Decarbonizing residential space and water heating: The case for electrification

ECEEE Summer Study
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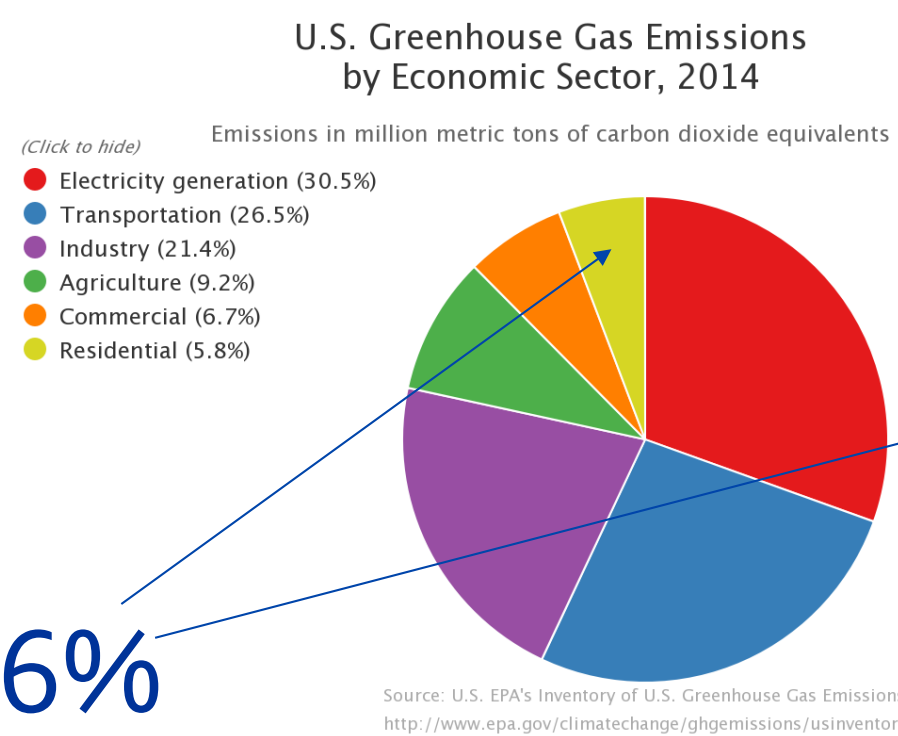
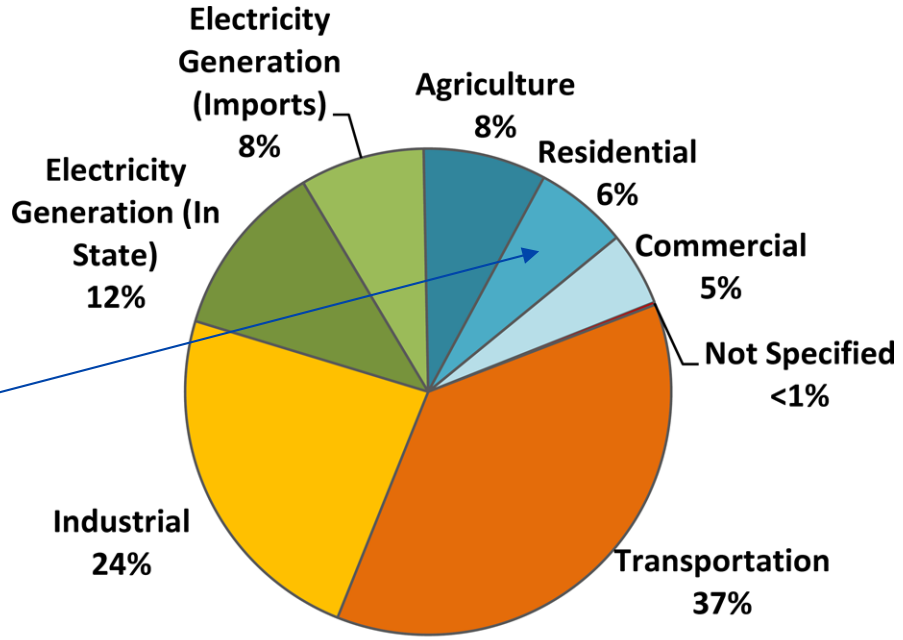


Source: U.S. EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014.
http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html

