Rethinking our Decarbonization Strategy for Existing Buildings

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Quick Context Review—California Example

- Quickly set context: we must decarbonize the existing building stock—most of it will still be here in 2045
- The math: 70-75% of existing homes right now will still be here and in service
  - That's at least 7 million homes that need to be decarbonized
- It is way too expensive using "BAU" replacement methods with existing equipment rosters
- Traditional rebates and incentives will be necessary but not (nearly) sufficient
- Entirely new equipment rosters specifically designed to replace combustion equipment
- We need to understand why it's so expensive to address this problem

Today's Presentation . . .

- I will provide a 'big picture' overview
- Numbers: mainly my own derived from CARB, the CEC and other agencies
- The 'scale' and 'speed' issues needed to decarbonize buildings are truly staggering
- In the buildings sector, the main problem = **existing** buildings
- My comments are mainly addressing the residential sector
- Equipment stocks are currently not adequate for space/water heating
- We need to address the equipment issue with more than rebates

Water Heater in My Garage . . . Just to Plant a Seed

Does This Look Like Your Water Heater?

Italian Product

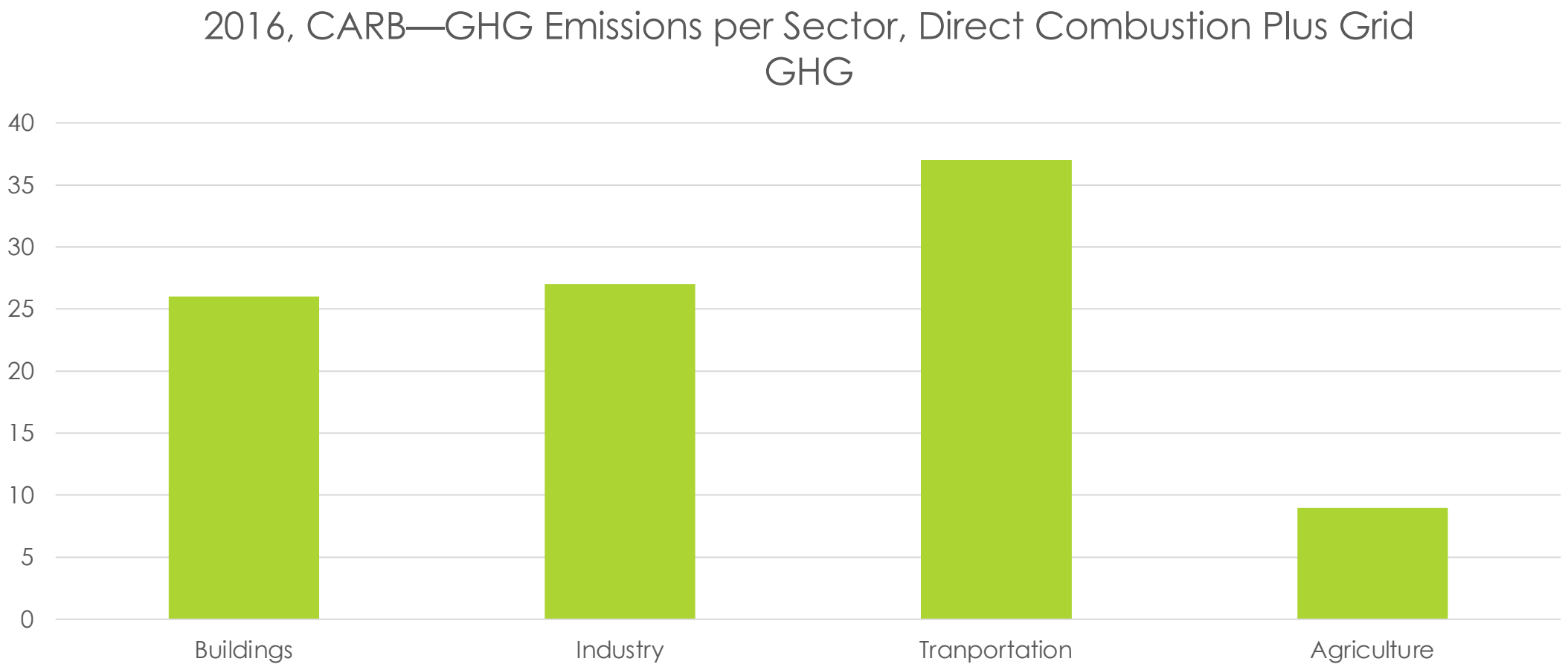
Wall mounted

Relatively attractive

Small, Quiet

Adequate for an apartment

Where's the Carbon?



What About That Chart?

- We know we need to electrify **transportation** (EVs), but some transport types will be very difficult
- Some **industrial** processes will prove to be difficult to electrify
- These end uses: a good target for "renewable" fossil fuel
  - Perhaps some hydrogen
  - Renewable fossil fuel: not *nearly* enough for "garden variety" residential uses
- **Ag**: same issues (and we all know what cows do)

Wasn’t me!

