of various sources *(Cochran 2018, Lennon 2019, SoCalGas 2014, Nemec 2015, Nogueras 2011)*

Energy Impacts

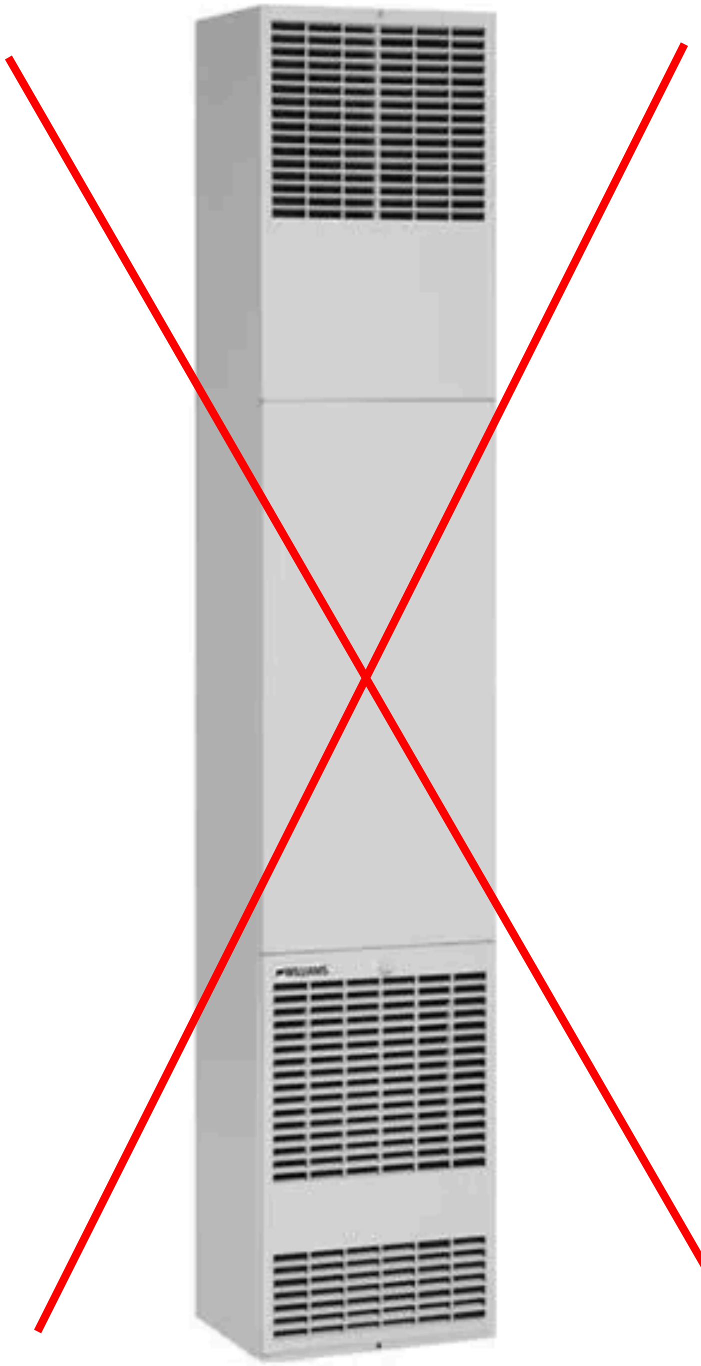
- Significant site savings using heat pumps – typically factors of 3-4 compared to fossil fueled appliances and electric resistance heat and DHW
- Primary or source energy less clear due to electric distribution system losses
  - Minimize primary energy by:
    - On-site generation: mainly PV but could include solar hot water
    - On-site storage: limits peak power, allows shifting energy use to time of greatest renewable generation
- Utilities willing… electrification allows homes to operate at minimum power using their own generation/storage – big increase in resiliency
- Energy is less of an issue of the goal is saving our civilization… but energy efficiency will help the transition and keep costs down

Health reasons to eliminate fossil fuels

- Burning fossil fuels emit several contaminants of concern: PM2.5, NO_2, CO, aldehydes and leaking unburned CH4
- In the home
  - Fossil fuels lead to higher pollutant levels
  - Field studies show key health-related contaminants related to bring fossil fuels: cooking and poor appliance venting
  - Electrification removes need for combustion safety testing, CO alarms
  - Electrification removes this health hazard
- Outside air: PM2.5 & NO2
  - Environmental Justice Issue – often worse in disadvantaged communities

Health and environmental justice

- Removing poor appliances: Wall Furnaces
  - Wall furnaces are chronically poor at venting
  - Causes moisture problems and high levels of combustion contaminants
  - Even worse if kitchen of bath exhausts are used
- Their low capacity serving small spaces makes them ideal candidates for low-cost replacement with a heat pump – possibly even a 120V heat pump
- ***This would serve low-income households the most***
  - More likely to have wall furnaces
  - Smaller dwellings have higher contaminant concentrations
  - Low income dwellings less likely to have ventilation systems
- Eliminate use of gas cooking appliances as supplemental heat
  - Need to provide good low operating cost options for low income households



Outdoor Air quality: Avoided Mortality

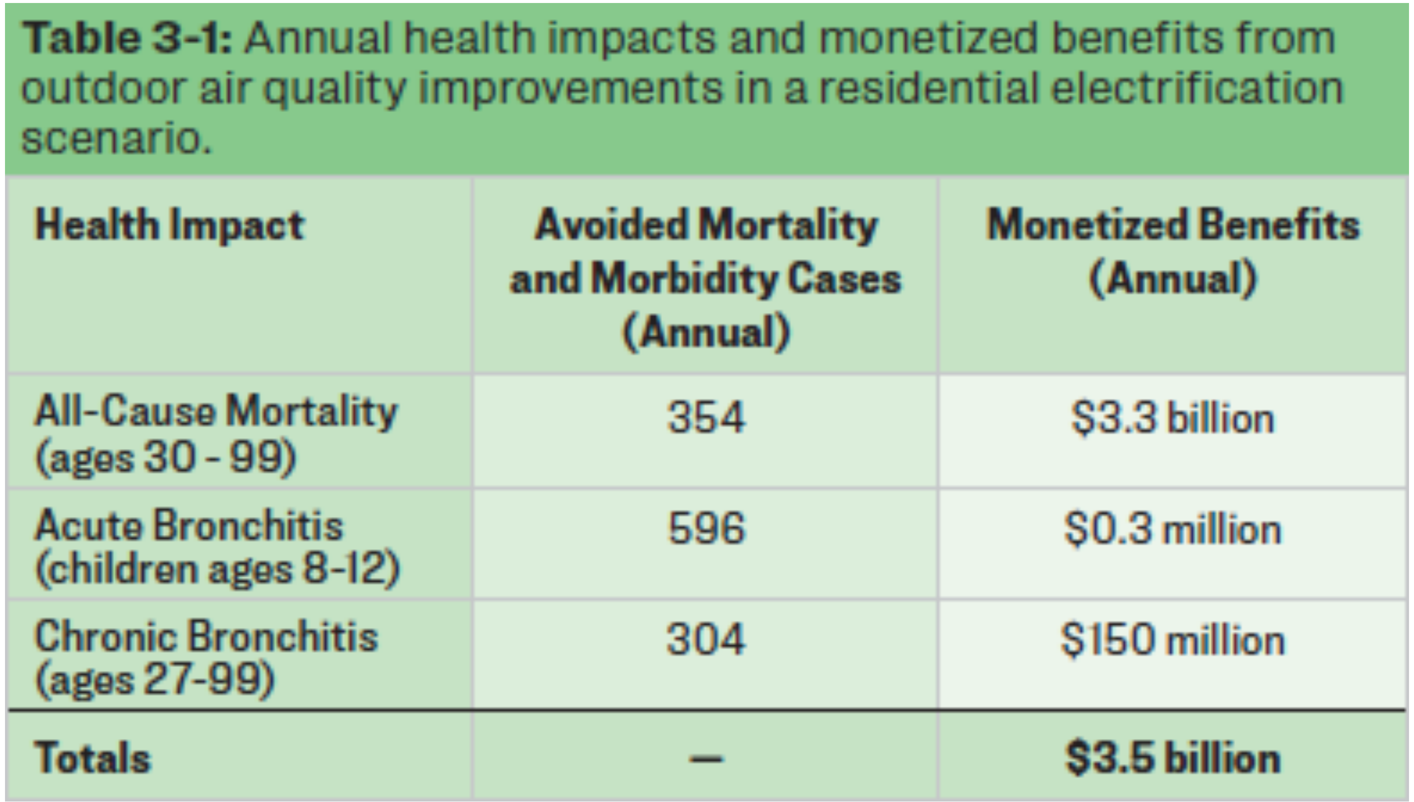


Table 3-1: Annual health impacts and monetized benefits from outdoor air quality improvements in a residential electrification scenario.

