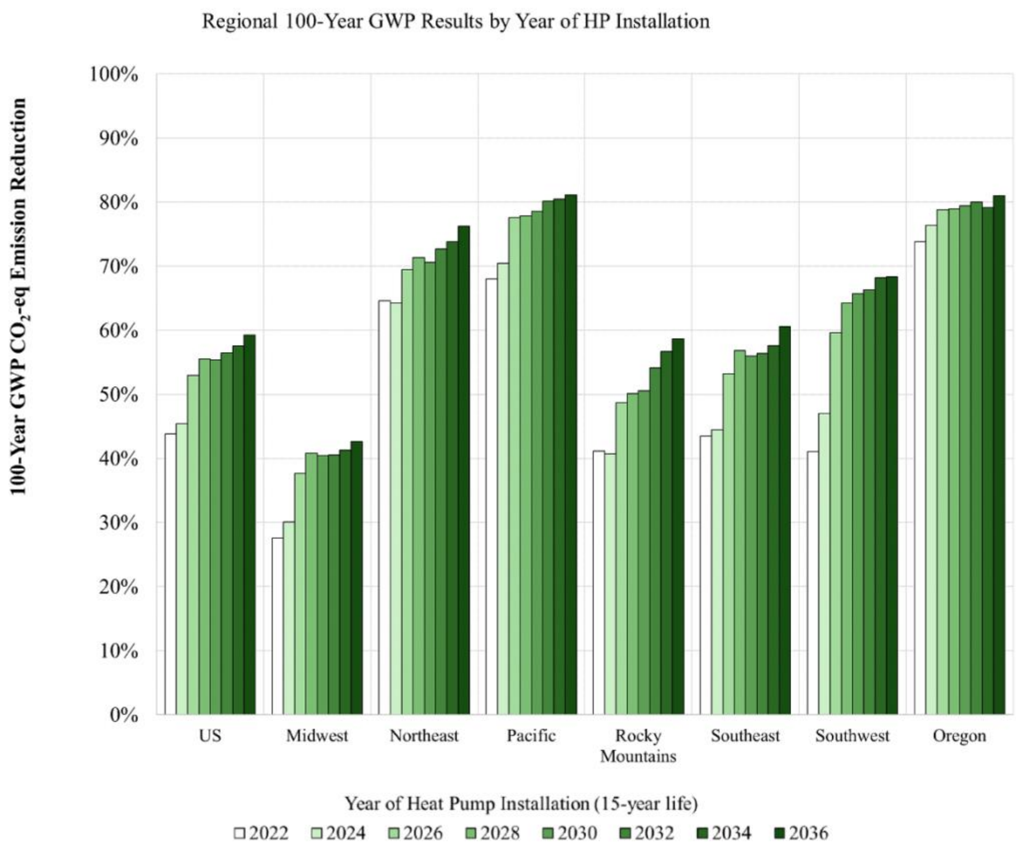
Kim Herb
JP Batmale
Oregon Public Utility Commission
October 10, 2021

RE: Natural Gas Fact Finding 2178 – Carbon Emissions from Heat Pumps vs Gas Furnaces in Oregon

Dear Ms. Herb and Mr. Batmale:

Given that the strategy of transitioning building heating loads away from methane toward electricity has been discussed as a potential method to reduce carbon emissions from the regulated gas utilities in Oregon, it is important to be aware of the available data regarding the carbon impact of that transition. The data is unequivocal and, as has been noted before in our comments to PUC staff, multiple studies have confirmed that heating with heat pumps produces far lower carbon emissions than even the highest efficiency gas furnaces in the Pacific Northwest.

The most recent study from the UC Davis Western Cooling Efficiency Center[1] includes data and conclusions specific to the Pacific Region and to Oregon. This research incorporates estimated global warming impacts from refrigerant leaks in heat pumps and methane emissions from gas distribution systems, and is the first to utilize newly available long run marginal emissions rates for the electricity production that would be needed to respond to increased electric grid loads from electrification of space heating. The study shows that heat pumps produce lower carbon emissions than gas furnaces in every region of the U.S. **The below graph, provided by the UC Davis research team in response to our request, shows that for Oregon, a heat pump installed in 2022 would produce over 70% fewer carbon emissions over its 15-year lifetime than a "high efficiency" gas furnace.**



It is important to note that this study is based on utility IRPs that do not reflect impacts to the Oregon electric grid resulting from HB 2021, which mandates 80% clean energy by 2030, and 100% clean energy by 2040. **The benefits of heat pumps relative to gas furnaces should therefore be expected to be even higher than estimated in this report due to the increased renewables in the grid resulting from HB2021.**

The study focused exclusively on space heating, but Pierre Delforge from the NRDC made this written comment regarding expected impacts from heat pump water heaters:

"The WCEC study did not analyze the electrification of water heating, but NRDC estimates that the results would be even more favorable for electrification because heat pump water heaters have a lower refrigerant charge and typically operate at a higher level of performance than heat pumps for space heating."

As it is likely that this topic will resurface in future workshops on regulatory tools, we feel it is critical that those discussions be enlightened by facts. The available science and research clearly indicate that heating with electric heat pumps is the most effective method to decarbonize buildings in Oregon.

Respectfully,

Brian Stewart
Founder
Electrify Now

electrify now

[1] "Greenhouse Gas Emission Forecast for Electrification of Space Heating in Residential Homes in the United States", UC Davis Western Cooling Efficiency Center, July 01, 2021

DOCKETED

Docket Number:	21-BSTD-02
Project Title:	2022 Energy Code Update CEQA Documentation
TN #:	238719
Document Title:	NRDC Comments on Draft Environmental Impact Report for 2022 Building Standards
Description:	N/A
Filer:	System
Organization:	NRDC
Submitter Role:	Public
Submission Date:	7/7/2021 3:31:16 PM
Docketed Date:	7/7/2021

Comment Received From: Pierre Delforge
Submitted On: 7/7/2021
Docket Number: 21-BSTD-02

NRDC Comments on Draft Environmental Impact Report for 2022 Building Standards

Additional submitted attachment is included below.