Let's focus on the Buildings . . . 26%

- In **round numbers**:
- **Half** of the 26% is GHG from electricity production that goes into buildings (70%)
  - CA's grid is quite clean compared to the US as a whole
  - CA has specific targets to move toward fully renewable generation
  - The CA grid will continue to get cleaner
  - Electric end use efficiency reduces GHG emissions
- **The other half**—emphasizing **round** numbers—is from on-site fossil fuel combustion
  - Residential > commercial for energy overall (somewhat)
  - Space- and water-heating are 85-90% of residential emissions
  - For over 40 years, CA code has encouraged "dual fuel" residential buildings (90%)

Why are we so worried about a fairly small number?

- Decarbonizing the economy will be expensive, least-cost path essential
- **Certain end uses** in industry, large commercial and agriculture will be **impossible to fully decarbonize**
- **All end uses** in buildings **can be decarbonized**
- All of the analysis repeatedly comes back identifying the elimination of on-site combustion in buildings as being on the least-cost path
- See **www.ethree.com** on electrification

Bottom Line: To Reach 2045 CA Goals . . .

We need to eliminate:

- All combustion in small residential buildings
- (Almost) all combustion in commercial buildings

What About ZNE and "Zero Energy" Buildings?

- **Definition**: they generate as much as they consume over a year
- They are terrific; they are "healthy," they are loved by occupants
- Renewables "must" be PV (as a practical matter)
- However: PV is available about 17% of the 8760 hours in a year (absent storage)
- If PVs, **but the GHG from the fossil combustion is still present**
- **Takeaway: efficient full electric (with heat pumps) > Zero Energy from a GHG perspective**
- If the building is **dual fuel**, the on-site combustion Btus can be offset mathematically by PVs, **but the GHGs cannot**

Full Electric New Construction

From LA Times, 9/23/2021

Mayor Catherine Blakespear announcing the Encinitas ban on natural gas in new construction

49th community in CA to do so! Good News! (But, there are 482)

Title 24 will favor full electric for **permits pulled** starting Jan, 2023

Full Electric New Construction: Not *Fait Accompli*, But Not a "Problem"

- **Does not cost more to build** (net)
  - Save cost of gas hookup
  - Save cost of gas piping and gas venting in the building
  - At scale, appliances won't cost more
- **Does not cost more to operate**
- Utility gas service likely to increase more rapidly than electric service
  - Gas itself is a relatively minor portion of the gas bill
  - The distribution infrastructure is the larger portion
  - Infrastructure costs don't decline much with fewer units of throughput

But What About Existing Homes?

- I'm 69 years old—I checked! All of the ~12 homes I've lived in are still there
- I put together this presentation in an 1885 house in Noe Valley of San Francisco
- In round numbers . . . On the order of 70-75% of the residential building stock in use today will still be in use in 2045 (and beyond)
- In CA, about 90% of homes are dual fuel (natural gas with a small amount of propane in rural areas; somewhat higher than national average)
- Conservatively, there are 7 million dual fuel homes we need to decarbonize in CA to meet the climate goals

High Level Housing Stock Demographics

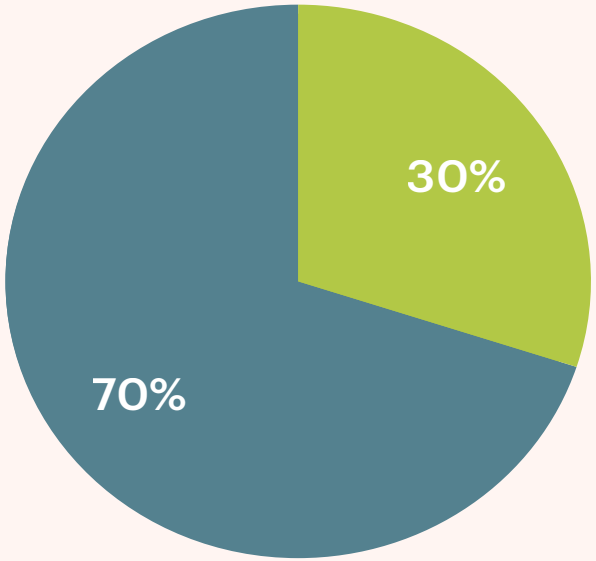
CA HOUSING STOCK IN SERVICE, 2045

Existing Homes in 2021 Still in Service, 2045 (about 70%)

Costs to convert very high, dominant
Cost is BTM electrical upgrade cost.
At scale, grid-side costs are in play.