Health Impact	Avoided Mortality and Morbidity Cases (Annual)	Monetized Benefits (Annual)
All-Cause Mortality (ages 30 - 99)	354	$3.3 billion
Acute Bronchitis (children ages 8-12)	596	$0.3 million
Chronic Bronchitis (ages 27-99)	304	$150 million
Totals	**—**	**$3.5 billion**

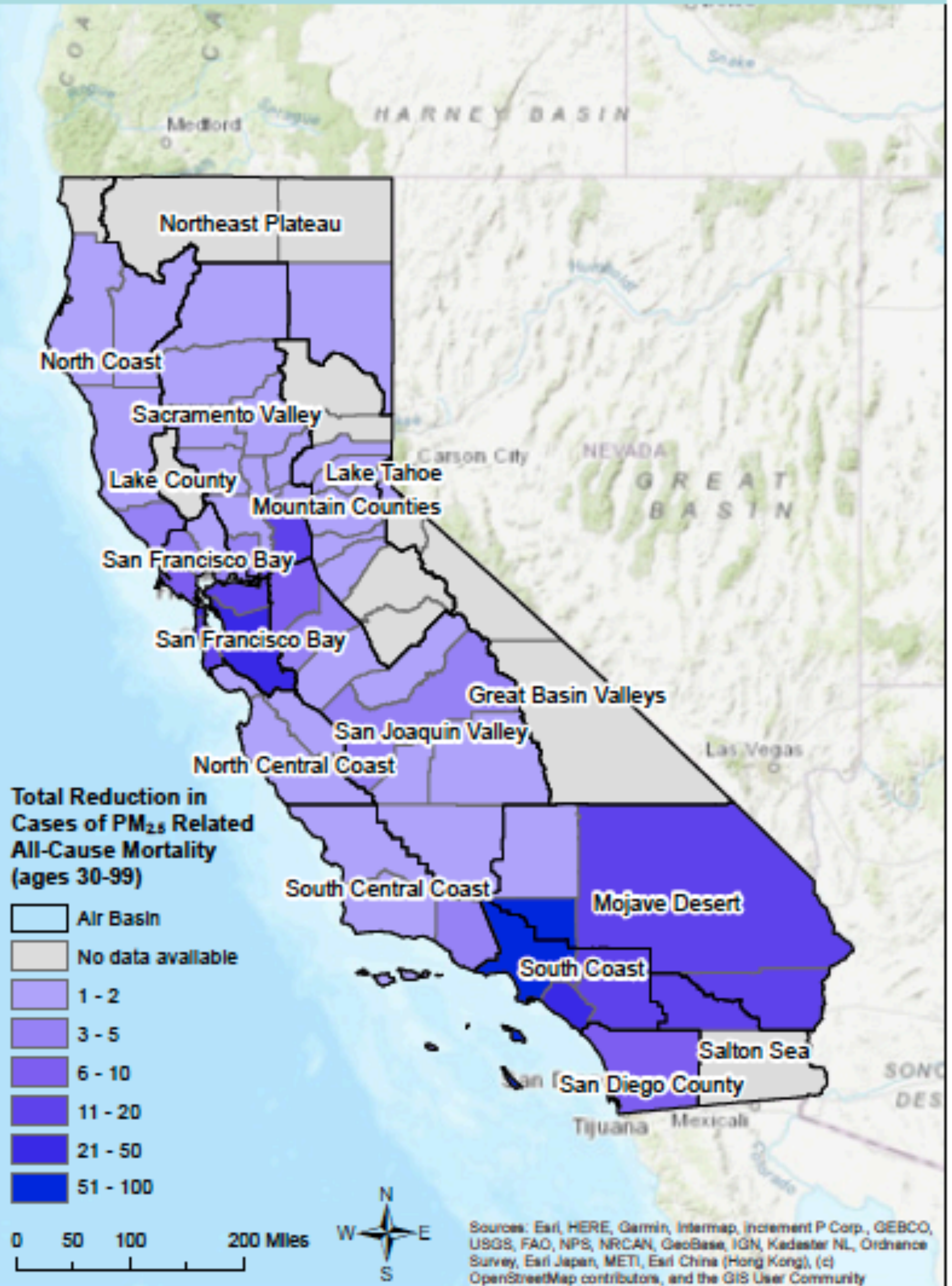


Figure 3-4: Total reduction in annual cases of $PM_{2.5}$ related all-cause mortality by county in 2018.

Sources: Esri, HERE, Garmin, Intermap, Increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Zhu et al. 2020. Effects of Residential gas Appliances on Indoor and Outdoor Air Quality and Public Health in California. UCLA Fielding School of Public Health

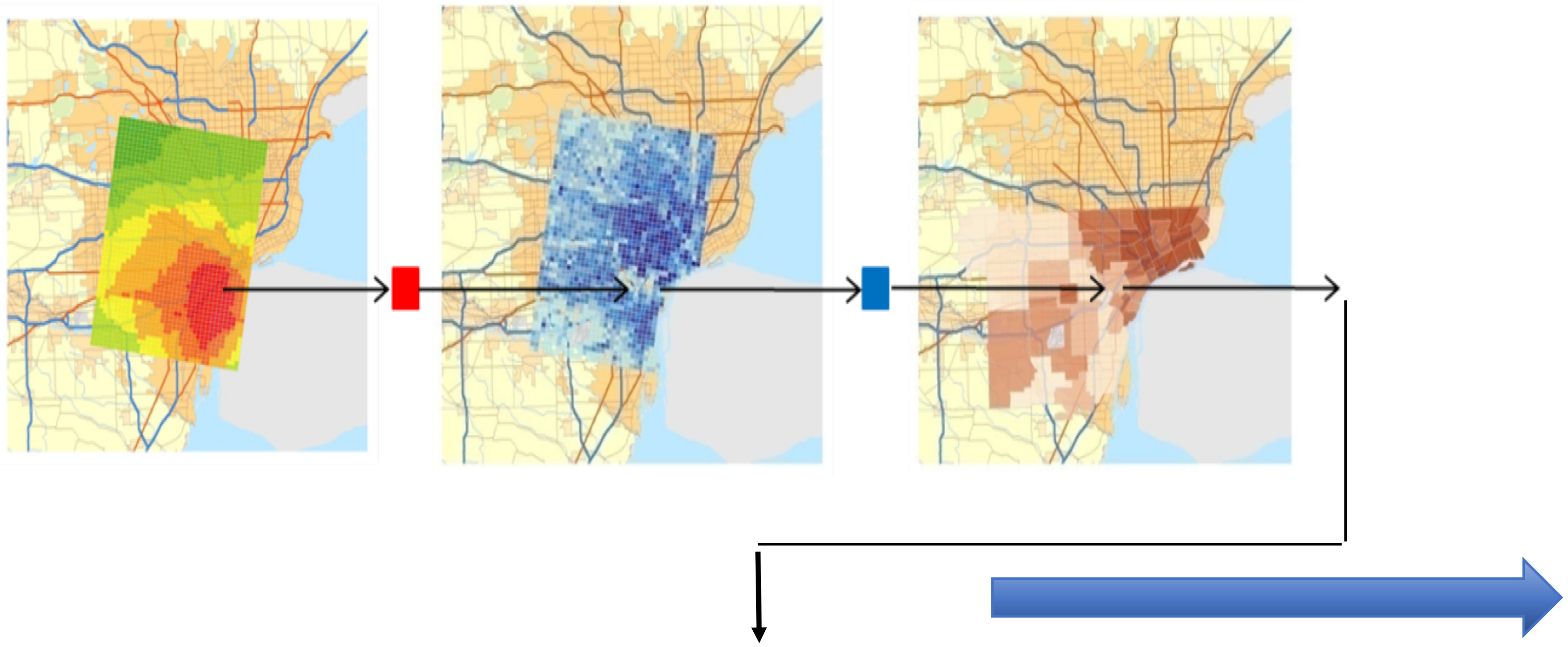
Indoor Air Quality Health Impacts at Scale (EPRI)

EPA's Environmental Benefits Mapping and Analysis Program (BenMAP)

Pollutant change

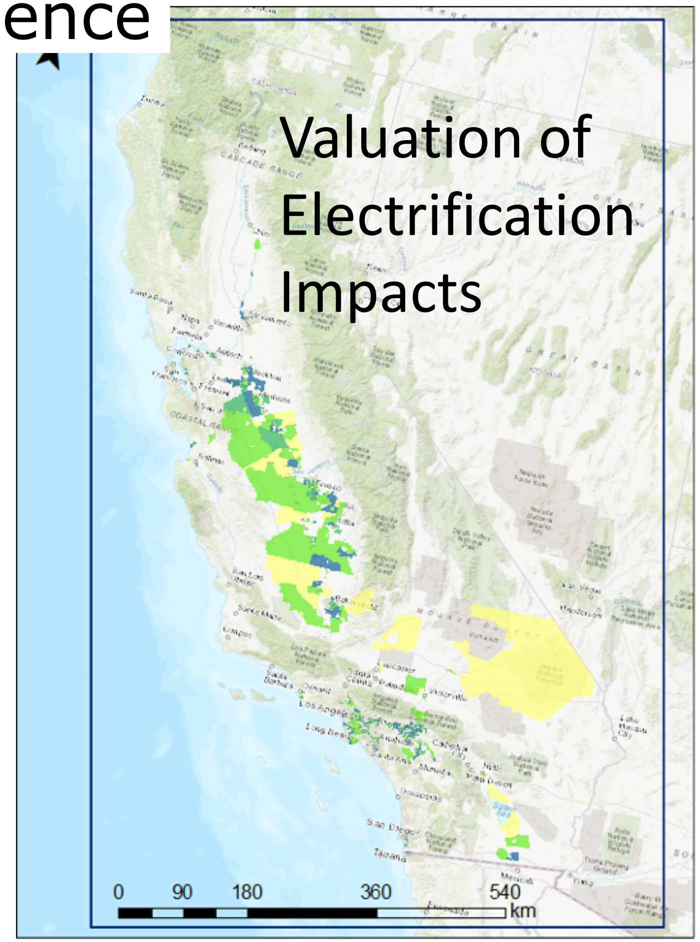
Population

Baseline incidence



Avoided mortality per year

EPA's Value of Statistical Life $8.7 million (2015$)