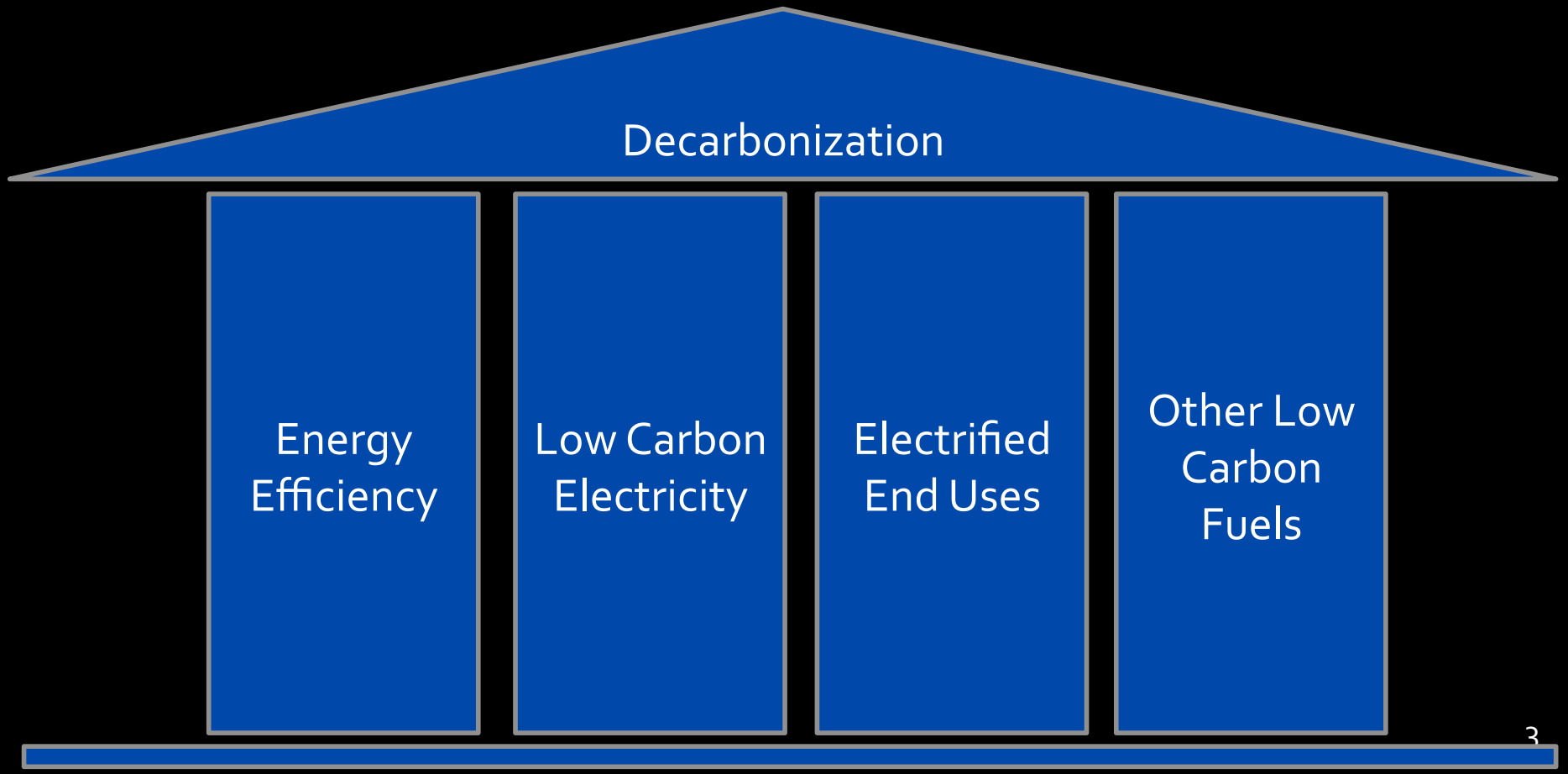
6%



2014 Total CA Emissions: 441.5 MMTCO2e

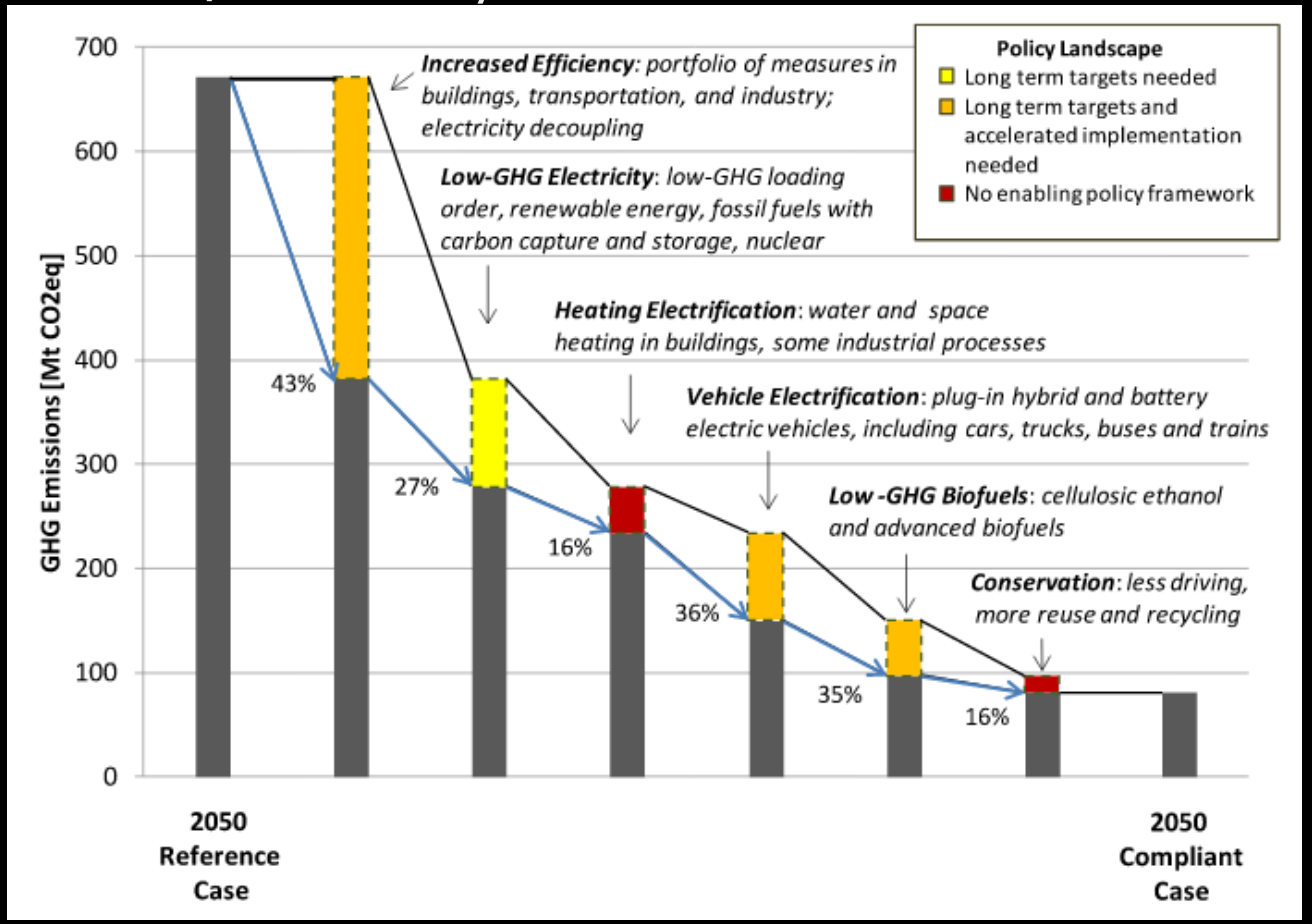
California Greenhouse Gas Emission Inventory - 2016 Edition
https://www.arb.ca.gov/cc/inventory/data/data.htm

Consistent Pillars of Decarbonization



For deep decarbonization, efficiency alone won't be sufficient

"Residential and commercial space and water heating are fully electrified by 2050 through a transition to high-efficiency heat pump technology."



Wei, Max, James H Nelson, Jeffery B Greenblatt, Ana Mileva, Josiah Johnston, Michael Ting, Christopher Yang, Chris Jones, James E McMahon, and Daniel M Kammen. "Deep Carbon Reductions in California Require Electrification and Integration across Economic Sectors." *Environmental Research Letters* 8, no. 1 (March 1, 2013): 014038. doi: 10.1088/1748-9326/8/1/014038.

Other than electrification, 3 main options exist for heating

Decarbonized Gas

Biogas

Synthetic methane

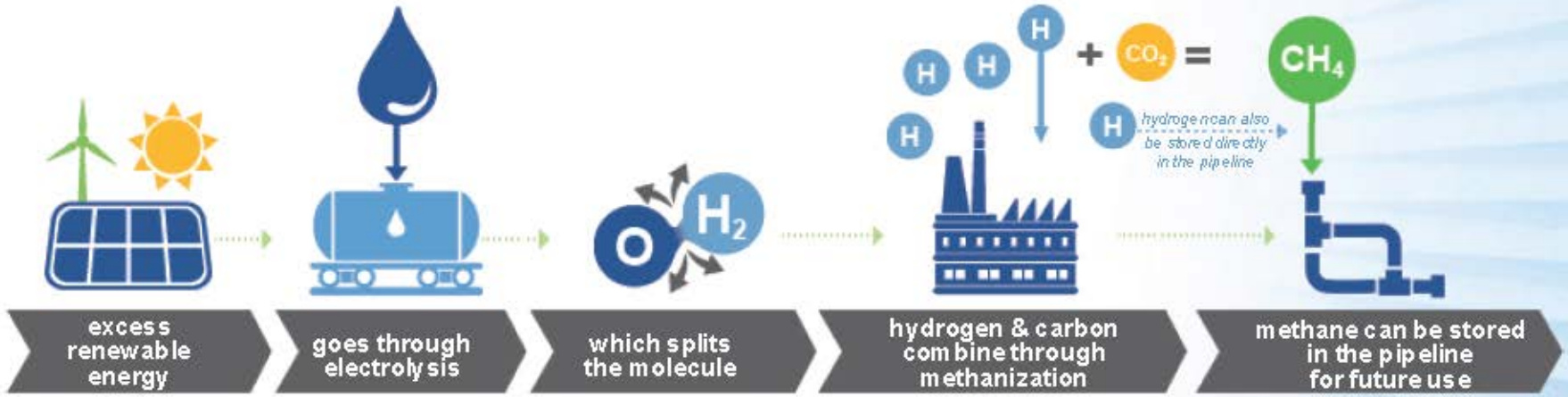
Solar Thermal

Biomass has higher value uses than heating (in warm climates)