Bill savings to customers range from
Modest positive to modest negative
Depending on electric vs. gas rates

Therefore, poor customer value given Current equipment rosters and Construction methods



For New Construction, 2021 Forward (about 30%)

No particular first cost barriers for
Full electric new construction; likely
Lower cost at scale

Customer operating cost
Impact not great, bills likely lower
over time

Health and safety benefits from full
Electric construction

Therefore, good customer value
Right now

Summarizing: Combustion in Existing Buildings is the 800 Pound Gorilla

- 70% of the building stock which will exist in 2045 exists today
- That 70% uses more energy per unit (and has a higher carbon footprint per unit) than recent construction or forthcoming NC
- That 70% is very expensive to convert and a poor customer value because it is so expensive (compared to NC, which does not cost more and is a good value)
- ~90% of "the problem" is decarbonizing existing buildings
- Solving the "90%" means replacing combustion quickly and at much lower cost than is possible today

Let's Do Some Math . . .

- 7 million houses in 24 years is how many per year?

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292,000

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Let's Do Some Math . . .

- 7 million homes in 24 years is how many per year?

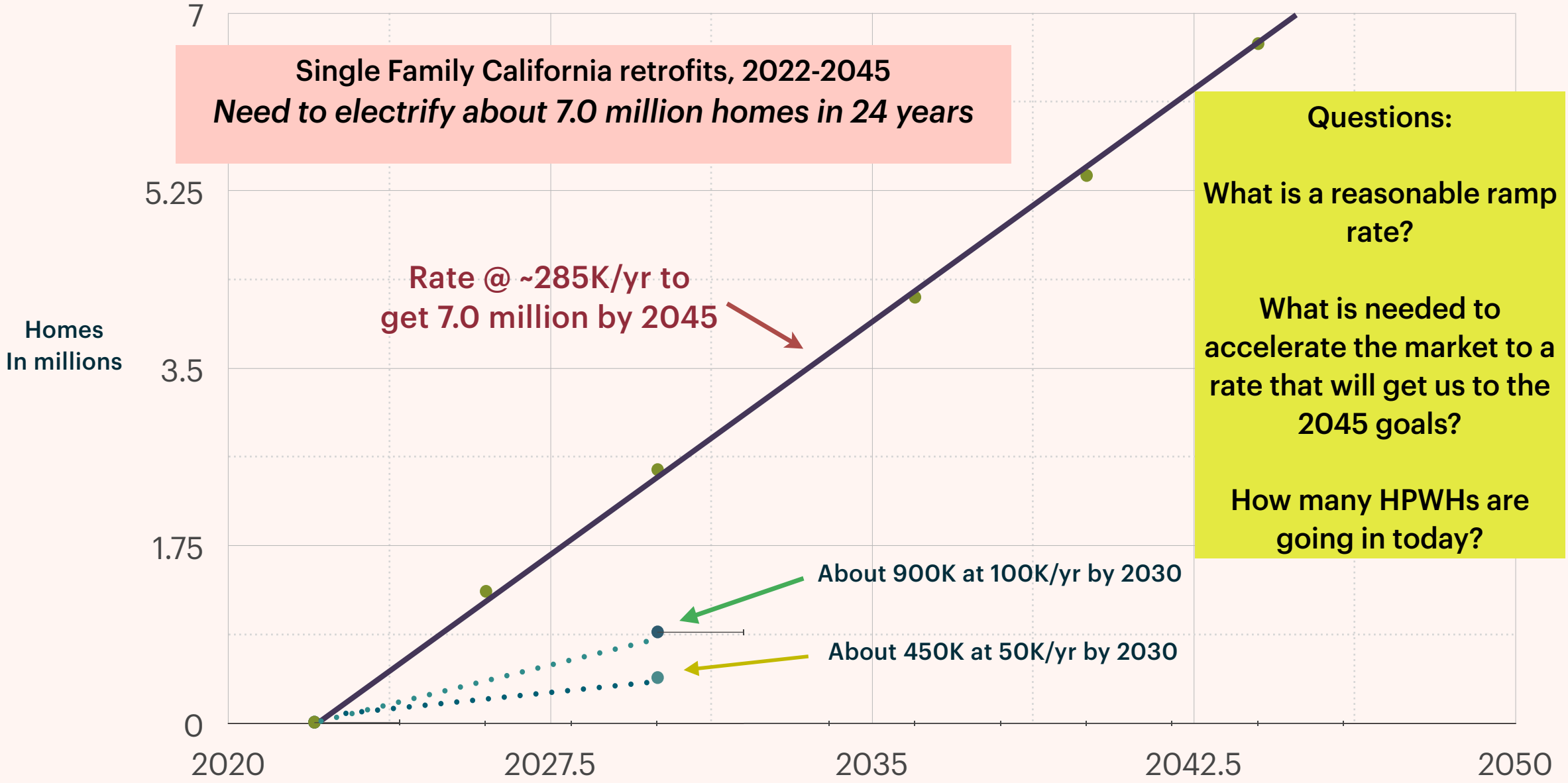
292,000

(Let's call it 300,000)

- Based on a six day work week, that's how many homes per day?