Valuation of Electrification Impacts

Indoor Air Quality Health Impacts at Scale (EPRI)

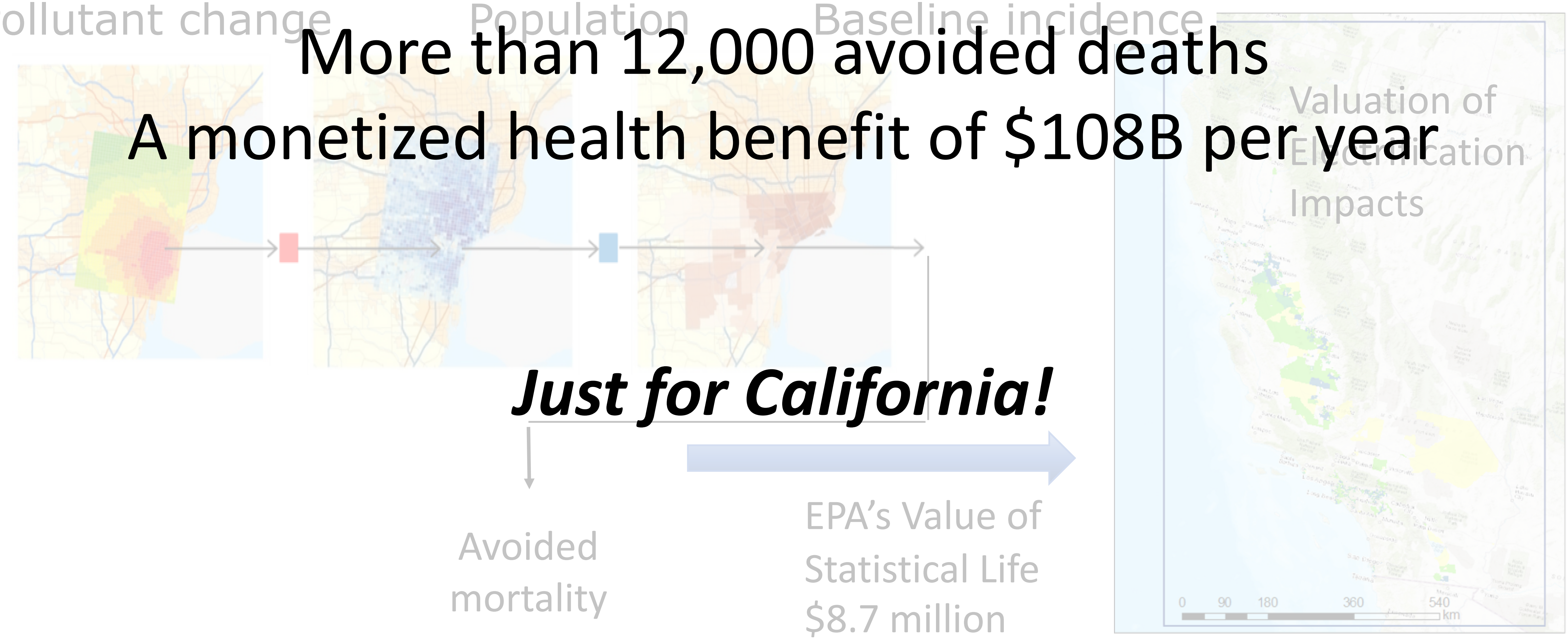
EPA's Environmental Benefits Mapping and Analysis Program (BenMAP)

Electrification results in

More than 12,000 avoided deaths

A monetized health benefit of $108B per year

Just for California!



Pollutant change

Population

Baseline incidence

Valuation of Electrification Impacts

Avoided mortality per year

EPA's Value of Statistical Life $8.7 million (2015$)

Safety reasons to go all-electric

- Key safety issues are
  - Carbon monoxide – no concerns if home is all-electric
  - Fire safety – no naked flames
  - Kitchen safety - no naked flames
    - Induction cooking inherently safer – cooler surfaces for induction cooktops, no flames
  - No gas explosions
    - A key risk factor for utilities – see, for example, PG&E's bad reputation from occasional home explosions
  - Earthquake safety
    - Post-earthquake fires usually a bigger hazard than the earthquake itself

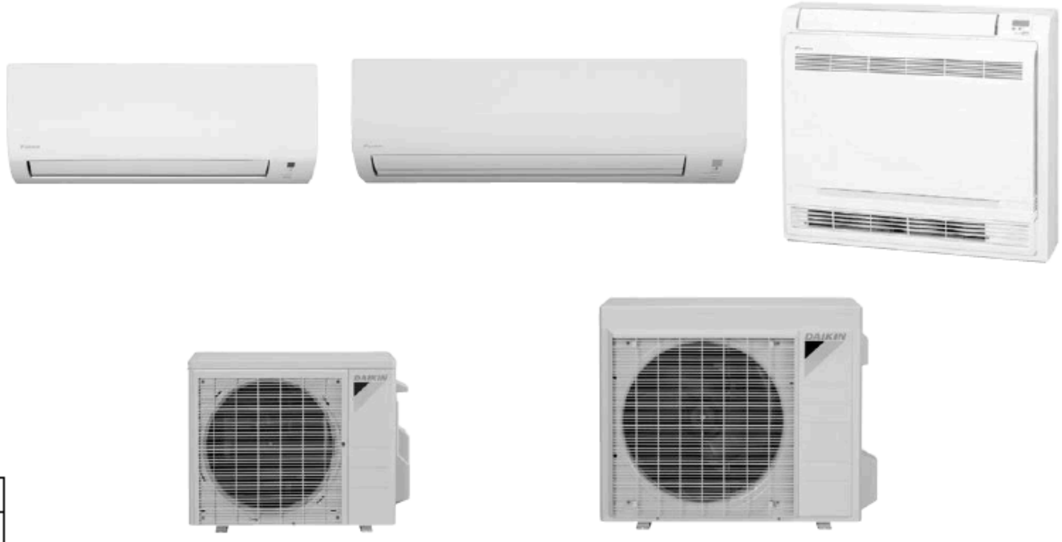
Kitchen Ventilation advantages for electric cooking