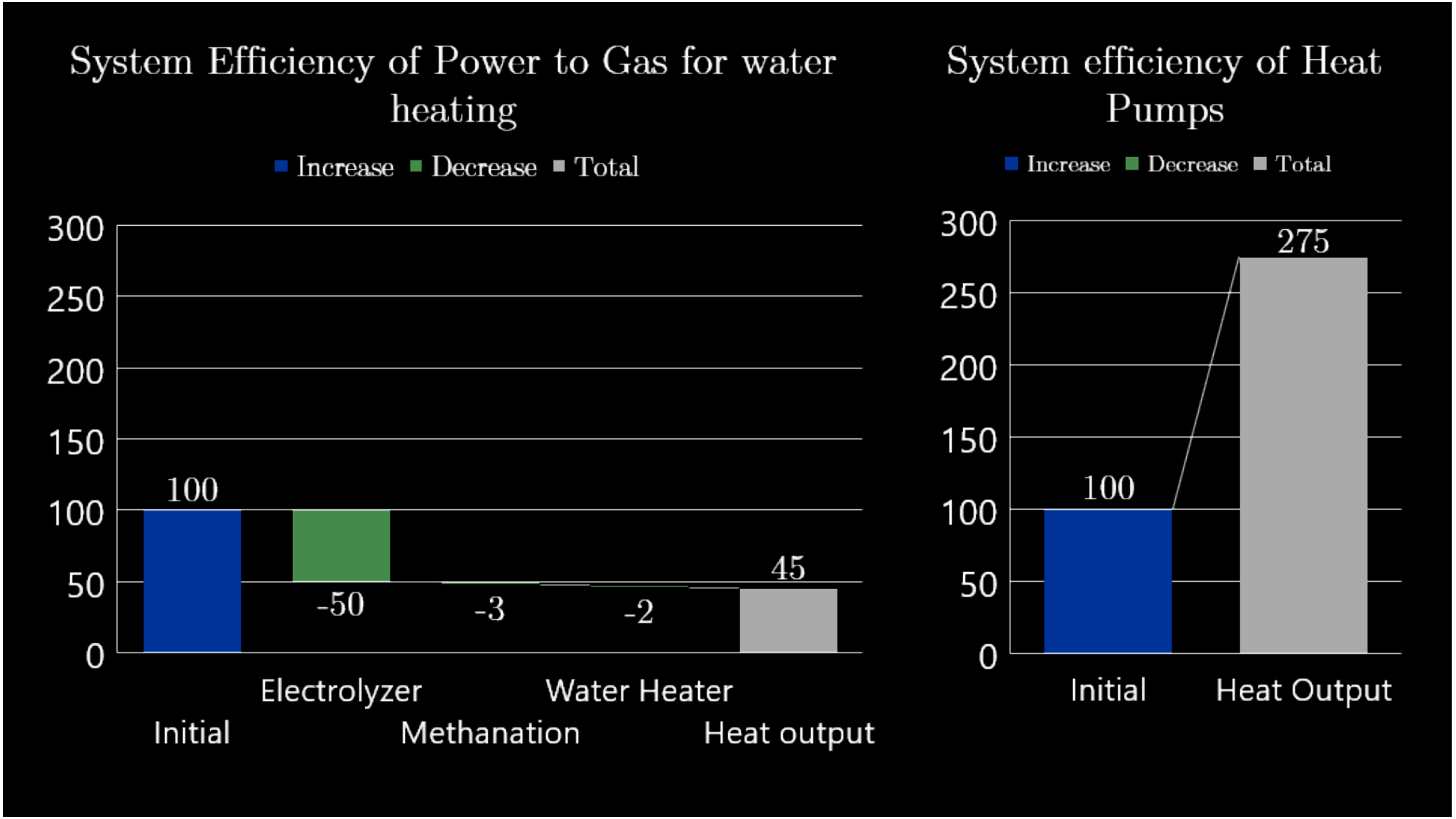
- Scarce resource: <1/5 of current fossil primary energy use.
- Industrial, aviation, heavy trucking, cold climate space heating will be more difficult to electrify.
- Biomass used in electricity generation with carbon capture could provide negative emissions.

POWER-TO-GAS

addresses the storage challenge



SoCalGas
A Sempra Energy utility


System Efficiency of Power to Gas for water heating
Increase
Decrease
Total
300
250
200
150
100
50
0
100
-50
-3
-2
45
Initial
Electrolyzer Methanation
Water Heater
Heat output
System efficiency of Heat Pumps
Increase
Decrease
Total
300
250
200
150
100
50
0
100
275
Initial
Heat Output

Solar Thermal

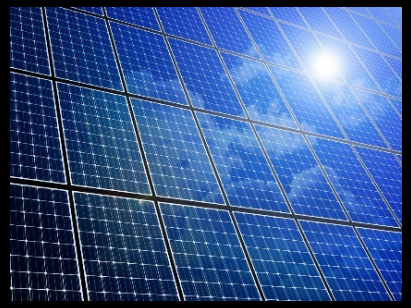
Solar Thermal + Backup

+

+ 30-50% of original energy use

vs.