942

(Let's call it 1000 per day)



Questions:

What is a reasonable ramp rate?

What is needed to accelerate the market to a rate that will get us to the 2045 goals?

How many HPWHs are going in today?

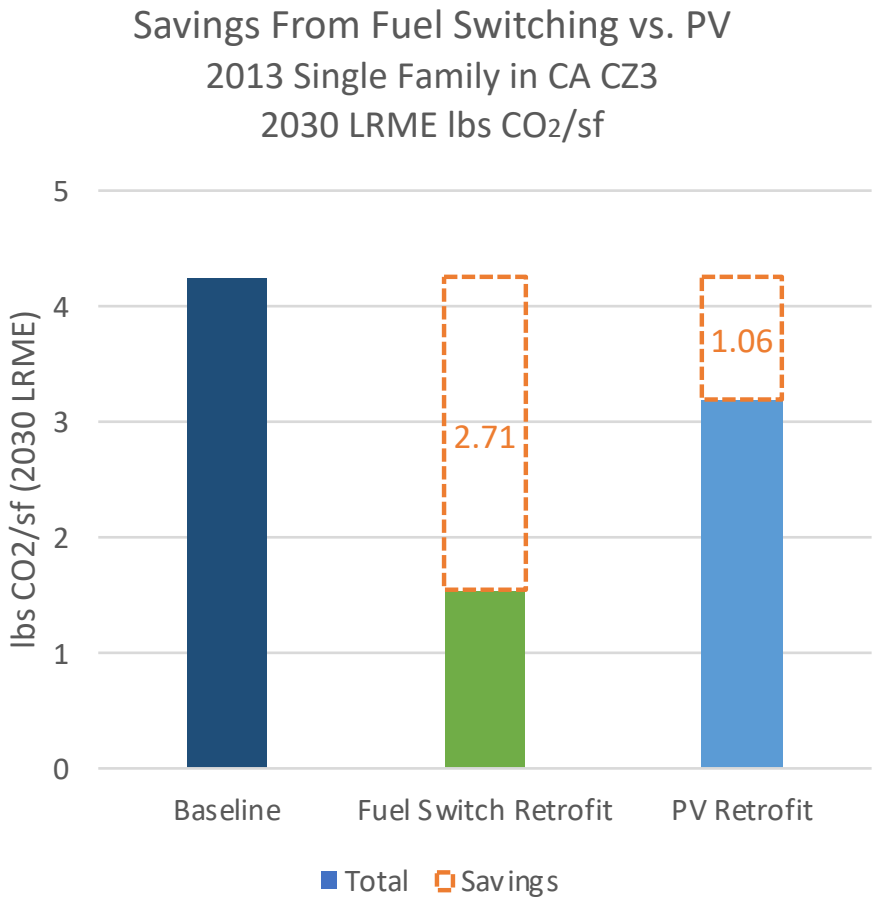
Can We Solve Residential GHG Emissions with Rooftop PV?

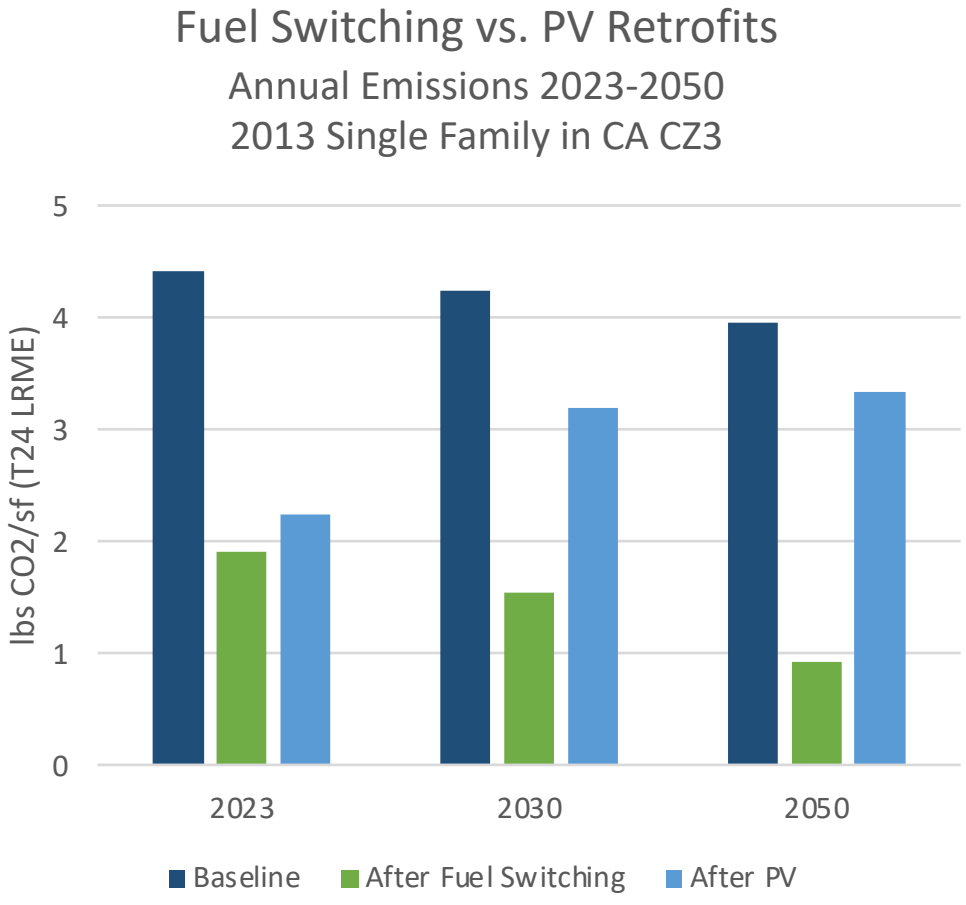
- Short Answer . . . NO
- Gas **is still being burned** no matter how much PV goes on the roof
- Longer answer: coming right up