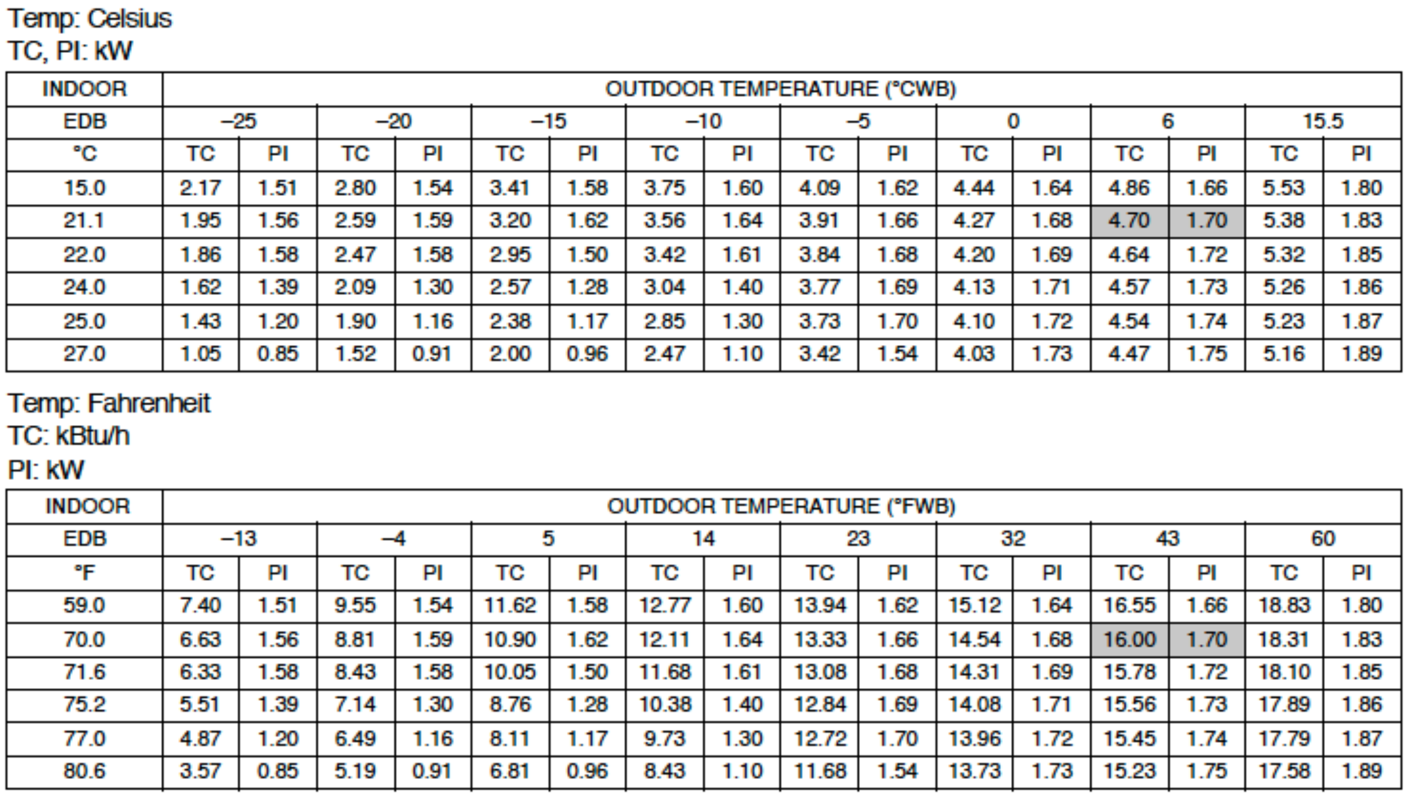
- Key health contaminants are PM2.5 (gas and electric cooking) and NO_2 (only from gas)
- To meet health guidelines more/better kitchen ventilation is required for NO_2, i.e. gas cooking

Cooking Fuel	Floor Area (ft^2)	ASTM Capture Efficiency	Airflow as installed (cfm)
Electricity	>1500 ft^2	0.50	110
	1000 - 1500 ft^2	0.50	110
	750 - 1000 ft^2	0.55	130
	<750 ft^2	0.65	160
Gas	>1500 ft^2	0.70	180
	1000 - 1500 ft^2	0.80	250
	750 - 1000 ft^2	0.85	280
	<750 ft^2	0.85	280

New-ish technology: Cold Climate Heat Pump

- Cold climate heat pumps – available now
  - New CCHP work at much lower ambient temp: -15F (-25C)





Temp: Celsius
TC, PI: kW

INDOOR	OUTDOOR TEMPERATURE (°CWB)															
EDB	–25		–20		–15		–10		–5		0		6		15.5	
°C	TC	PI	TC	PI	TC	PI	TC	PI	TC	PI	TC	PI	TC	PI	TC	PI
15.0	2.17	1.51	2.80	1.54	3.41	1.58	3.75	1.60	4.09	1.62	4.44	1.64	4.86	1.66	5.53	1.80
21.1	1.95	1.56	2.59	1.59	3.20	1.62	3.56	1.64	3.91	1.66	4.27	1.68	4.70	1.70	5.38	1.83
22.0	1.86	1.58	2.47	1.58	2.95	1.50	3.42	1.61	3.84	1.68	4.20	1.69	4.64	1.72	5.32	1.85
24.0	1.62	1.39	2.09	1.30	2.57	1.28	3.04	1.40	3.77	1.69	4.13	1.71	4.57	1.73	5.26	1.86
25.0	1.43	1.20	1.90	1.16	2.38	1.17	2.85	1.30	3.73	1.70	4.10	1.72	4.54	1.74	5.23	1.87
27.0	1.05	0.85	1.52	0.91	2.00	0.96	2.47	1.10	3.42	1.54	4.03	1.73	4.47	1.75	5.16	1.89

Temp: Fahrenheit
TC: kBtu/h
PI: kW

INDOOR	OUTDOOR TEMPERATURE (°FWB)															
EDB	–13		–4		5		14		23		32		43		60	
°F	TC	PI	TC	PI	TC	PI	TC	PI	TC	PI	TC	PI	TC	PI	TC	PI
59.0	7.40	1.51	9.55	1.54	11.62	1.58	12.77	1.60	13.94	1.62	15.12	1.64	16.55	1.66	18.83	1.80
70.0	6.63	1.56	8.81	1.59	10.90	1.62	12.11	1.64	13.33	1.66	14.54	1.68	16.00	1.70	18.31	1.83
71.6	6.33	1.58	8.43	1.58	10.05	1.50	11.68	1.61	13.08	1.68	14.31	1.69	15.78	1.72	18.10	1.85
75.2	5.51	1.39	7.14	1.30	8.76	1.28	10.38	1.40	12.84	1.69	14.08	1.71	15.56	1.73	17.89	1.86
77.0	4.87	1.20	6.49	1.16	8.11	1.17	9.73	1.30	12.72	1.70	13.96	1.72	15.45	1.74	17.79	1.87
80.6	3.57	0.85	5.19	0.91	6.81	0.96	8.43	1.10	11.68	1.54	13.73	1.73	15.23	1.75	17.58	1.89

Daikin Engineering Data Sheets

New technology: Time Shifting Using Storage

Can be charged from onsite solar or low-cost mid-day grid power

Good for disadvantaged/low income communities: avoid peak pricing and demand charges

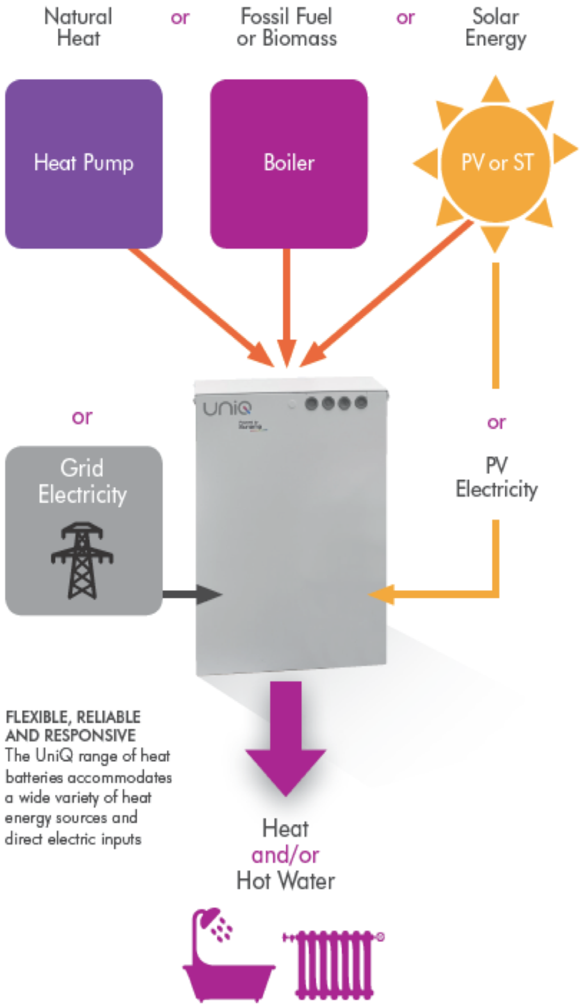
Electric Battery

- 3 to 5 KWh in every home – much less than 13.5 kWh ($13k) Tesla Powerwall

Thermal Storage

- Safe, common, cheap phase change materials
- 10.5 KWh in same space as 50 gallon tank

- Smart Panels/controls – available now
  - Sean will talk more about this



FLEXIBLE, RELIABLE AND RESPONSIVE
The UniQ range of heat batteries accommodates a wide variety of heat energy sources and direct electric inputs

What are the key barriers?

- In general
  - To fully electrify ALL energy use in the US need 3 to 4 times the current delivered electricity
    - Residential – would be about 10% of this
    - More energy sources and investment in distribution infrastructure
  - Managing extra electric grid loads – particularly peak
  - Higher cost of appliances for DHW and heating (less so if homes were going to have AC)
  - In many locations: bigger energy bills if there is no on-site generation and we don't manage loads
    - Will need relief for disadvantaged communities
    - How to connect health savings to offset higher electric bills?
  - Desire to cook with natural gas

- In retrofit:
  - Added cost of panel upgrades and interior home wiring (Sean will talk about how to avoid them)
  - Some noisy heat pump water heaters

What are issues for raters?