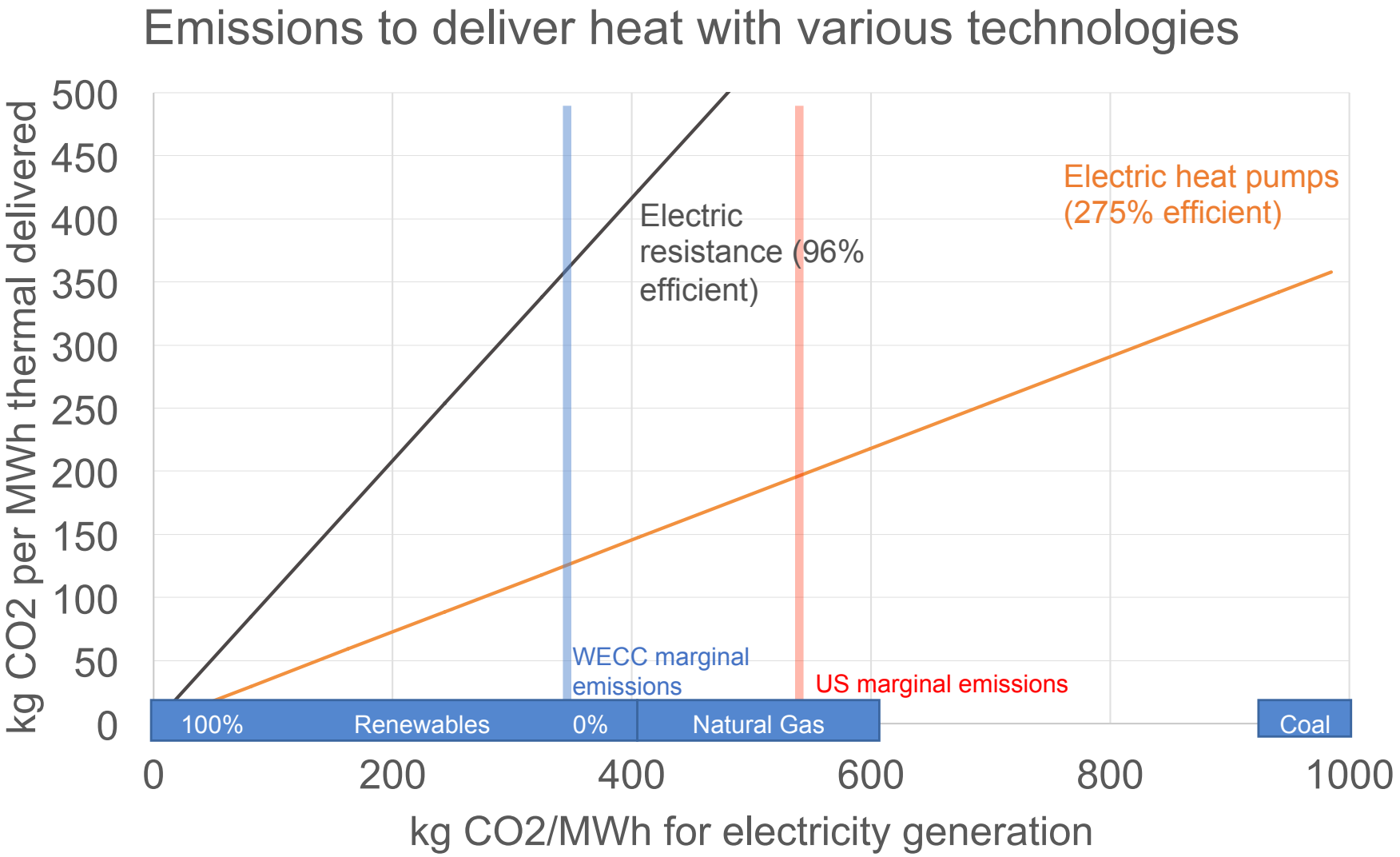
Photovoltaic + Heat pump

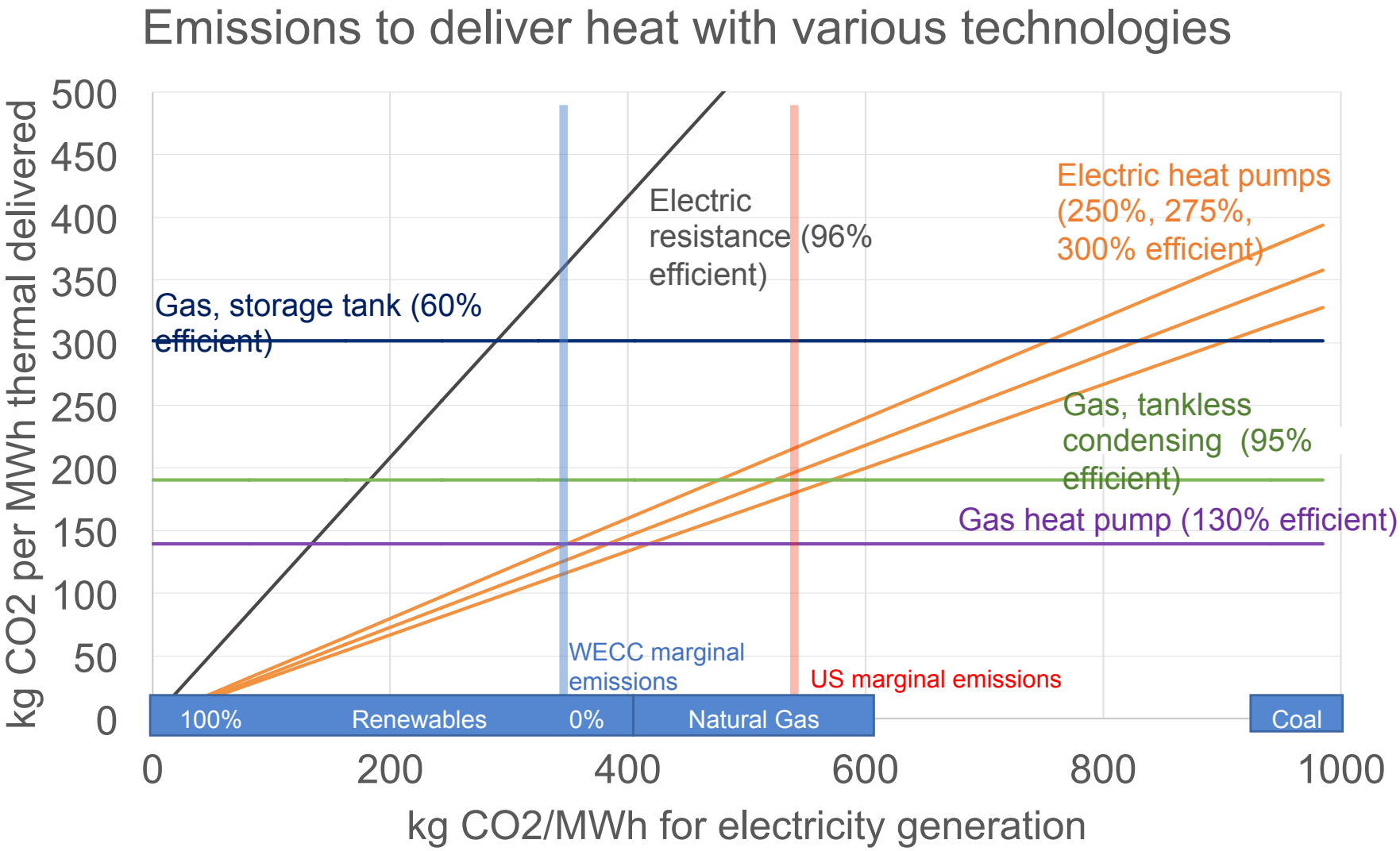


+

Zero net energy

Same capital cost. Which would you choose?