Fuel Switching vs. PV Retrofits in 2013 Vintage SF

In 2030, fuel switching saves **2.5x** CO_2 as compared to PV offsets.

This difference will **increase** over time as the grid becomes cleaner.



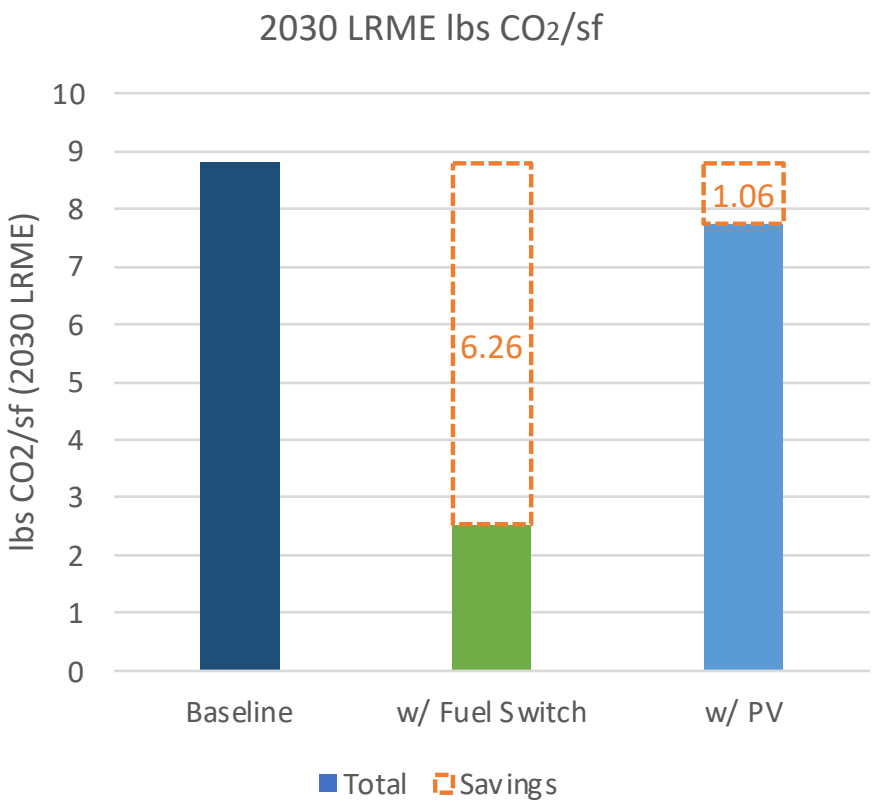


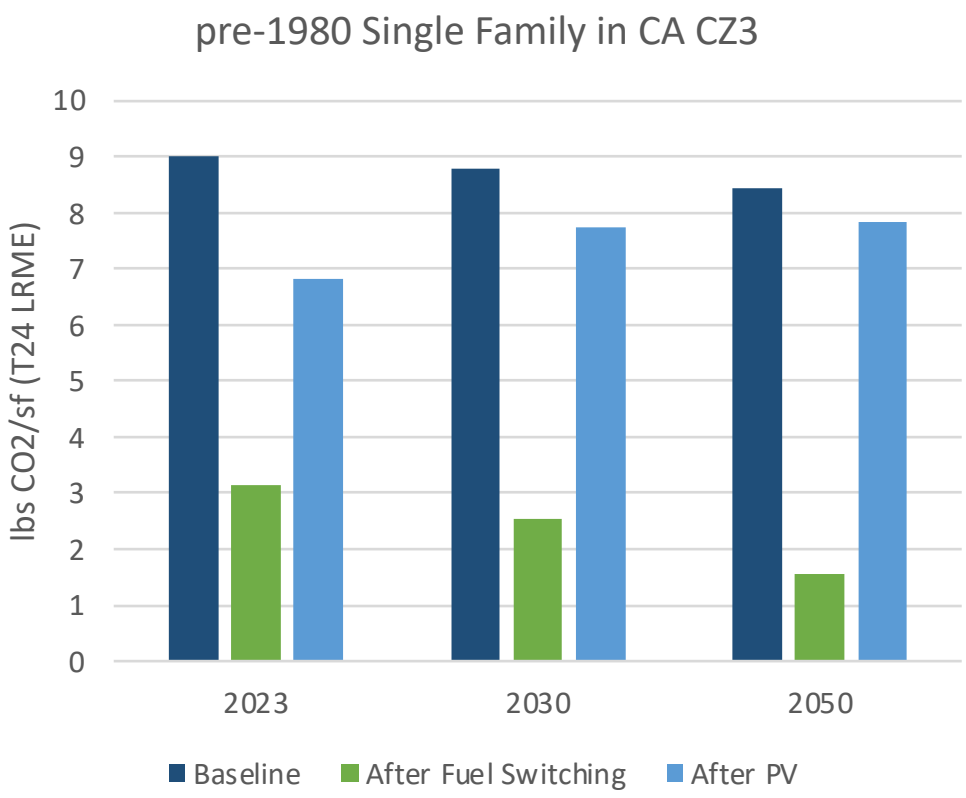
Charts adapted by Resource Refocus from *Zero-Carbon Buildings in California: A Feasibility Study (CARB)*

Fuel Switching vs. PV Retrofits in pre-1980 Vintage SF

In 2030, fuel switching saves **6x** CO_2 as compared to PV offsets.

This difference will **increase** over time as the grid becomes cleaner.





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Takeaways . . .

- **PV does not help much with GHG reduction** in an existing dual fuel home—storage helps, but at (greatly) increased cost.
- **PV does reduce the customer's energy bill** (so there is a solid role for PV, especially with added electric load)
- **Electrification** alone today **does not reduce the customer's energy bill** (compared to the cost)

Pleasant View Apartments, Fresno CA: 60 apartments units total, multiple low-rise buildings—common in Central Valley (EPRI project)

Why is Electrification So Expensive?

- **Real Project: 60 units** of low income housing in **9 buildings** on a few acres, Fresno, CA (common!)
- **Existing:** wall furnaces, gas water heaters (outside wall cabinets), no A/C, stove already electric (swamp coolers . . . Yikes!)
- **Simple!** Just replace the furnaces with heat pumps and the water heaters with HPWHs . . .
- **But:** there is no "swap out" unit for the gas water heater and none for the wall furnace