- No combustion safety testing
- No appliances to relight after blower door air leakage test
- Learning about new equipment: batteries, thermal storage, smart panels
- Learning new sizing paradigms
  - A small capacity unit with storage = same performance as a large capacity unit
- How to rate for CO_2 as well as energy
  - Note – current RESNET ratings do not allow comparison between different fuel sources

How to Electrify Your Home Without Panel Upgrades

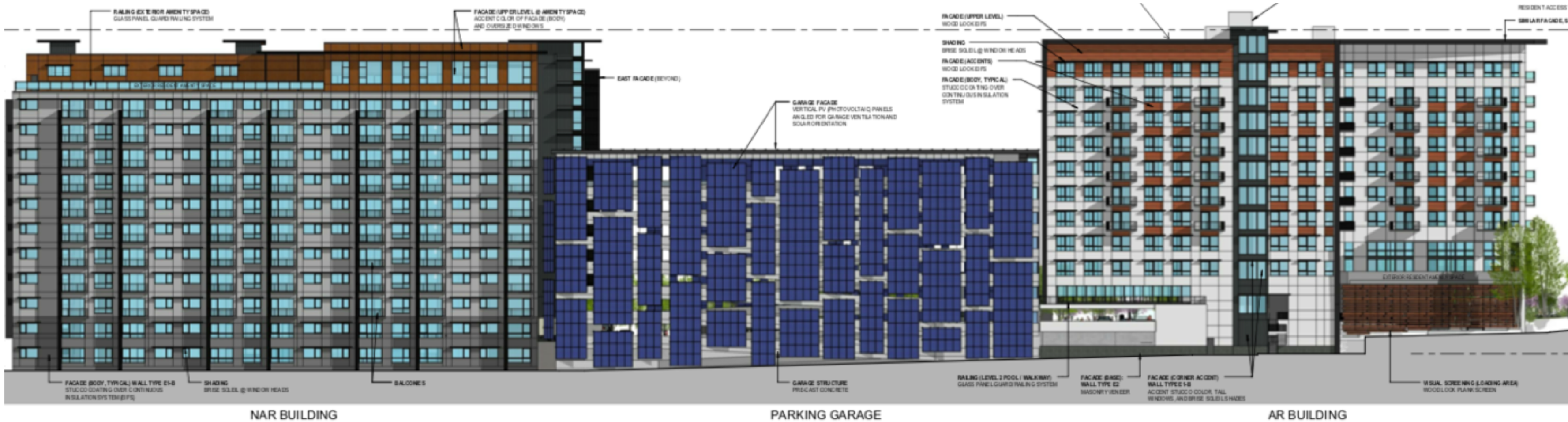
Sean Armstrong

Redwood Energy

Sean Armstrong

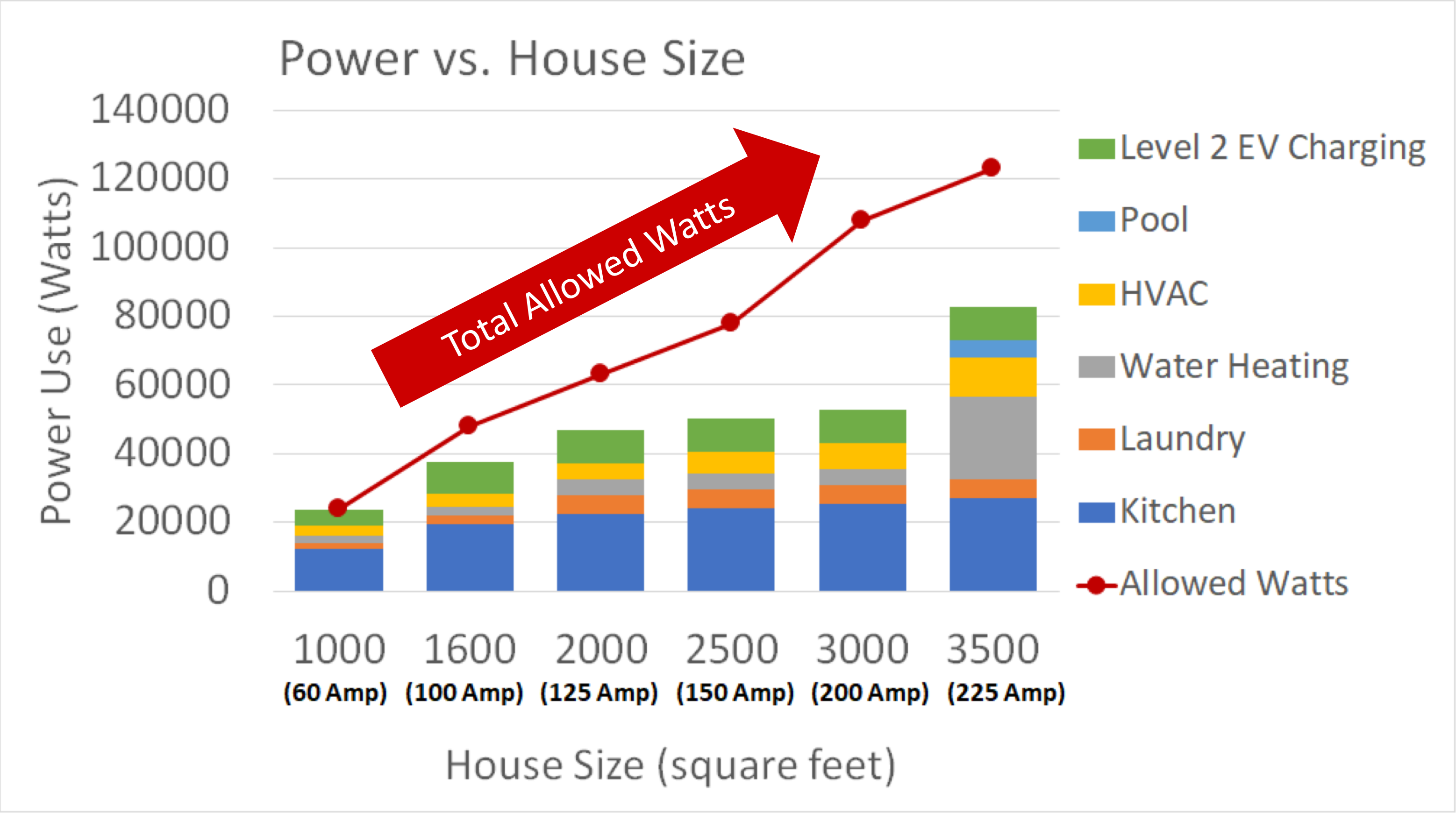
Managing Principal
at Redwood Energy
seanarmstrongpm@gmail.com
707.826.1450

- **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.



We define the "Watt Diet" as the total power used in a home that determines what panel size the home should use.

- The bigger the home, the bigger the electrical panel
- Most panels (newer, bigger homes) have enough space for all electric end uses
- The focus of this presentation is on smaller, retrofit homes



Fitting All the Appliances on Small Panels

- Electrical Panel Sizes:

Small Trailer Home or Apartment	Apartment	Single Family Home
30 Amps	50 Amps	100-200 Amps
		

“Conventional” 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	Low-Amp Window Heat Pump	120V 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				

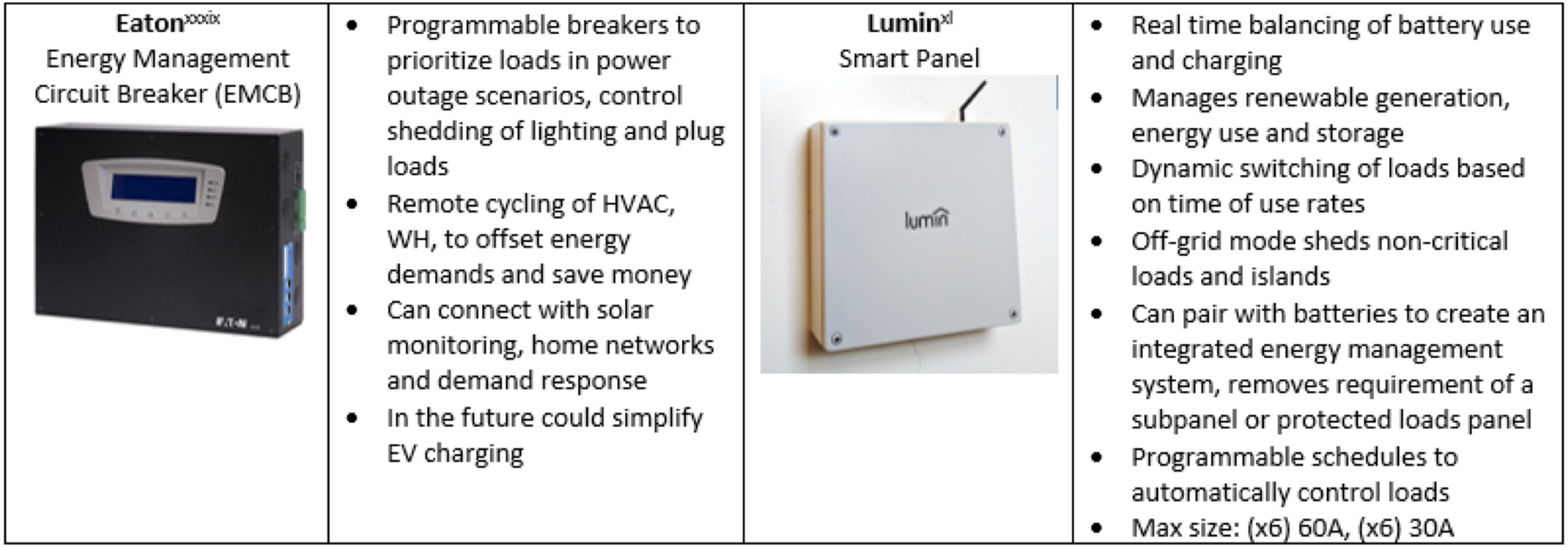
Smart Circuit Splitters and Sharing

- 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[xli] Dryer Buddy	**Neo Charge**[xlii] Smart Splitter	**EV-PowerShare**[xliii] EV-PS Smart	**SimpleSwitch**[xliv] 240V / EV Circuit Switch
				