Emissions to deliver heat with various technologies
kg CO2 per MWh thermal delivered
500
450
400
350
300
250
200
150
100
50
0
Electric resistance (96% efficient)
Electric heat pumps (275% efficient)
WECC marginal emissions
US marginal emissions
100%
Renewables
0%
Natural Gas
Coal
0
200
400
600
800
1000
kg CO2/MWh for electricity generation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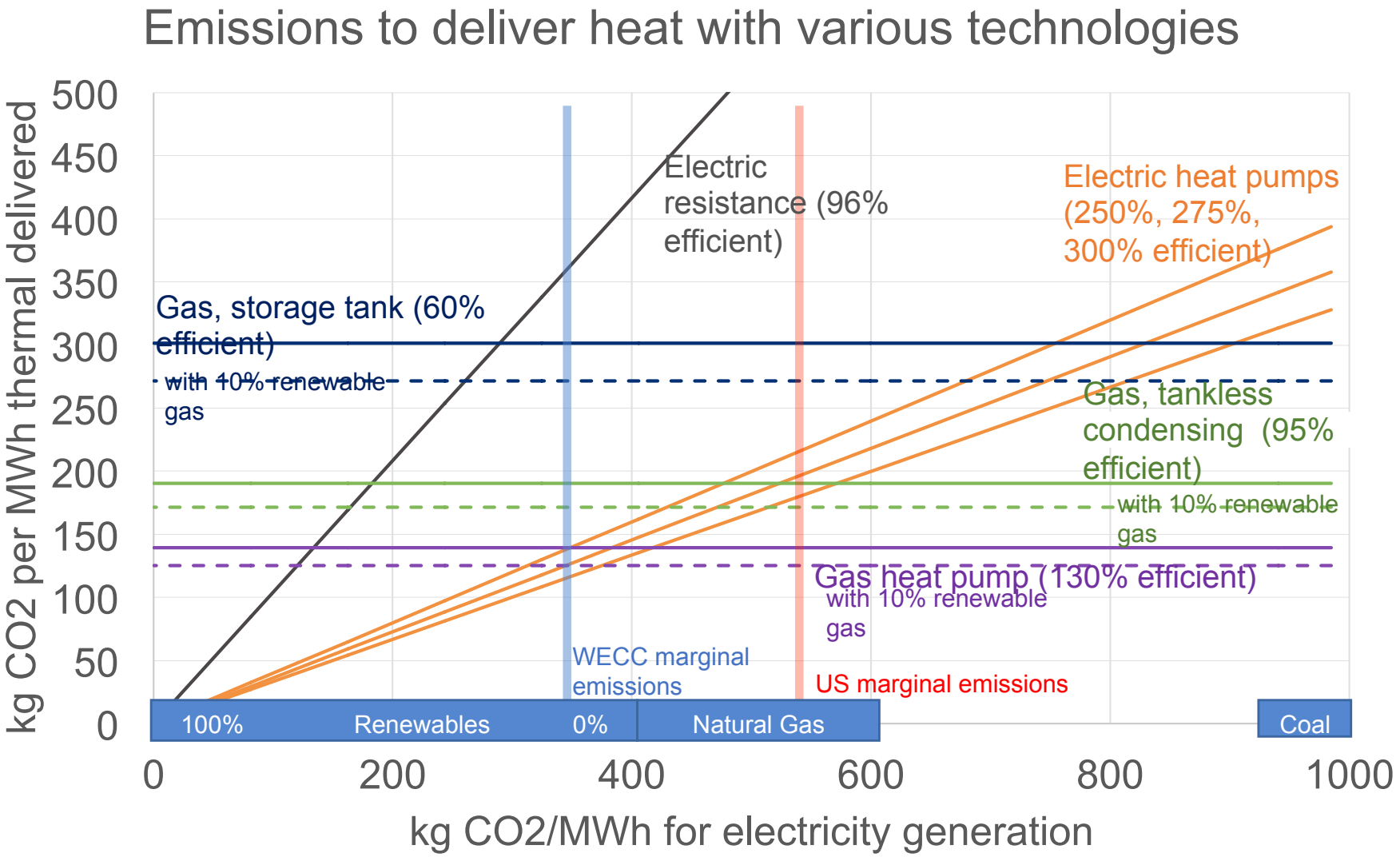
0
Electric resistance (96% efficient)
Electric heat pumps (250%, 275%, 300% efficient)
Gas, storage tank (60% efficient)
Gas, tankless condensing (95% efficient)
Gas heat pump (130% efficient)
WECC marginal emissions
US marginal emissions
100%
Renewables
0%
Natural Gas
Coal
0
200
400
600
800
1000
kg CO2/MWh for electricity generation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200
150
100
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0
Electric resistance (96% efficient)
Electric heat pumps (250%, 275%, 300% efficient)
Gas, storage tank (60% efficient)
with 10% renewable gas
Gas, tankless condensing (95% efficient)
with 10% renewable gas
Gas heat pump (130% efficient)
with 10% renewable gas
WECC marginal emissions
US marginal emissions
100%
Renewables
0%
Natural Gas
Coal
0
200
400
600
800
1000
kg CO2/MWh for electricity generation

Summary of potentials and costs

Option	Potential emission reduction	CO2 cost ($/ton)
Biogas	20%	~$300
Synthetic Methane	2-100%	$500-1000+
Solar Thermal	50-70%	~$200
Electrification	100%	$100-150

Takeaways

- With high renewables fraction, electrification provides far greater emissions reduction than improving efficiency of gas appliances.
- Biogas and synthetic methane will be scarce, and better suited to more difficult end uses.
- Solar thermal comes at higher cost and lower emissions savings than Heat Pump + PV.

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- Natural Resources Defense Council: Pierre Delforge and Merrian Borgeson

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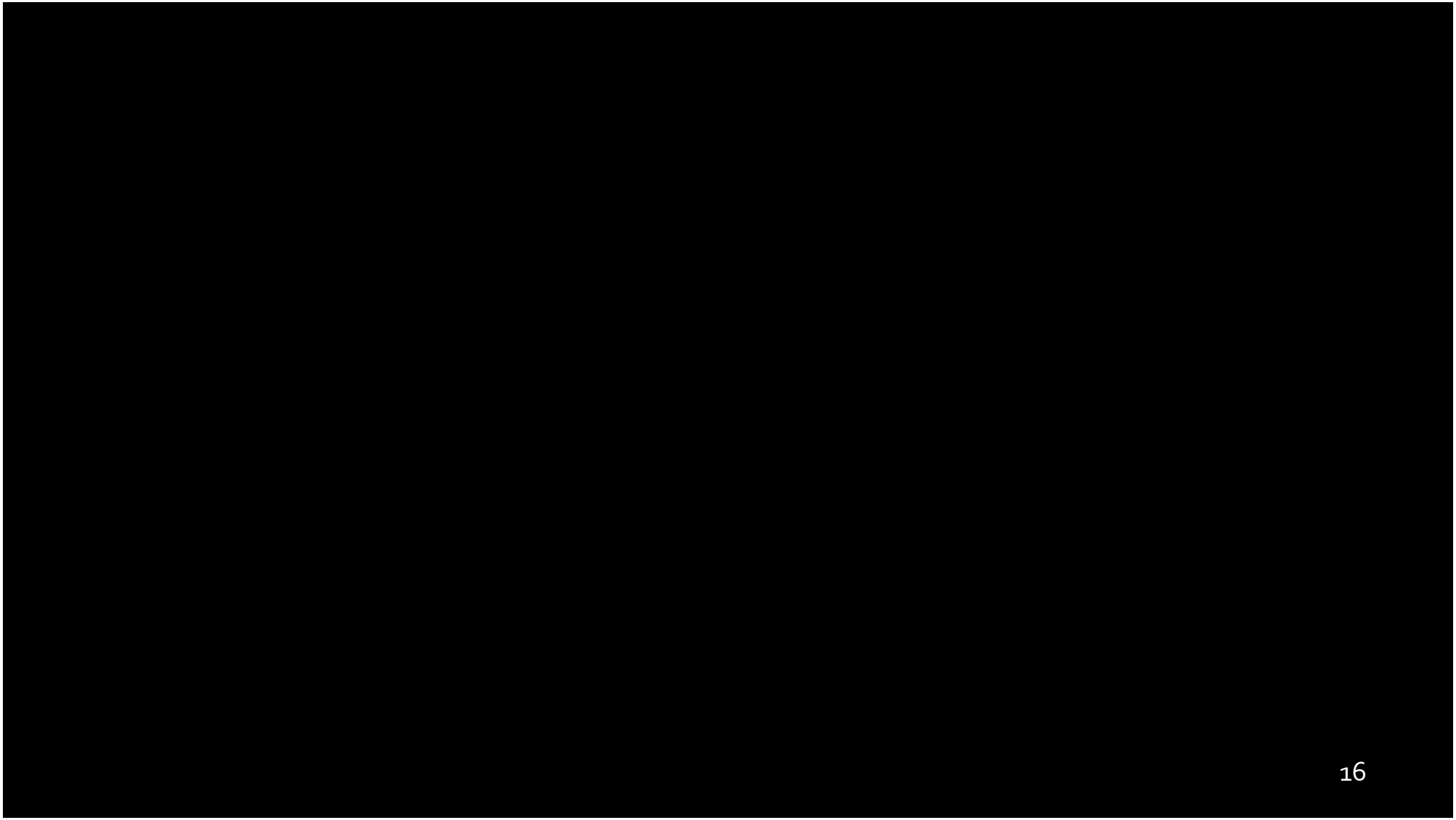