- **Lesson(s)**: With an enormous engineering/technical effort, solutions were found, but not on a "swap out," BAU basis: the project used new technologies not generally available in the US, served multiple units with single compressors, etc. *These solutions need to be refined on an industrial scale.*

A Few Cost Reduction Strategies . . .

- Existing exterior cabinets for water heaters . . . There is no existing HPWH available in the US that will fit in this cabinet. Sure, enlarge the cabinet, but at what cost?

Categories of Cost

- **Form factor**: HPWHs are larger per effective unit volume—at Fresno, would not fit in available cabinet space (major adjustment with today's available equipment)
- **Form factor**: For space conditioning, no "drop in" heat pump available to replace a wall furnace (ubiquitous in apartment buildings; again, major adjustment)
- **In-unit electric panel**: may not have enough capacity, must run new circuits
- **Building electric panel**: may not have enough capacity
- **Service drop**: from utility to each building (underground direct burial)-–cable may not have enough capacity
- **Utility transformer**: many not have enough capacity
- Still have to buy and install the units

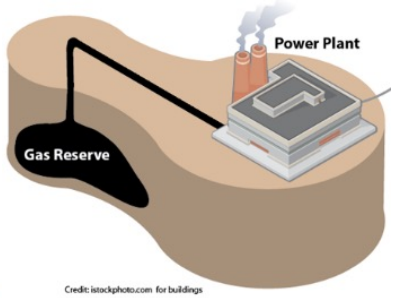
We Need Heat Pumps, Not Resistance Elements

- Resistance elements are cheap and easy on site, but create massive costs upstream to the *distribution* system, the *transmission system* and the *generation* system AND to the BTM distribution in the buildings
- Homes built to dual fuel standards would need huge electrical upgrades to accommodate resistive loads for space- and water-heat
- 3x multiplier: energy use, energy demand and grid emissions
- *Occasional* spot use of resistance heat is sometimes OK
- **Heat pumps: key to cost mitigation of BTM and utility electric infrastructure, not to mention customer bills (2/3rds savings)**