Dear Commissioner McAllister and Energy Commission Staff,

July 7, 2021

Re. NRDC Comments on NRDC Comments on Draft Environmental Impact Report for 2022 Building Standards Released May 19, 2021, Docket Number 21-BSTD-02

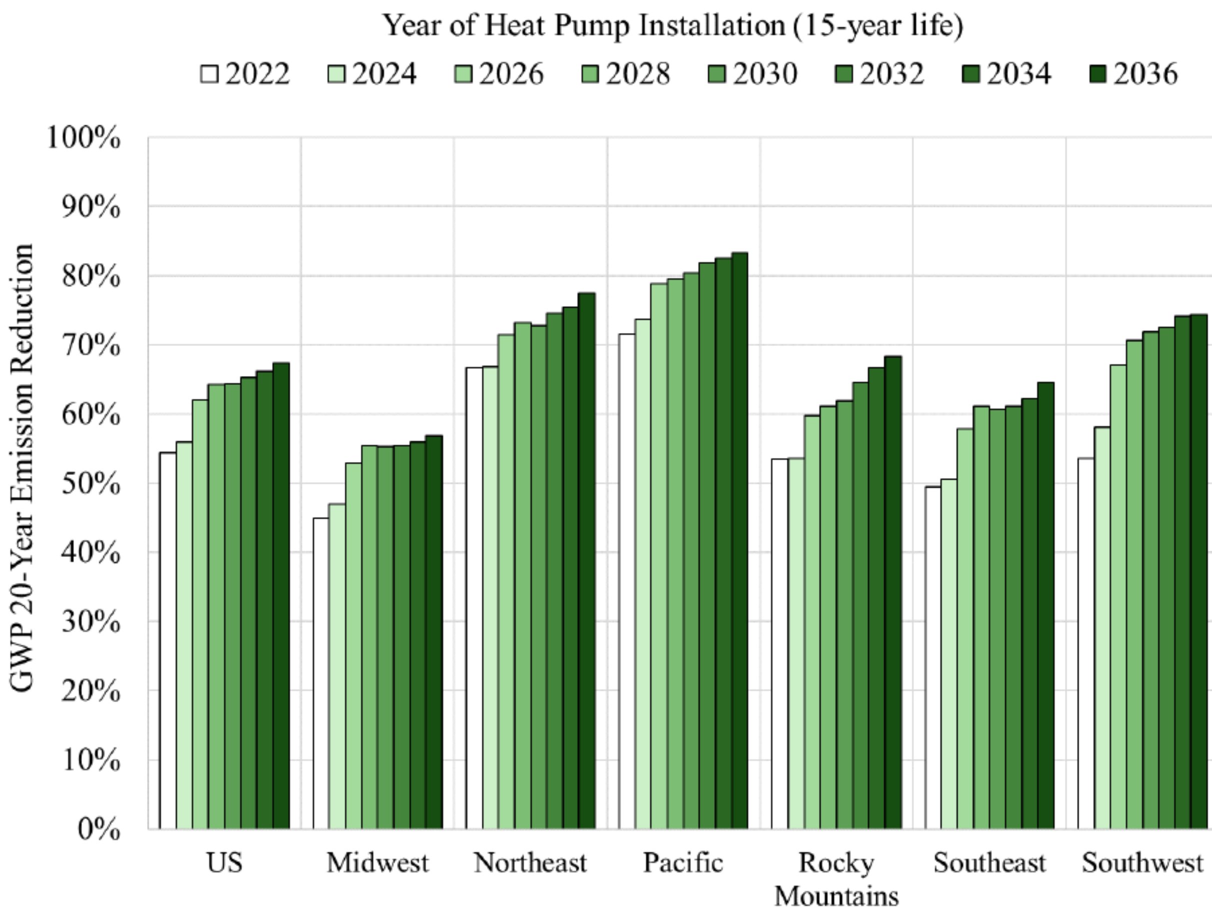
On behalf of the Natural Resources Defense Council (NRDC), we submit the following comments in response to the California Energy Commission's (CEC) Draft Environmental Impact Report for the 2022 Title 24 Efficiency Standards released May 19, 2021. Our comments are focused on the potential greenhouse gas (GHG) emissions impacts associated with 2022 Building Energy Standards.

NRDC supports the findings of the Draft Environmental Impact Report that the 2022 building energy code (the "2022 Code") would result in a reduction of GHG emissions statewide. In fact, CEC's analysis is overly conservative for several reasons, and NRDC estimates that the 2022 Code would result in a much larger reduction of GHG emissions statewide.

The biggest reason is that CEC's analysis does not include the indirect benefits of all-electric new construction: as space and water heating in new construction transitions from fossil fuels to highly-efficient electric heat pump technologies, the price of these technologies will fall as it did with solar energy technologies over the past 15 years, and familiarity and capacity among installers will increase, leading to much lower equipment and installation costs. This will accelerate electrification of space and water heating in existing buildings, which are responsible for the bulk of energy related GHG emissions in buildings. Therefore, **the 2022 Code will indirectly contribute to energy related GHG emissions reductions in California's building sector in excess of 70 percent for heat pumps installed in the 2023-2025 time period, and more than 80 percent by 2030**.

These reduction estimates are based on the preliminary results of a study commissioned by NRDC to the UC Davis Western Energy Cooling Center (WCEC) on the GHG impacts of electrification of residential space heating, included as Appendix A.

Figure 1: Lifetime Emissions Reductions from Installing a Heat Pump vs. a Gas Furnace With 20-Year Global Warming Potential



The study uses a comprehensive and robust methodology by accounting for:

- **Hourly long-run marginal emissions rates for the electric grid**, from the National Renewable Energy Laboratory (NREL) Cambium dataset. Contrary to average or short-run marginal emissions rates often used in similar studies, NREL's dataset forecasts the mix of generation resources that would serve a persistent and large-scale change in end-use demand, taking into account structural changes to the grid in response to the change in demand, which is the most appropriate way to model the impacts of widespread electrification of space and water heating.
- **Methane emissions** associated with methane production and behind-the-meter leaks in residential homes.
- **Refrigerant emissions from heat pumps**, including refrigerant leakage during operation and at end of life, the proportion of homes that already have air conditioning or are projected to adopt it over the study's time period, and the increased refrigerant charge in heat pumps vs. air conditioners.

- **The use of electric resistance backup** in heat pumps when the outdoor temperature drops below the threshold where the heat pump can provide sufficient capacity in compressor-only mode, or when needed to recover from nighttime thermostat setbacks.