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

Programmable Subpanels

Sub Panels



Eaton[xxxix] Energy Management Circuit Breaker (EMCB)	• Programmable breakers to prioritize loads in power outage scenarios, control shedding of lighting and plug loads • Remote cycling of HVAC, WH, to offset energy demands and save money • Can connect with solar monitoring, home networks and demand response • In the future could simplify EV charging	**Lumin**[xl] Smart Panel	• Real time balancing of battery use and charging • Manages renewable generation, energy use and storage • Dynamic switching of loads based on time of use rates • Off-grid mode sheds non-critical loads and islands • Can pair with batteries to create an integrated energy management system, removes requirement of a subpanel or protected loads panel • Programmable schedules to automatically control loads • Max size: (x6) 60A, (x6) 30A

Programmable Panels

Whole House Panels

(some still in development, some with full energy management between loads)

Thermolec[xxxv] DCC-9	**Span**[xxxvi]	**Eaton**[xxxvii] Pow-R-Command	**Koben**[xxxviii] GENIUS Smart Panel
			
$1025 – 1125	$2,500 including installation costs	-	-
• Connects EV charger to panel to manage energy loads • real-time reading of total power consumption of electrical panel; if panel exceeds 80% rated load, then temporarily de-energizes the vehicle charger. Reconnects automatically when other loads allow	• Replaces traditional electrical panel in the home • Can monitor and control electrical usage at the circuit level • Puts control into the hands of the homeowner with intuitive smartphone app • Plug in play solution for rooftop solar, battery storage and EV charging	• Control lighting and plug loads with time and space occupancy schedules to maximize energy savings • 15 A, 20 A and 30 A configurations in single- and two-pole models suitable for voltage systems up to 480V • Can add expansion panels up to 168 controllable circuit breakers	• Replaces old electrical panel and allows home to become "Smart Grid" ready • integrates EV Charging, Solar, Battery Storage, Generator and your utility whether you are planning for the new energy era or have already installed your new energy technology.

7200 Watt (30 Amp) Trailer Home Challenge

- Sacramento Climate
- Peak day is heating, low temp of 34F
- Need to use all 120V products to save power at the panel
- Need to use load-sharing devices similar to a NeoCharge or a Simple Switch, coming to market
- Four circuits can fit on a 30-Amp panel

7200 Watt (30 Amp) Trailer Home Challenge

- Can deliver 7,200 Watts of power to a 30-Amp panel: 240V x 30A = 7,200W
- All 120V appliances, use SimpleSwitch or 120V NeoCharge to keep under 1,800W per circuit
- Code requires 2 kitchen circuits, 20A Laundry, 20A Bathroom
- 1,100 square feet, delivers 21,000 BTUh on the coldest day

Kitchen Circuit 1	**Kitchen Circuit 2**	**Laundry Circuit**	**Bathroom Circuit**	
Refrigerator 120-500W	Plug-in Induction Cooktop 1,500W	Condensing Washer 1,200W	120V Heat Pump Water Heater 1,200W	
Innova HPAC 1,400W	Innova HPAC 1,400W	(Innova HPAC 1,400W optional)		Total
1,800W Managed	*1,800W Managed*	*1,800W*	*1,800W*	*7,200W*

7200 Watt (30 Amp) Trailer Home Challenge

- Placing the Laundry unit in the bathroom can save space and lighting
- A maximum of 1,800W could be available for EVSE with a 120V NeoCharge style device if HVAC demand is low
- 120-Volt Mini Splits can replace Innova window units in the right applications for more amp savings

12,000 Watt (50-Amp) Apartment Challenge

- Many existing apartments have a 50 Amp panel in each apartment, and are served with central Hot Water and Laundry.
- We first examined 2-bedroom, 1,100 sq ft apartments in San Francisco early in our own Watt Diet journey

50-Amp San Francisco Apartment Unit

			Code Circuits Required	9.9	kW
			Required kW @ 100%		4.00
Appliance with Dedicated Circuit			Required kW 40%	5.9	2.36
	# of devices	Volts	Amps	Design Rated Watts	
Fridge	1	110	0.91	100	0.04
Disposal	1	120	3	311	0.12
Overhead Microwave	1	120	5	600	0.24
Built in Oven	1	240	24	5760	2.30
Induction 2 Burner	1	120	15	1800	0.72
120 V HP WH	1	120	8.3	996	0.40
HP chosen	1	240	12	1,430	1.43
				Total Panel power (kW)	11.62
				Total Amps at 240V	48.4
				Minimum Panel Size	50 A panel

12,000 Watt (50-Amp) Apartment Challenge

- These large two-bedroom units meet the appliance expectations of savvy apartment tenants
- We found that central water and laundry systems help avoid panel upgrades
- Keeping power use low is especially important in cities with impacted transformer sizing from utilities

2000 Square Foot Single Family Homes - From Bakersfield to Truckee

24,000 Watt (100-Amp) Home - Bakersfield

- 2,000 square feet
- It turns out that many warm CA climates can still live large on 100 Amps
- High efficiency condensing washers and the 120V GeoSpring HPWH were chosen to allow for more fun electric appliances
- A ton of extra room on the panel beyond the necessities

Bakersfield Single Family Load Calculations

			Subtotal from Code Required Circuits	12.6	Panel kW
			Required kW @ 100%		8.00
Appliance with Dedicated Circuit			Required kW at 40%	4.6	1.84
	# of devices	Volts	Label Amps	Watts	
Fridge	1	120	3.5	420	0.17
Chest Freezer	1	120	3	360	0.14
Disposal	1	120	3	310.5225	0.12
Dishwasher	1	120	10	1200	0.48
Pool	1	230	12	2760	1.10
Lawn Sprinklers	1	120	15	1800	0.72
Hot Tub	1	120	15	1800	0.72
Fireplaces	1	120	15	1800	0.72
Combi Microwave	1	120	7	840	0.34
Range (cooktop on oven)	1	240	40	9600	3.84
Combined Wash/Dryer	1	120	10	1200	-
120 V HP WH	1	120	8.3		0.40
HP SC 2 tons	1	120	12	4,400	4.40
EVSE 40 Amp	1	240	40		4.80
EVSE Charge Pauser	1	240	-40		- 4.80
				Total Panel kW	23.70
				Total Amps	98.7
				Minimum Panel size required	100 A panel

24,000 Watt (100-Amp) Home - Bakersfield

- Winter heating was the peak load, because of dry CA summers
- Want to have a winter pool party? We included a pool heat pump, two refrigerators, a small hot tub, and an electric fireplace!
- Ample opportunities to save power with an all-electric home and a 100-amp panel, many homes may not have all these amenities

100-Amp Home - Truckee

- Temperatures down to 7 Degrees Fahrenheit
- 1450 Square feet
- Peak Heating Load similar to Long Island, NY
- Nearly ⅓ of power going to ductless heating on Peak Day
- Uses a 240V HPWH, could go down to 120V for power savings

Truckee Single Family Load Calculations

				Subtotal from Code Required Circuits	10.8	Panel kW
				Required kW @ 100% Coinc.		8.00
Appliance with Dedicated Circuit	Coincidence Factor			Required kW portion at 40% coincidence	2.8	1.12
		# of devices	Volts	Label Amps	Watts	
Fridge	**0.4**	1	120	3	360	0.14
Disposal	**0.4**	1	120	2.6	311	0.12
Dishwasher	**0.4**	1	120	10	1,200	0.48
Grill	**0.4**	1	120	14.6	1,750	0.70
Hot Tub	**0.4**	1	120	15	1,800	0.72
Fireplaces	**0.4**	1	120	12.5	1,500	0.60
Range (cooktop on oven)	**0.4**	1	240	40	9,600	3.84
HP only WH	**0.4**	1	240	13	3,120	1.25
Heat Pump Selected	**1**	1	240	29.2	7,000	7.00
EVSE 40 Amp	**0.5**	1	240	40	9,600	4.80
Charge Pauser		1	240	-40	-9,600	- 4.80
					Total Power (kW)	23.98
					Total Amps	***99.9***
					Minimum Panel size required	100 A panel