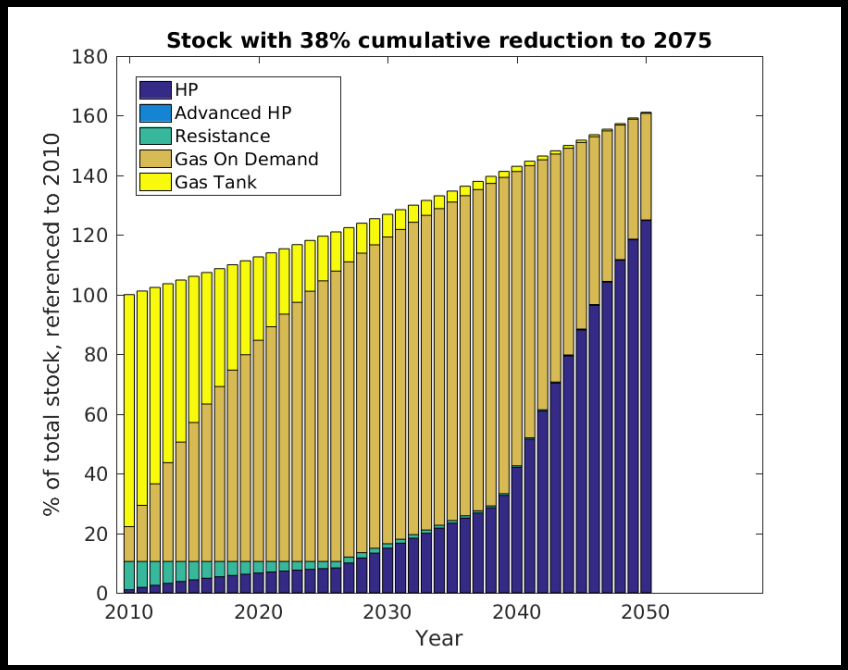
Appendix

Discussion questions

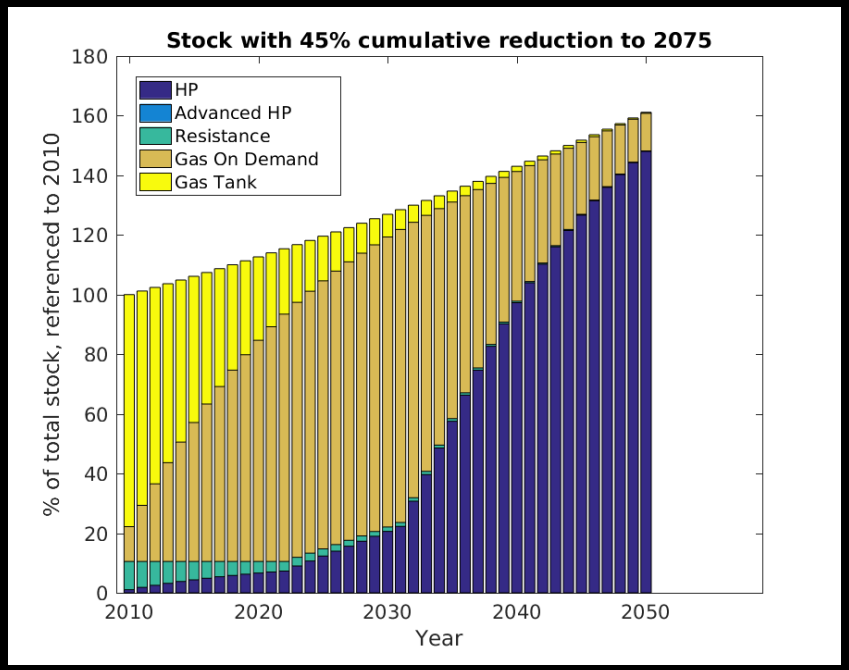
- Other than efficiency, what strategies are you aware of to reduce gas combustion in buildings?
- Are there any policies in place in Europe to promote electrification if heating?

New buildings need to electrify in mid 2020s, existing in 2030s.

80% reduction in 2050

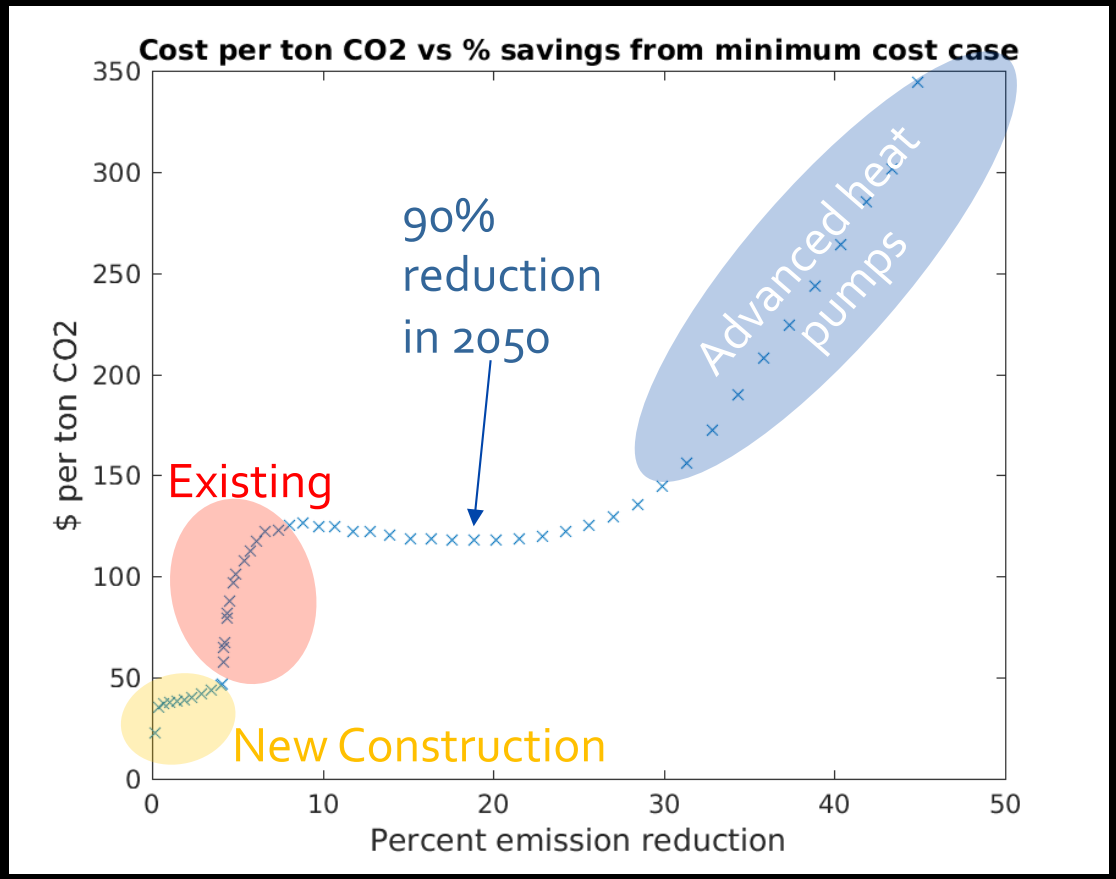


90% reduction in 2050



Sheikh, I., M. Tabone, and D. Callaway. "Optimal deployment of electrified heating systems in California." In prep.