The WCEC study's methodology is generally aligned with CEC's with two notable differences:

- Figure 1 shows emissions impacts for the entire U.S. Pacific region, which includes the states of California, Oregon, and Washington. NREL emissions factors are slightly lower for California than for other Pacific states, so California-specific results would show higher emissions reductions than for the entire Pacific region.
- WCEC's study includes out-of-state methane emissions associated with gas imported into California for use in buildings, whereas CEC's includes in-state leakage only. California imports 90 percent of the gas used in the state, and the majority of methane emissions takes place at the extraction well. Phasing out gas use in California's buildings will result in fewer new gas wells drilled, and therefore a reduction in associated methane emissions. California Air Resources Board accounts for out-of-state emissions for electricity generation, the same approach should be used with fugitive methane emissions for consistency and to allow for a fair comparison of the GHG impacts of fossil fuels vs. electric alternatives.

However, the WCEC study shows that both methane and refrigerant emissions are significantly lower than the direct CO2 emissions of gas furnaces and heat pumps, so they do not directionally change the results of the study. The WCEC study therefore corroborates CEC's analysis findings that electrification of space heating significantly reduces emissions compared to gas furnaces.

The WCEC study did not analyze the electrification of water heating, but NRDC estimates that the results would be even more favorable for electrification because heat pump water heaters have a lower refrigerant charge and typically operate at a higher level of performance than heat pumps for space heating.

Finally, the WCEC study does not consider the potential beneficial impacts of heat pump demand flexibility controls, which shift heat pump operation from peak-demand and GHG times to times when lower carbon intensity electricity is available, through strategies such as smart thermostats that pre-heat buildings ahead of peak time periods, and use of thermal storage particularly for water heating and hydronic heating systems.

Sincerely,

Pierre Delforge
Senior Scientist
Natural Resources Defense Council
pdelforge@nrdc.org

UCDAVIS
Western Cooling Efficiency Center

Greenhouse gas emission forecasts for electrification of space heating in residential homes in the United States

by Theresa Pistochini
tepistochini@ucdavis.edu

July 01, 2021

Acknowledgements

- Project Team, UC Davis
  - Theresa Pistochini, R&D Engineering Manager
  - Subhrajit Chakraborty, R&D Engineer
  - Mitchal Dichter, Programmer
  - Nelson Dichter, R&D Engineer
  - Aref Aboud, Student Researcher
- Sponsor
  - Natural Resources Defense Council
- Cambium Dataset Assistance
  - Pieter Gagnon, National Renewable Energy Laboratory (NREL)

NRDC

Updates from April Webinar

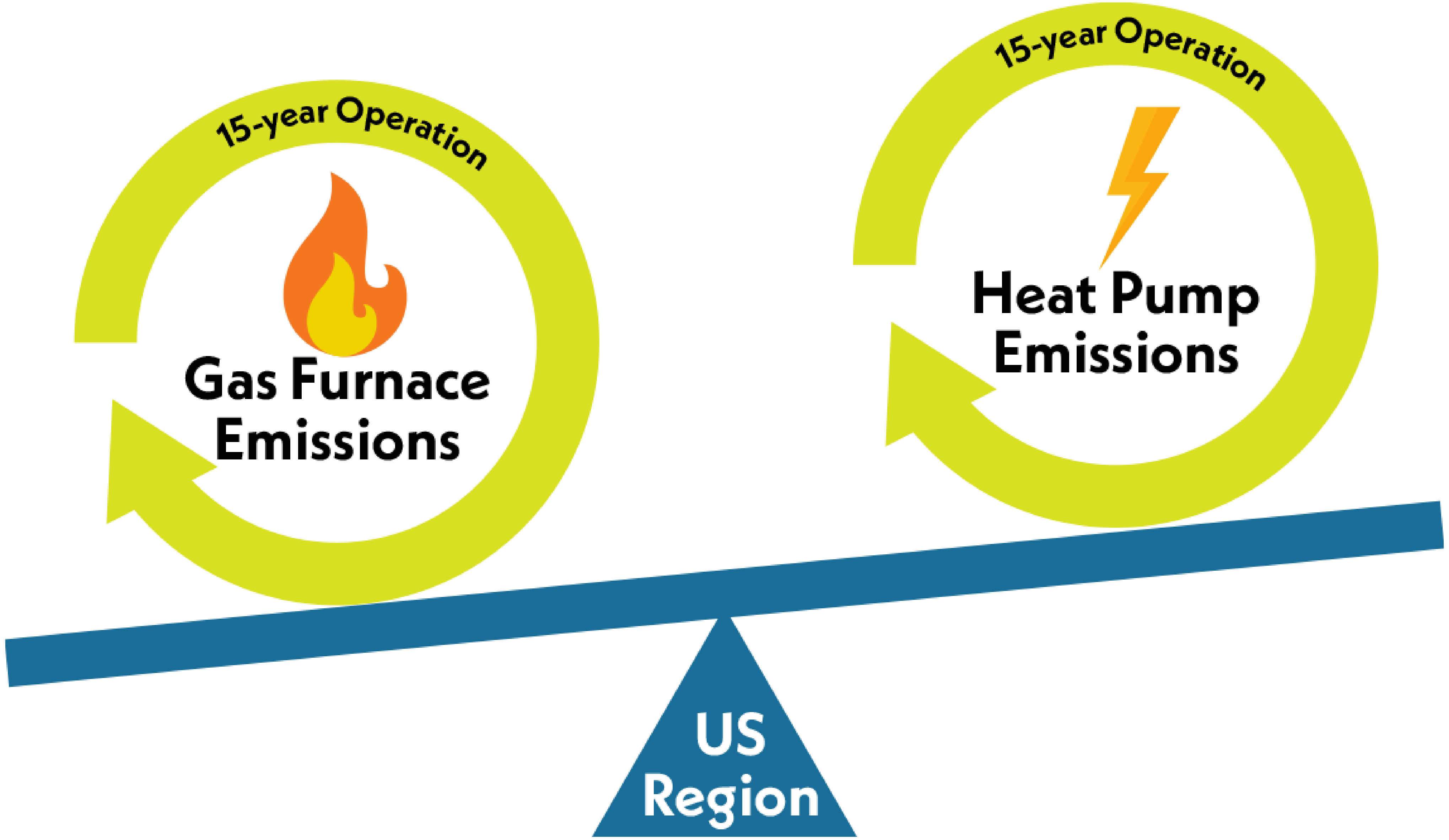
» Accounted for reverse-cycle defrost energy in the heat pump compressor electricity use
  - Changed results negligibly for cold climates

» Corrected population averaging errors for 2006 construction model results
  - Small changes in results - 2006 model results closely aligned to 2018 model results

» Included incremental refrigerant charge for heat pumps compared to air conditioners
  - Reasonable hypothesis from a dataset of Trane 14,16, 18 SEER units
  - Increased fugitive refrigerant emissions