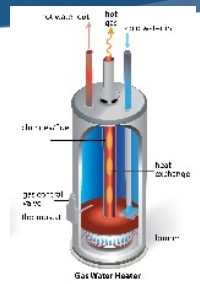
Energy Flows—Example with hot water

Gas Hot Water Heater

1.74 unit of gas in



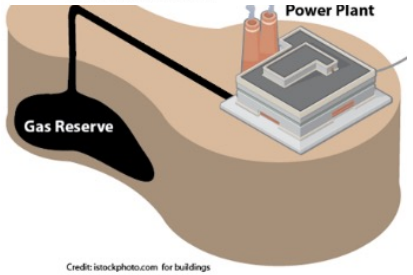
1.6 unit of gas in



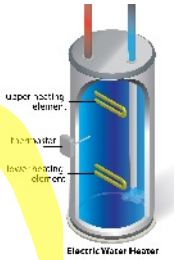
1 unit of hot water out

Electric (Resist) Hot Water Heater

1.87 unit of gas in



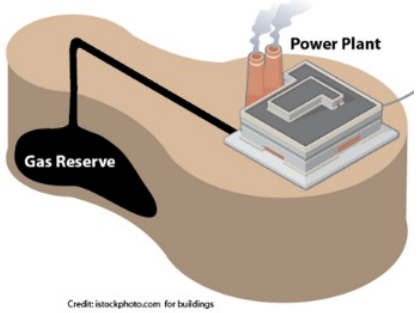
1.02 unit of electricity in



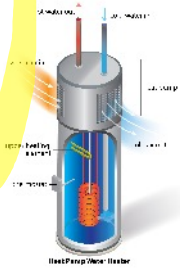
1 unit of hot water out

Heat Pump Hot Water Heater

0.61 unit of gas in



0.33 unit of electricity in



1 unit of hot water out

Credit: Paul Torcellini, NREL

All in Cost in the Fresno Project

- **Lesson(s)**: With an enormous engineering/technical effort, solutions were found, but not on a "swap out," BAU basis.
- The project used new technologies not generally available in the US, served multiple units with single compressors, etc. *These solutions need to be refined on an industrial scale*.
- **Cost:** At this project, these modest units cost $27,000 each to retrofit
- San Joaquin Valley Disadvantaged Communities Cost Estimates: $25,000-$30,000 per home (1200 units over four years, cost estimates)
- **We need these projects to cost well under $10,000**

How Do We Do This? (Math, Part II)

- 300,000 homes per year at $27,000 per home = $8.1 Billion per year
- Entire DSM spend in state is $2-3 Billion (and pays for itself, nominally)
- Over 24 years, **this is not quite $200 Billion**—a non-starter
- RD&D targeted at cost-reduction has worked before