Cost per ton pretty constant, independent of emission reduction

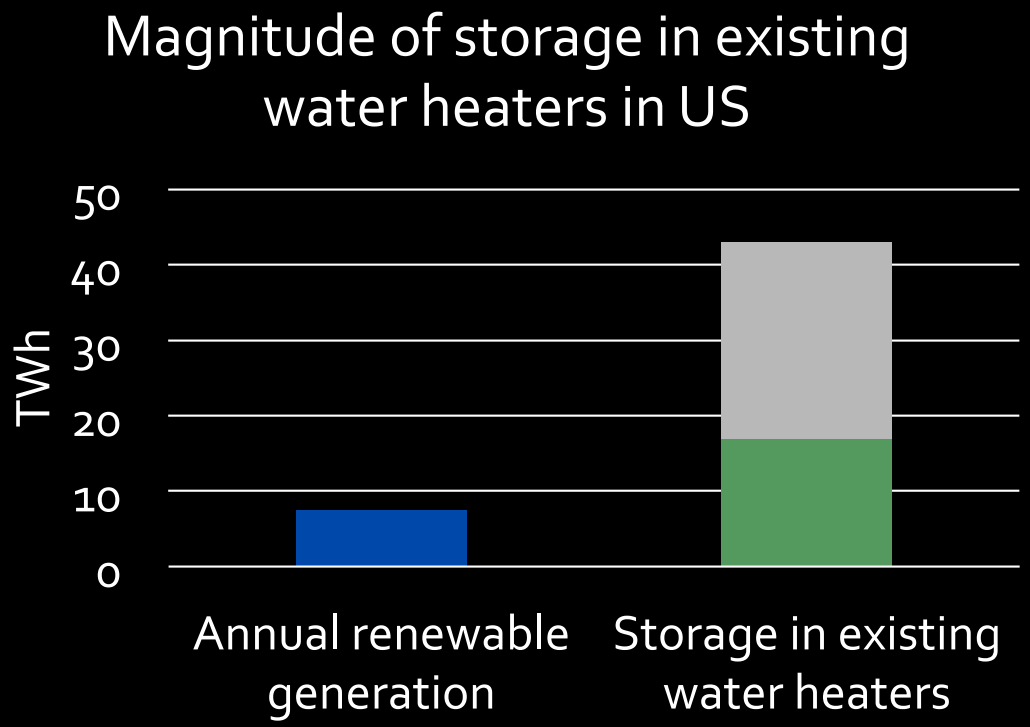


- 10% reduction or 30% reduction costs about the same per ton.

Sheikh, I., M. Tabone, and D. Callaway. "Optimal deployment of electrified heating systems in California." In prep.

Hot water heaters could be a huge energy storage resource

- 47 Million housing units use electric water heating
- The energy difference in a 50 Gallon tank at 140F vs 120F is 2.5 kWh (or 1 kWh for a heat pump).



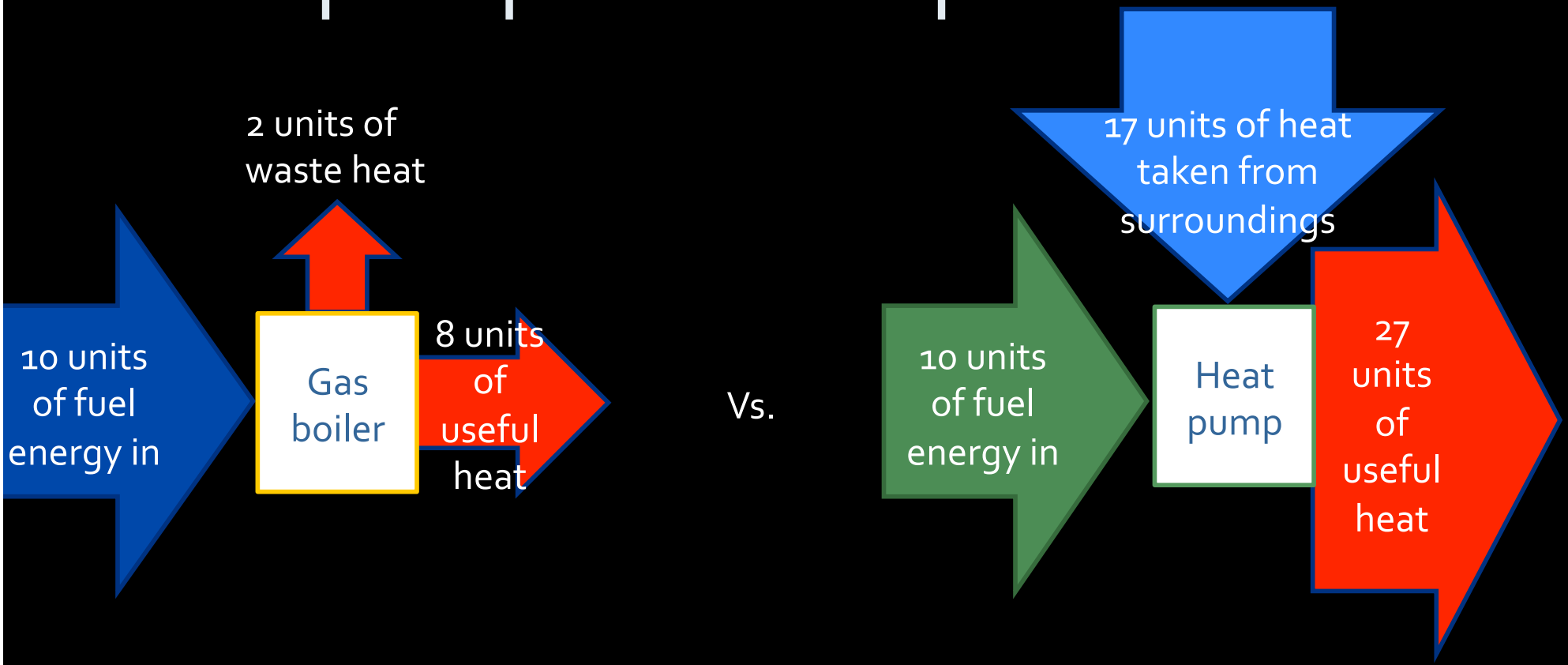
Tesla Powerwall vs. Grid integrated water heater

- 14 kWh
- $5500+ installation
- $300/kWh
- Install base: 10k?