Study Objective

Analyze the expected 15-year lifecycle operational greenhouse gas (GHG) emission impacts resulting from replacing a residential natural gas furnace with a variable speed heat pump in a single-family home simulated in locations across the US



Metrics Analyzed

Metric	Source	Heat Pump (HP)	Gas Furnace (GF)
Carbon Dioxide	End-Use Electricity – Air Handler Fan	✔	✔
Carbon Dioxide	End-Use Electricity – Compressor	✔	
Carbon Dioxide	End-Use Electricity – Electric Resistance Strip Heat	✔	
Carbon Dioxide	End-Use Natural Gas – Combustion		✔
20-Year GWP 100-Year GWP	Refrigerant Leaks	✔	
20-Year GWP 100-Year GWP	Methane Leaks – Production	✔	✔
20-Year GWP 100-Year GWP	Methane Leaks – Downstream of Meter		✔

Global Warming Potential (GWP) – A metric used to compare the heating impact of gases in the atmosphere to an equivalent mass of carbon dioxide (CO2) over the specified timeframe. By definition, the GWP of CO2 over any timeframe is 1.

GWP Values Applied

Gas	20-Year GWP [1]	100-Year GWP [1]
Refrigerant R-410A	4,260	1,924
Refrigerant R-32	2,430	677
Methane	84	28

[1] G. Myhre, W. Collins, F. M. Breon, W. Collins, J. Fuglestvedt, J. Huang, D. Koch, J. F. Lamarque, D. Lee, B. Mendoza, T. Nakajima, A. Robock, G. Stephens, T. Takemura and H. Zhang, "Anthropogenic and Natural Radiative Forcing. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change," Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2013.

Locations and Weather

» TMY3 Weather Data [2]

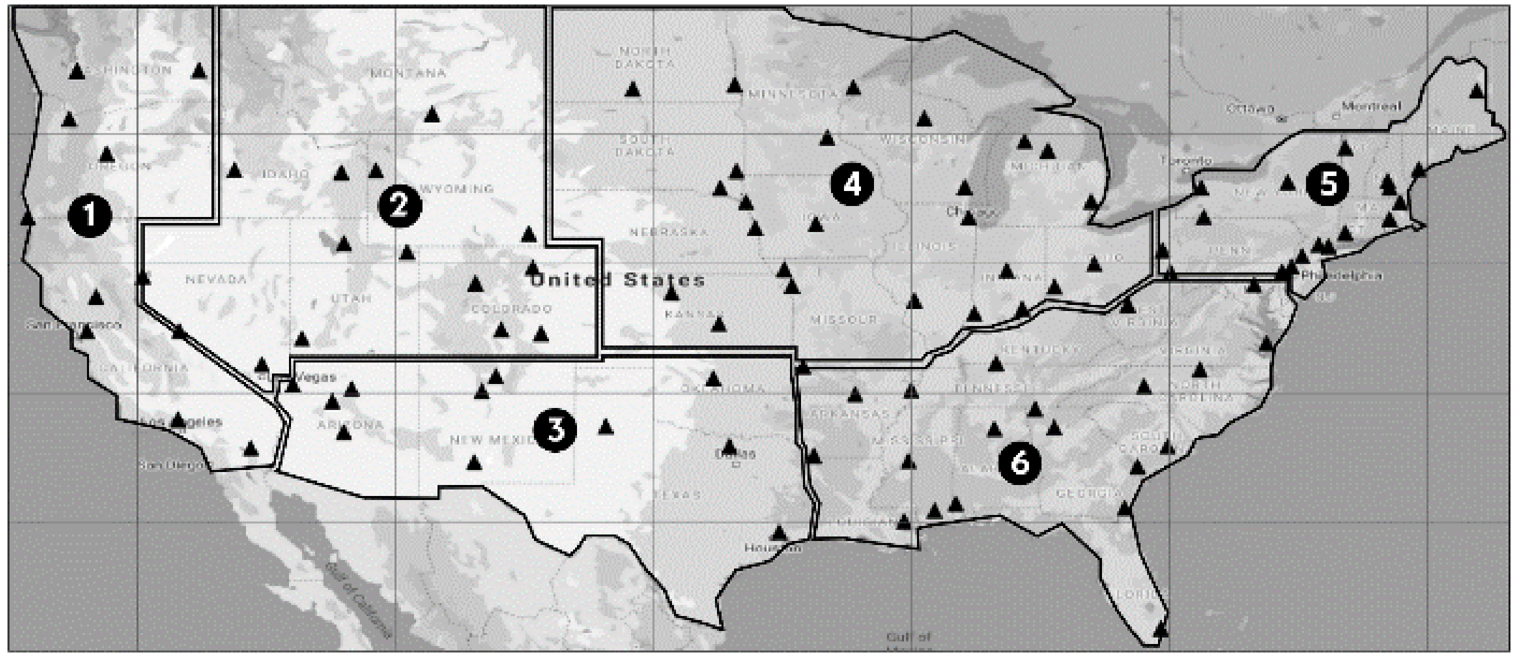
» 99 cities covering:

- Largest city in each combination of 48 states and 7 DOE climate zones [3]
- Plus San Jose and Sacramento for increased resolution of CA

» 2019 Census data for County population size for the selected city [4]

» Results presented as County-population weighted averages by region [4]

Regions Analyzed



1. Pacific
2. Rocky Mountains
3. Southwest
4. Midwest
5. Northeast
6. Southeast

[2] White Box Technologies, "Weather Data for Energy Calculations," 2015 4 2. [Online]. Available: http://weather.whiteboxtechnologies.com/TMY3. [Accessed 2016 15 12].
[3] Pacific Northwest National Laboratory, "Volume 7.3 Guide to Determining Climate Regions by County," U.S. Department of Energy, Building Technologies Office, 2015.
[4] United States Census Bureau, "County Population Totals 2010-2019," [Online]. Available: https://www.census.gov/data/tables/time-series/demo/popest/2010s-counties-total.html. [Accessed 3 2 2021].