24,000 Watt (100-Amp) Home - Truckee

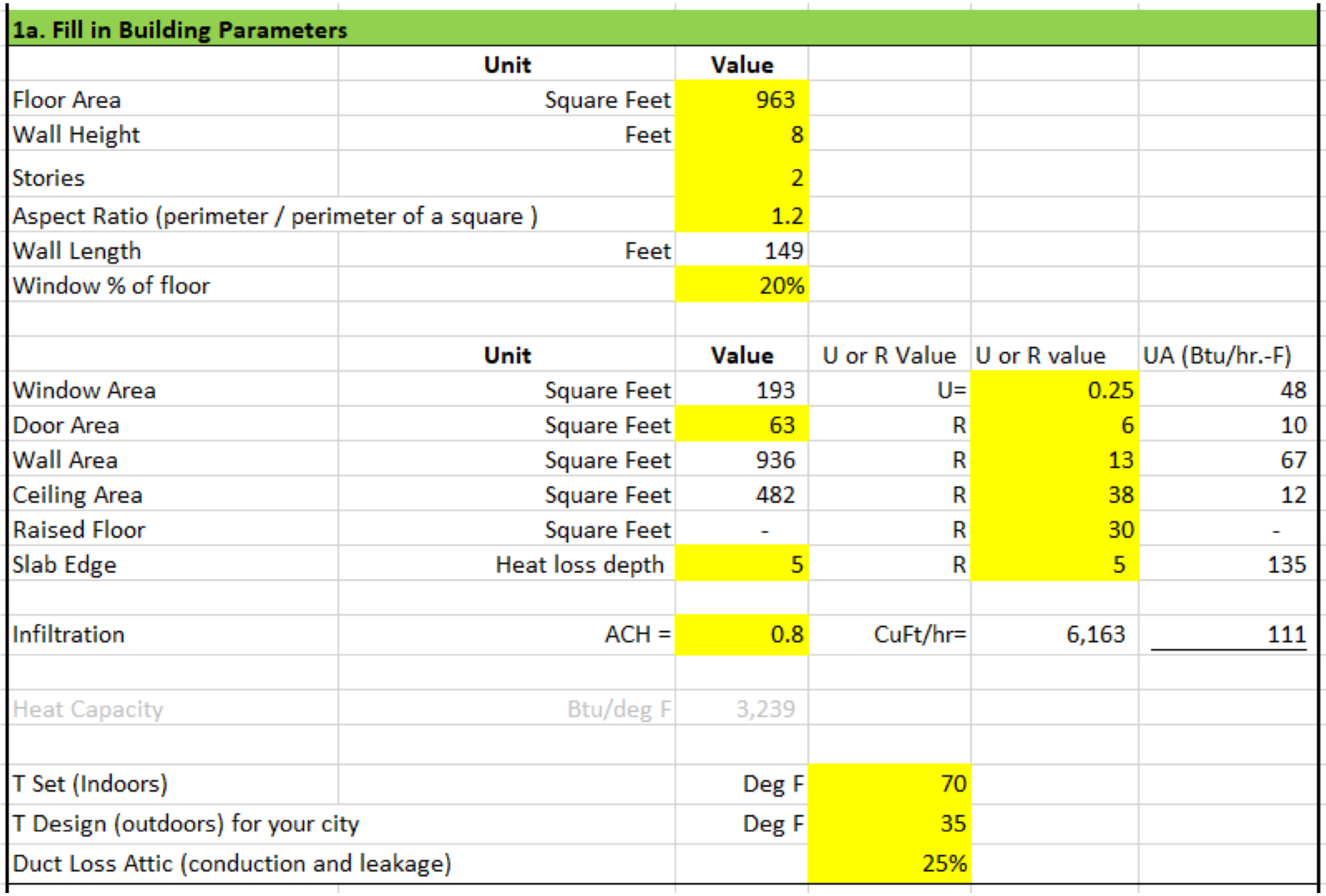
- Goal was to provide more stuff while meeting HVAC
- You could take off things like Fireplace, Hot Tub, Grill, etc for more spare capacity
- Can use the required laundry circuit to charge EV with NeoCharge device
- Cold climate retrofits are possible even without panel upgrades!

The Watt Diet Calculator

- Developed by Tom Kabat and edited by 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

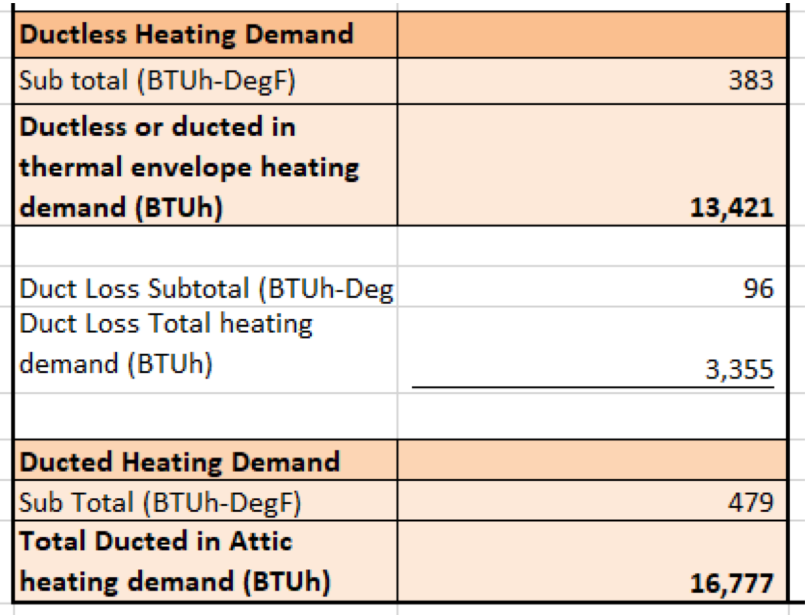
Step 1: Heating Load Estimate

Enter building parameters and design temperatures



1a. Fill in Building Parameters					
	Unit	Value			
Floor Area	Square Feet	963			
Wall Height	Feet	8			
Stories		2			
Aspect Ratio (perimeter / perimeter of a square)		1.2			
Wall Length	Feet	149			
Window % of floor		20%			
	Unit	Value	U or R Value	U or R value	UA (Btu/hr.-F)
Window Area	Square Feet	193	U=	0.25	48
Door Area	Square Feet	63	R	6	10
Wall Area	Square Feet	936	R	13	67
Ceiling Area	Square Feet	482	R	38	12
Raised Floor	Square Feet	-	R	30	-
Slab Edge	Heat loss depth	5	R	5	135
Infiltration	ACH =	0.8	CuFt/hr=	6,163	111
Heat Capacity	Btu/deg F	3,239			
T Set (Indoors)		Deg F	70		
T Design (outdoors) for your city		Deg F	35		
Duct Loss Attic (conduction and leakage)			25%		

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



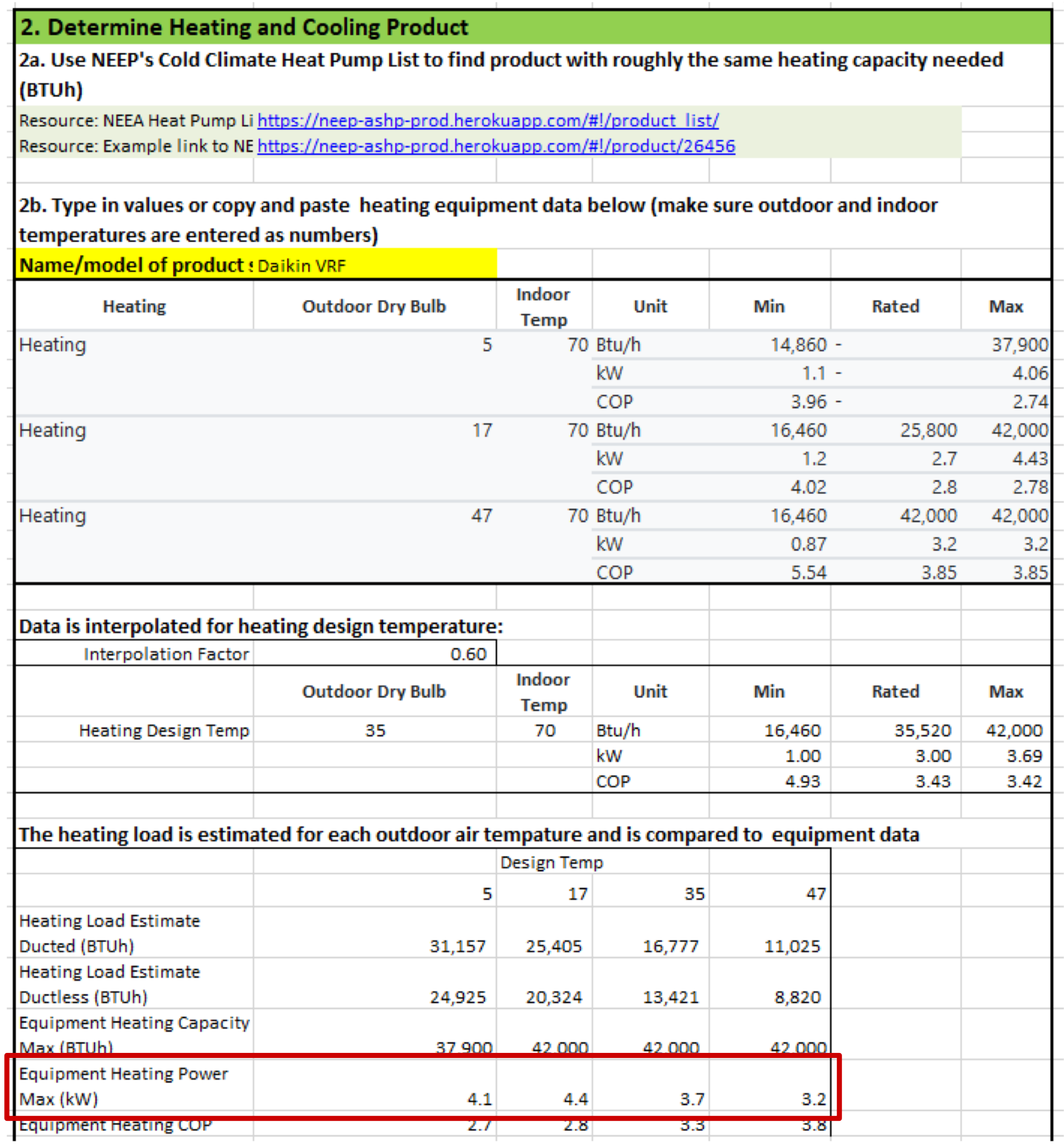
Ductless Heating Demand	
Sub total (BTUh-DegF)	383
Ductless or ducted in thermal envelope heating demand (BTUh)	**13,421**
Duct Loss Subtotal (BTUh-Deg	96
Duct Loss Total heating demand (BTUh)	3,355
Ducted Heating Demand	
Sub Total (BTUh-DegF)	479
Total Ducted in Attic heating demand (BTUh)	**16,777**