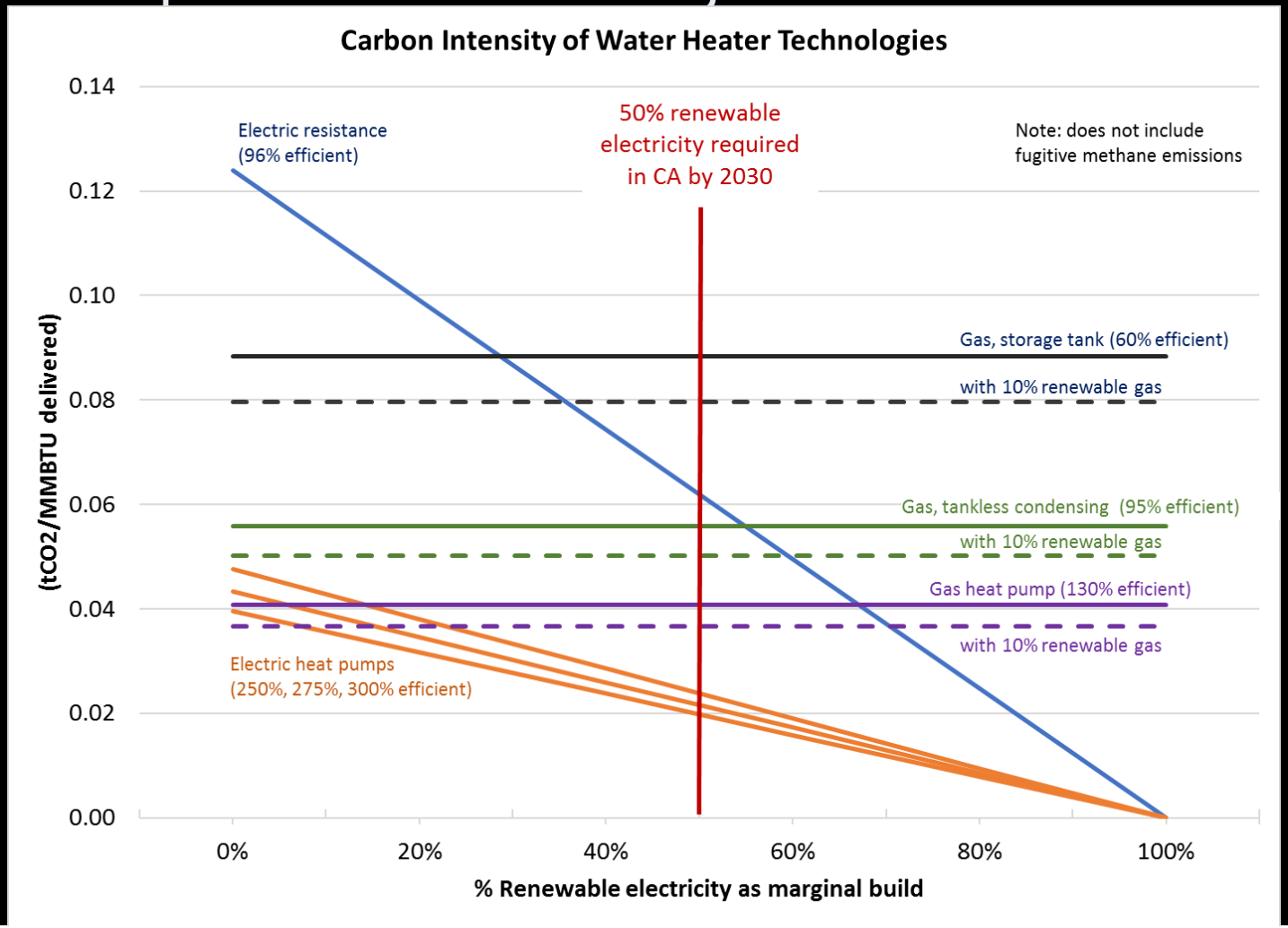
vs.

- 1-2.5 kWh
- $50-150
- $20-150/kWh
- Install base: 47 Million in US

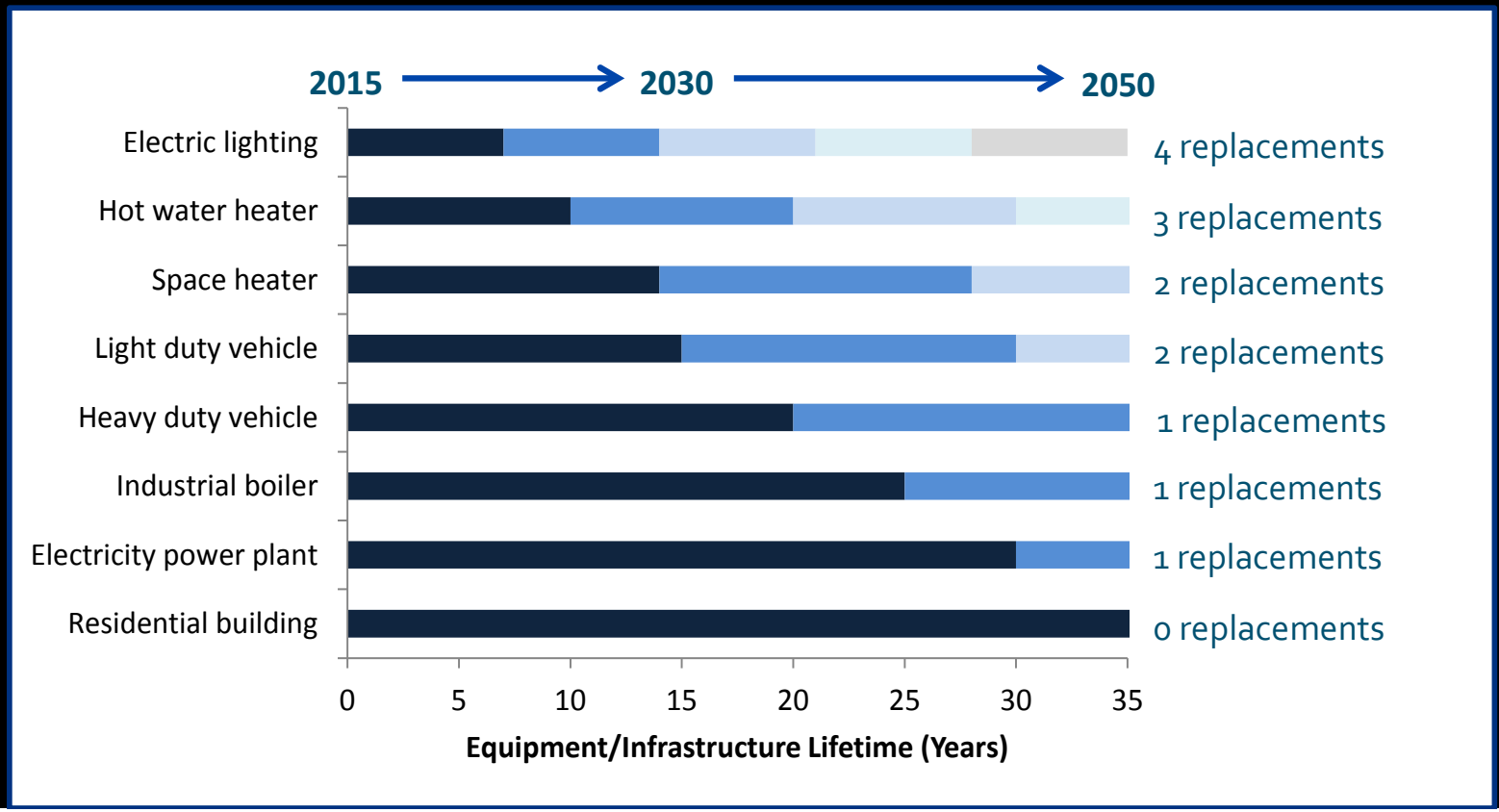
Heat pumps make it possible



Electrification provides increasing benefit over time



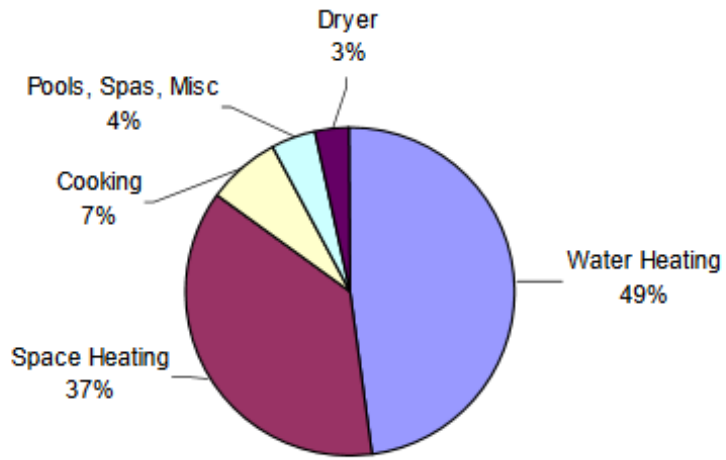
A couple replacements before 2050



CA Residential Gas Breakdown

Figure ES-6: Statewide Natural Gas Energy Consumption

354 therms per household



Source: *2010 California Residential Appliance Saturation Survey*

Figure ES-1: Statewide Electricity Consumption per Household

6,296 kWh per Household