Residential Building Model

- Pacific Northwest National Laboratory, "Residential Prototype Building Model" representing 2006 and 2018 construction years [5]
- Single family home, two stories, concrete slab with attic
- Converted to EnergyPlus v9.4 [6]
- Heating setpoints: 68 F 7am-11pm, 65 F 11pm-7am [7]

Differences in construction parameters for 2006 and 2018 years

	2006	2018
Attic Floor Insulation R-value	26.2	31.3
Exterior Wall Insulation R-value	8.7	13.9
Exterior Door Insulation R-value	1.5	3.1
Occupied Space Effective Leakage Area [in^2]	147.7	55.4
Attic Effective Leakage Area [in^2]	57.4	57.4
Window U-factor	0.7	0.3
Window Solar Heat Gain Coefficient	0.3	0.2

[5] Pacific Northwest National Laboratory, "Residential Prototype Building Models," U.S. Department of Energy, 7 10 2020. [Online]. Available: https://www.energycodes.gov/development/residential/iecc_models. [Accessed 25 2 2020]
[6] U.S. Department of Energy, "EnergyPlus," [Online]. Available: https://energyplus.net/. [Accessed 28 1 2021]
[7] California Energy Commission, "Residential Alternative Calculation Method Reference Manual," California Energy Commission, Sacramento, 2019.

Natural Gas Furnace (GF) 🔥

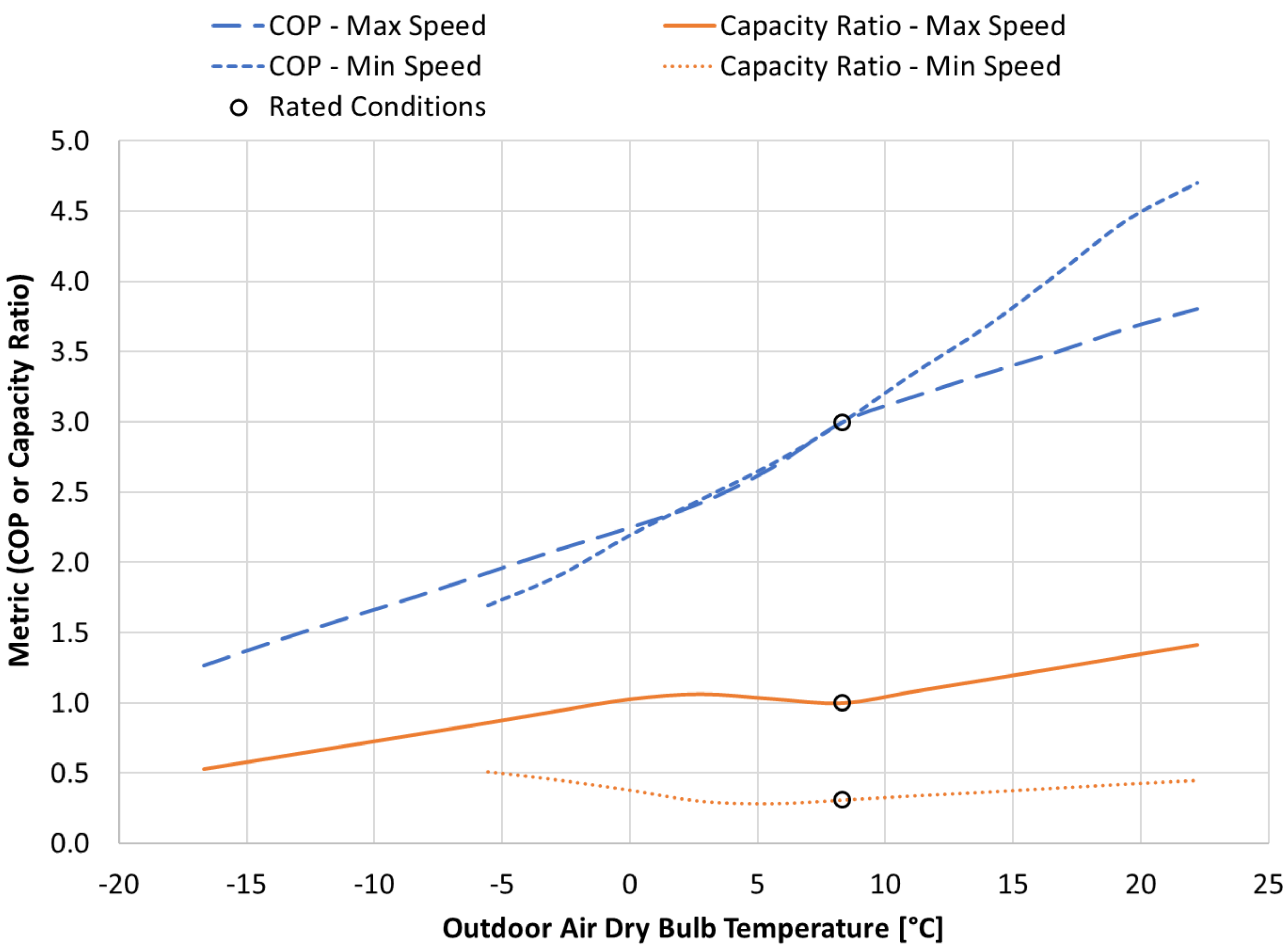
- 96% Annual Fuel Utilization Efficiency
  - Trane S9X1
- Sized at 100,000 Btu/hr in all climates such that unmet heating hours are less than 25 hours in every climate
- Sizing does not change CO2/GHG analysis as long as there are no significant unmet heating hours
- Analysis includes fan energy use associated with heating mode

Heat Pump (HP) Efficiency

» Based on manufacturer extended data tables for:
  - Trane Outdoor Unit: Model 4TWV0036A1
  - Trane Indoor Unit: Model TAM9A0C36V31
  - Heating seasonal performance factor (HPSF) = 10