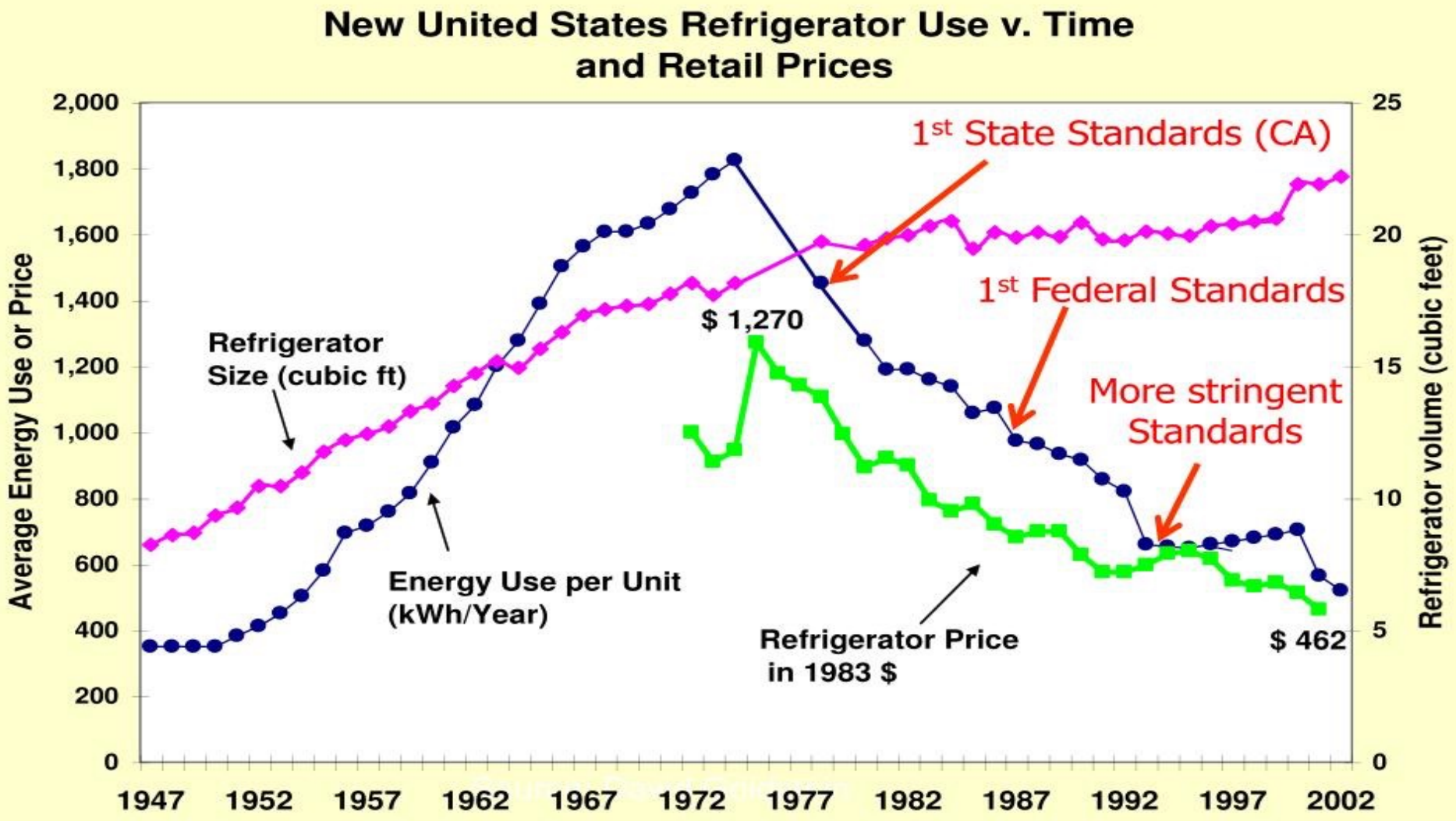
We Need Speed, Scale, Cost-reduction

We <u>do not have today</u> the technologies and installation methods we need

- In CA only, res sector: At $27K/per home, about $8 billion/yr for 23 years, about $175 billion total: a nonstarter
- Robust RD&D targeting <u>cost reduction</u> and <u>speed</u> would likely be effective. TECH and BUILD: $50 million/yr over 4 years . . . but, that's compared to $8 billion project cost per year.
- Should we front-load a tiny fraction of that total cost--$175 billion--to RD&D
- PV cost reduction driven early on by RD&E; Refrigerator efficiency results in recent decades, but took substantial RD&D over long periods of time
- Issues: Form factor, power draw, lack of drop-in solutions.
- Major effort to import equipment (and configure for US grid) as useful. Utility side: Large-scale, mass-market approach to infrastructure improvement

The Great Story of Refrigerator Efficiency…

Since 1975, 25% bigger, 1/3 the energy, 1/3 the cost



Credit:

David Goldstein

NRDC

HPWH National Market Share and Quantities

- Unitary water heater sales in the US: 8,000,000 per year
- Heat pump water heater sales: 85,000 per year (1%)
- Proportional CA share: about 10,000 per year (12% of US sales)
- However, due to Title 24's former dual fuel emphasis, far less than that
- New Construction market (small low rise and single family): ~75,000
- Replacement of existing electric resistance tanks: ~30,000
- **More than the entire US production** (25% of CA's needs)
- A market in need of massive market transformation

What Will it Take?

- We need full electric new construction (**120,000 units per year**)
- We need technologies that can be used for conversions at a sustained rate of 1000/day or **300,000 per year**
- Based on current equipment rosters and installation methods, the conversion costs exceed **$8 billion/yr** if we are to meet the CA goal
- TECH ($30 MM) and BUILD ($20 MM) are small compared to $8 Billion
  - Code efforts are necessary but not sufficient
  - Rebates and incentives (utility, tax, etc.) and necessary but not sufficient
  - "Enlightened self-interest" is necessary but not sufficient
- Need: Major RD&D effort targeted at **cost reduction** and **speed**

A Few Cost Reduction Strategies . . .

- **110 V HPWHs and HPs**—reduces need for electrical upgrades (happening)
- **"Smart" panels** and breakers that rotate and limit loads, reducing BTM electrical costs (can be done but code barriers); **smart HPs and HPWHs**
- **Import and licensing programs** to move technologies developed elsewhere into CA and the US
- **"Industrialized" methods of retrofit**: the wet/dry mechanical "box" that bolts to the building with space conditioning, water heating, PV inverter and storage
- "Industrialized" (vs. 'one at a time') methods of doing **utility side upgrades**
- "Free water heater with your Tesla" program: upgrade the panel **once**
- Capturing and monetizing **health care insurance cost savings** from electrification

Many Issues to Address Electrification in Existing Buildings

In scope for design/manufacturing community:

- Building design innovation around building space and water heating systems; need for load flexibility
- Manufacturing innovation--new classes of systems costing less to install (form factor, placement electrical draw)
- Development of "industrial" methods of retrofit (vs. "one at a time" status quo—fewer hammers, nails, saws)

In scope: for policy makers

- Electric and gas rate design issues to favor electrification,
- Policies to support socialization of electrification costs (on both sides of the meter)
- Equity issues for remaining gas customers; equity issues for owners of the gas system

Rethinking our Decarbonization Strategy for Buildings

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