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 and Cooling Product

2a. Use NEEP's Cold Climate Heat Pump List to find product with roughly the same heating capacity needed (BTUh)

Resource: NEEA Heat Pump Li https://neep-ashp-prod.herokuapp.com/#!/product_list/

Resource: Example link to NE https://neep-ashp-prod.herokuapp.com/#!/product/26456

2b. Type in values or copy and paste heating equipment data below (make sure outdoor and indoor temperatures are entered as numbers)

Name/model of product : Daikin 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	17	70	Btu/h	16,460	25,800	42,000
			kW	1.2	2.7	4.43
			COP	4.02	2.8	2.78
Heating	47	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 heating design temperature:

Interpolation Factor 0.60

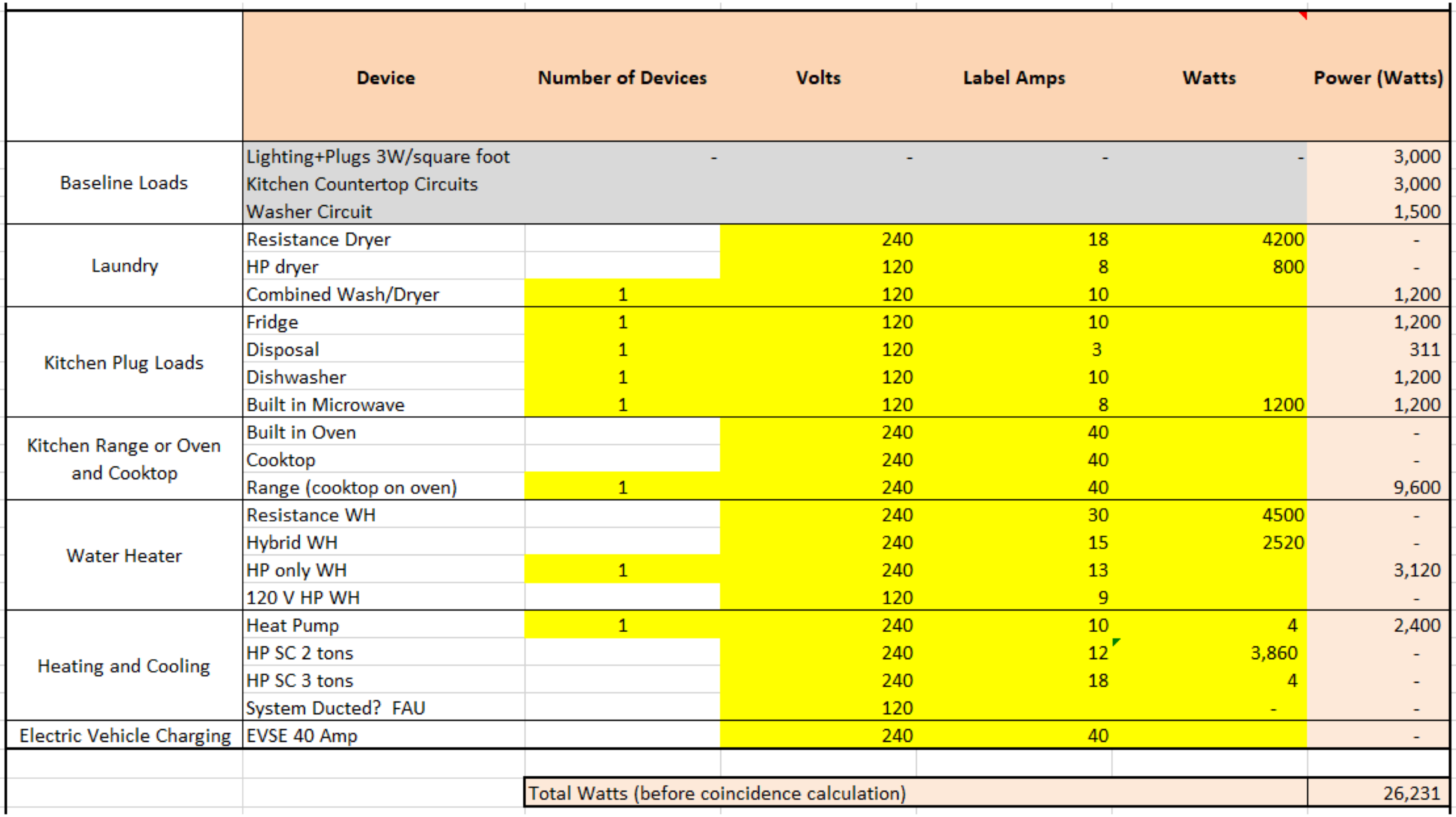
	Outdoor Dry Bulb	Indoor Temp	Unit	Min	Rated	Max
Heating Design Temp	35	70	Btu/h	16,460	35,520	42,000
			kW	1.00	3.00	3.69
			COP	4.93	3.43	3.42

The heating load is estimated for each outdoor air tempature and is compared to equipment data

		Design Temp		
	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	3.3	3.8

Step 3: Calculated total *device* watts

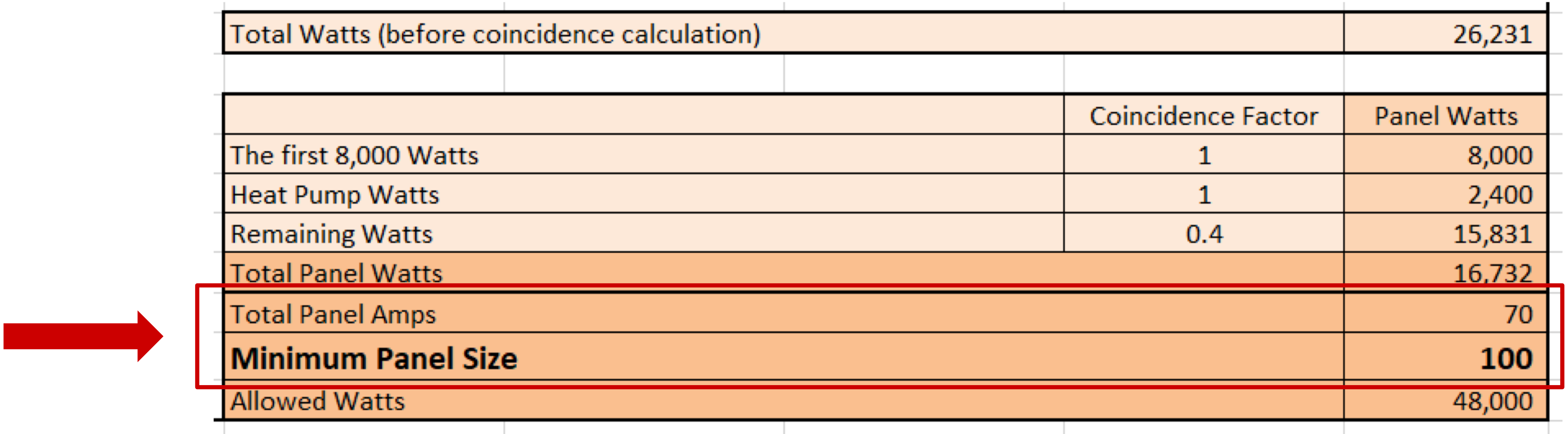
- Enter in number of devices
- Enter in either volt and amps or watts for each device
- Total device watts are calculated



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

Questions?

© Ron Niebrugge