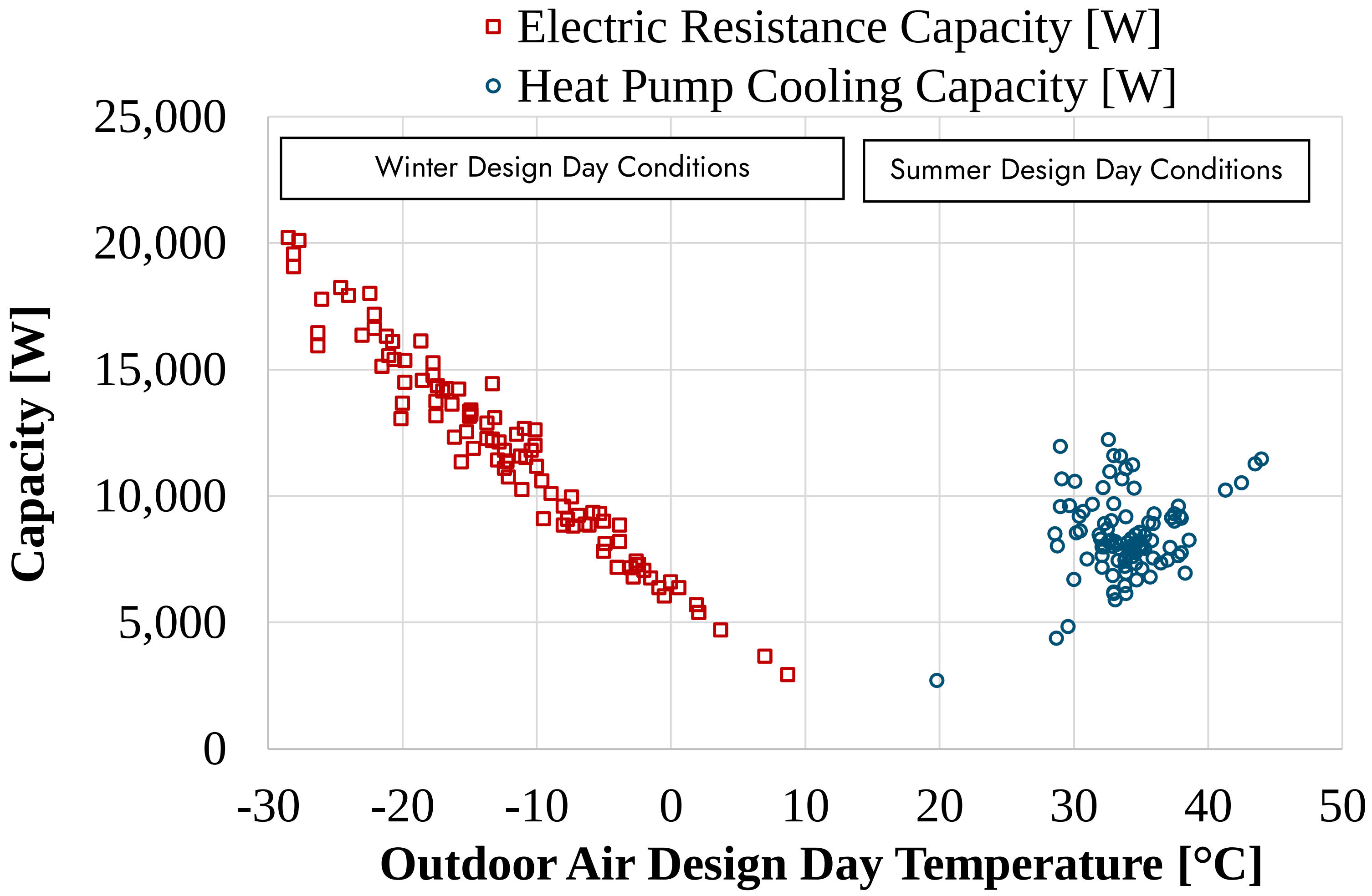
» Capacity is determined from multiplying the capacity ratio by the capacity at the rating conditions (8.3 C)

» Minimum speed increases as outdoor temperature decreases below 5 C

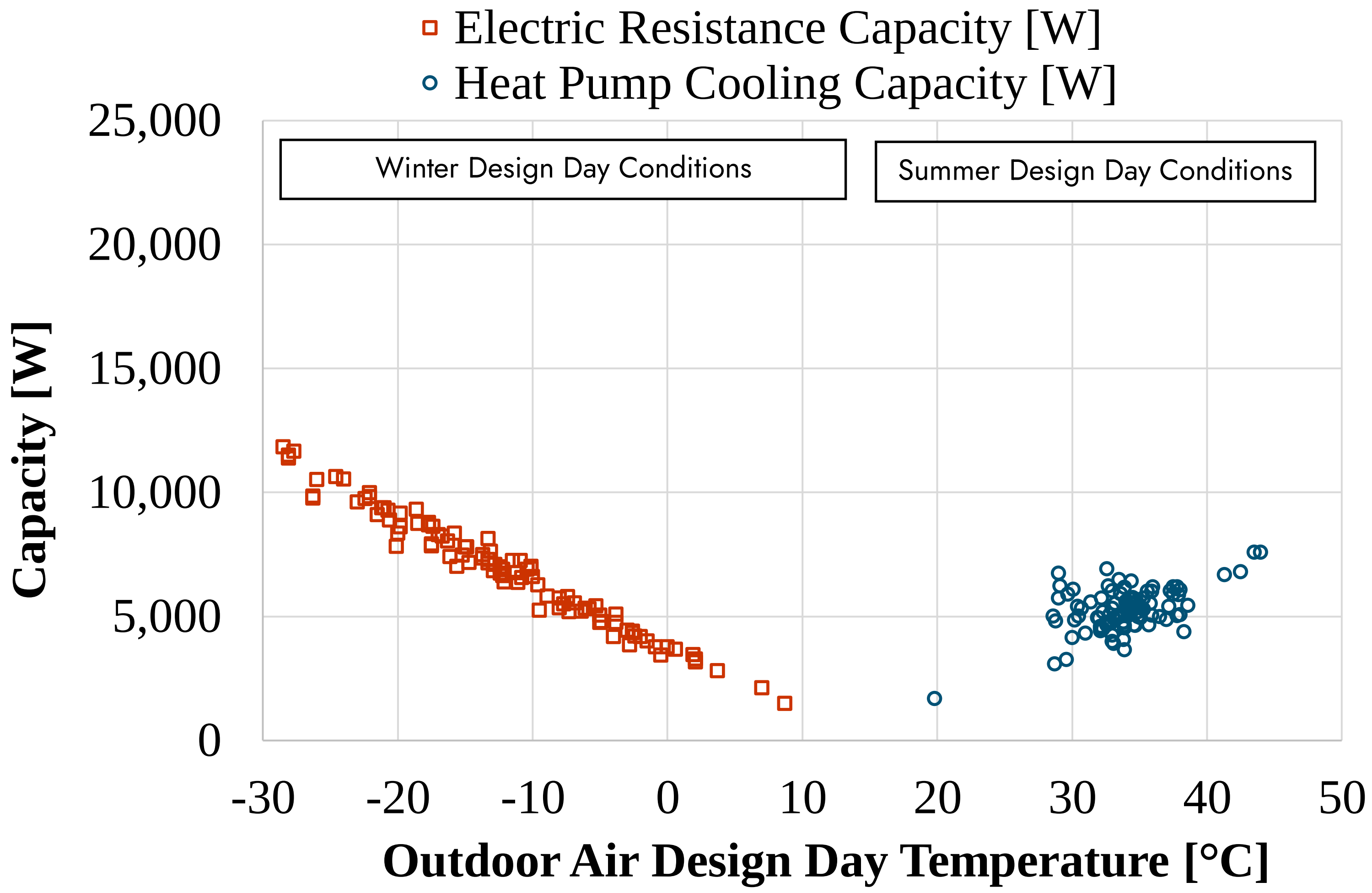


Heat Pump Sizing

- » HP capacity is sized @1.4 times design day cooling load [8]
- » Switches to electric resistance only at -18C/0F
- » Electric resistance capacity is sized @1.4 times design day heating load



2006 Construction

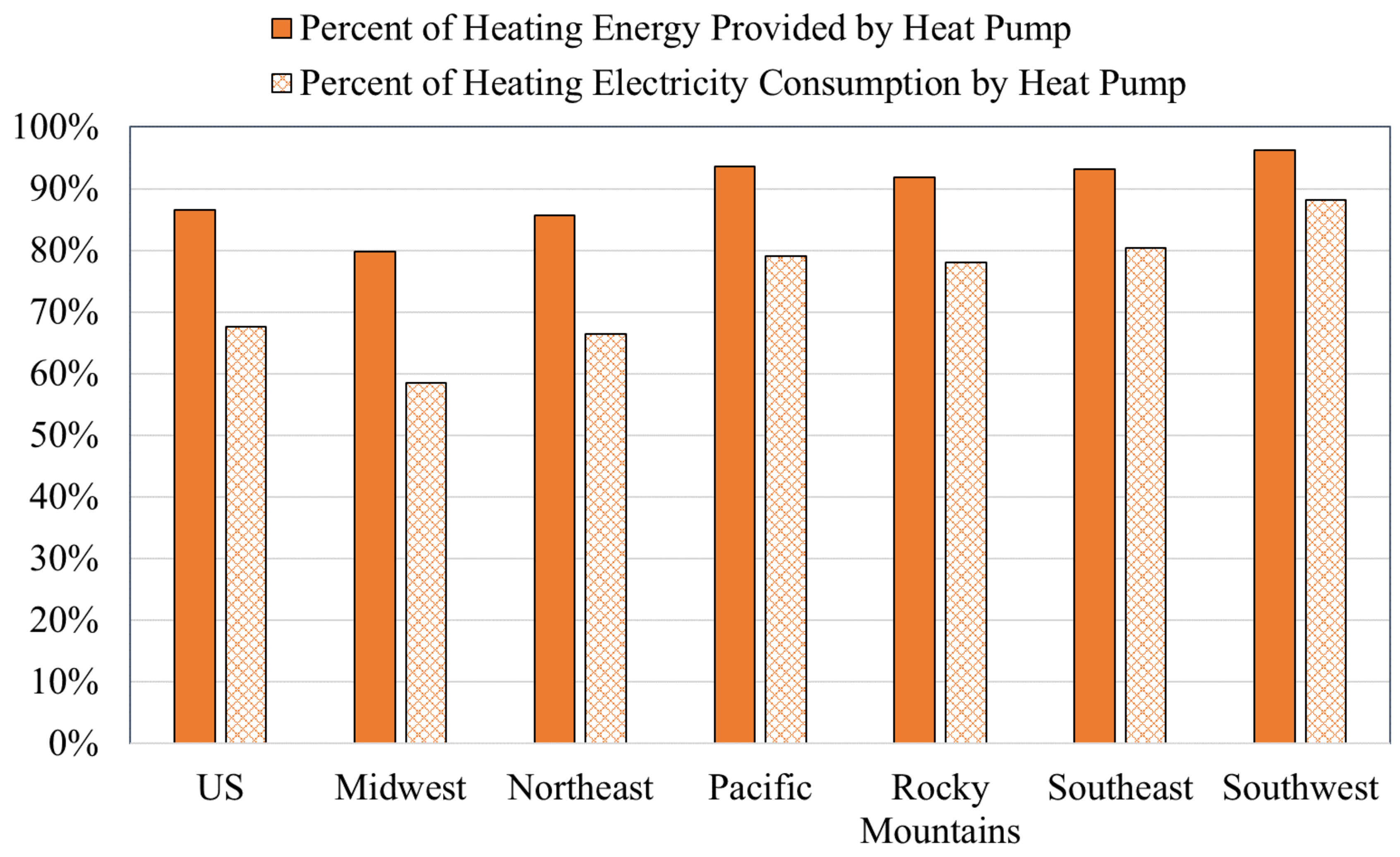


2018 Construction

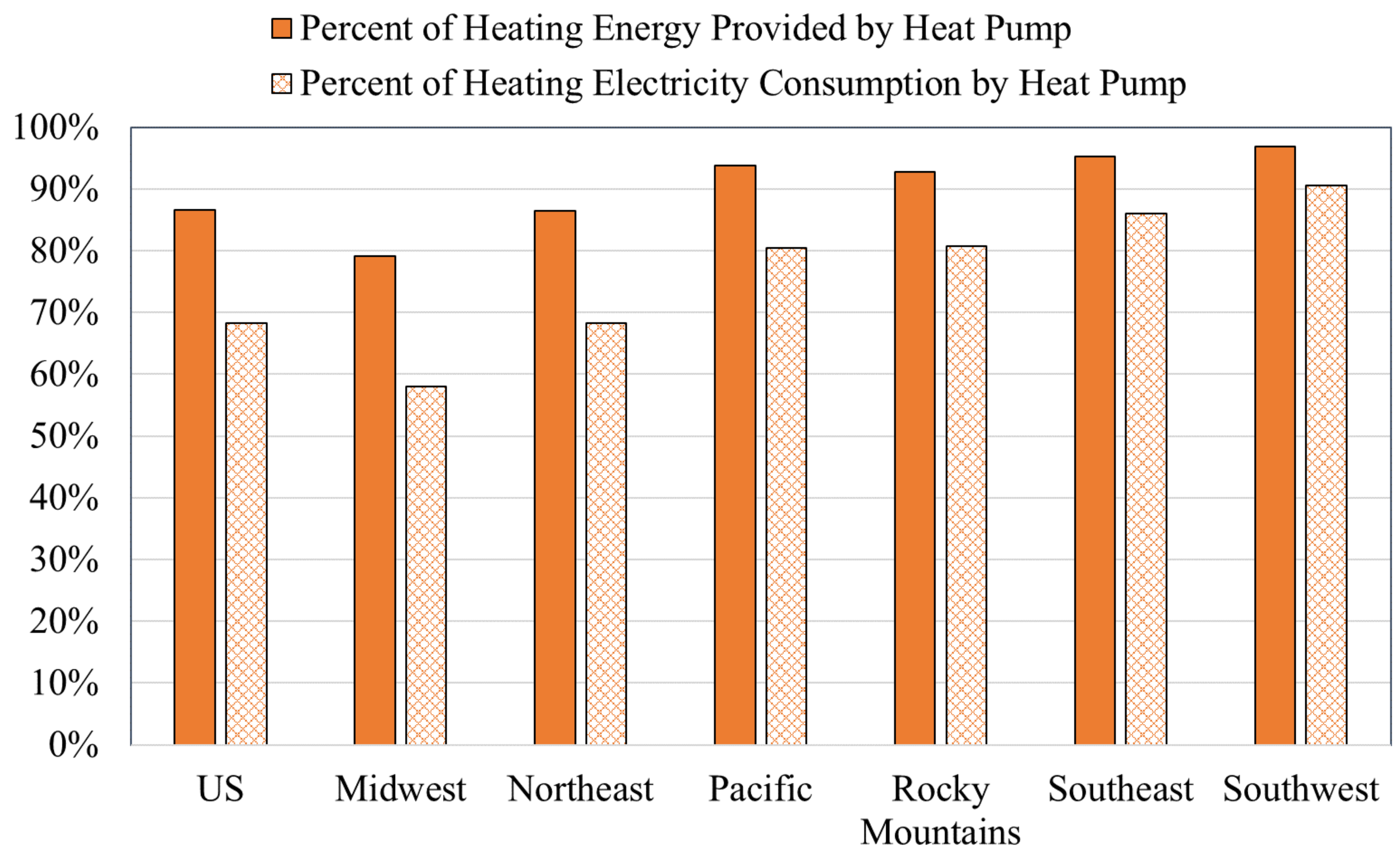
[8] Office of Energy Efficiency & Renewable Energy, "Residential HVAC Installation Practices: A Review of Research Findings," U.S. Department of Energy, 2018.

Heat Pump vs Electric Resistance

Percent of heating provided by heat pump with remainder provided by electric resistance strip heat



2006 Construction



2018 Construction

Long-Range Marginal Emissions Rate for End-Use Electricity

- NREL Cambium Data long-run marginal emission rate (LRMER) [9] [10]
- Hourly forecast from 2020-2050 by State
- LRMER calculated from the mixture of generation that would serve a persistent change in end-use demand, taking into account structural changes to the grid in response to the change in demand. [9]
- Significantly lower than the short-run marginal emissions rate, which calculates emissions for a change in a load for the *existing* grid.
- Conservative forecast based on state level legislation passed as of June 30, 2020 [11]
- Applied the low-cost renewable scenario, reflective of policies that encourage additional renewables [11]

[9] P. Gagnon, W. Frazier, E. Hale and W. Cole, "Cambium Documentation: Version 2020," National Renewable Energy Laboratory, Golden, CO, 2020.
[10] National Renewable Energy Laboratory, "Cambium," [Online]. Available: https://www.nrel.gov/analysis/cambium.html. [Accessed 3 2 2020].
[11] W. Cole, S. Corcoran, N. Gates, T. Mai and P. Das, "2020 Standard Scenarios Report: A U.S. Electricity Sector Outlook," National Renewable Energy Laboratory, Golden, CO, 2020.

15-Year Average: Long-Range Marginal Emission kg C02/Mwh End Use

Long-Run Marginal End-Use Emissions Forecast Averaged over 15-years [kg C02/MWh]

		Pacific			Rocky Mountains						Southwest				Midwest											
	State	CA	OR	WA	CO	ID	MT	NV	WY	UT	AZ	OK	NM	TX	IL	IN	IA	KS	OH	MI	MN	MO	NE	ND	SD	WI
15-Year Period	2020-2035	104	117	122	390	209	249	225	485	451	324	321	438	336	271	435	368	282	423	334	272	382	347	434	391	377
	2022-2037	85	105	108	331	178	223	195	445	378	261	258	372	297	242	394	325	291	388	290	232	335	300	361	319	352
	2024-2039	80	88	91	333	177	228	181	439	396	225	254	311	285	231	368	319	337	363	308	225	330	289	343	290	331
	2026-2041	76	91	93	307	152	189	162	402	363	209	211	278	257	211	325	309	333	324	283	209	287	276	283	224	294
	2028-2043	74	93	95	296	160	177	161	393	366	203	161	253	242	209	310	288	308	293	301	181	257	262	255	181	268
	2030-2045	67	94	96	308	158	176	145	400	362	195	130	246	241	211	294	313	312	277	310	201	262	262	274	181	258
	2032-2047	59	93	91	287	147	162	141	380	332	189	119	236	240	199	274	335	326	268	294	222	256	268	294	168	263
	2034-2049	57	97	90	309	132	151	126	368	290	180	96	219	233	213	261	331	339	252	273	213	254	263	274	139	283

		Northeast											Southeast											
	State	CT	DE	MA	MD	ME	NH	NJ	NY	PA	RI	VT	AL	AR	FL	GA	KY	LA	MS	NC	SC	TN	VA	WV
15-Year Period	2020-2035	144	229	100	224	147	43	169	136	333	100	35	481	333	348	342	439	329	369	311	313	323	150	343
	2022-2037	123	203	74	205	130	35	157	108	312	81	4	456	303	325	336	380	292	334	292	286	269	115	313
	2024-2039	122	209	69	215	128	33	165	111	317	81	3	454	302	290	298	382	282	333	279	246	288	123	273
	2026-2041	115	195	72	204	117	29	154	105	278	83	4	419	268	247	244	332	262	303	250	218	248	123	238
	2028-2043	114	179	71	199	113	22	167	114	240	80	7	407	249	226	229	291	253	275	229	206	236	108	224
	2030-2045	111	189	73	208	109	21	186	122	250	87	9	404	242	225	223	278	258	270	238	211	252	110	232
	2032-2047	107	181	60	193	101	22	186	118	230	84	10	400	248	233	214	296	268	276	229	211	250	103	241
	2034-2049	113	172	65	205	99	27	178	121	210	87	11	365	238	210	181	299	256	259	211	214	250	107	240

Legend - Average kg C02/Mwh End-Use

100	200	300	400	500

CO2 Emissions from Natural Gas

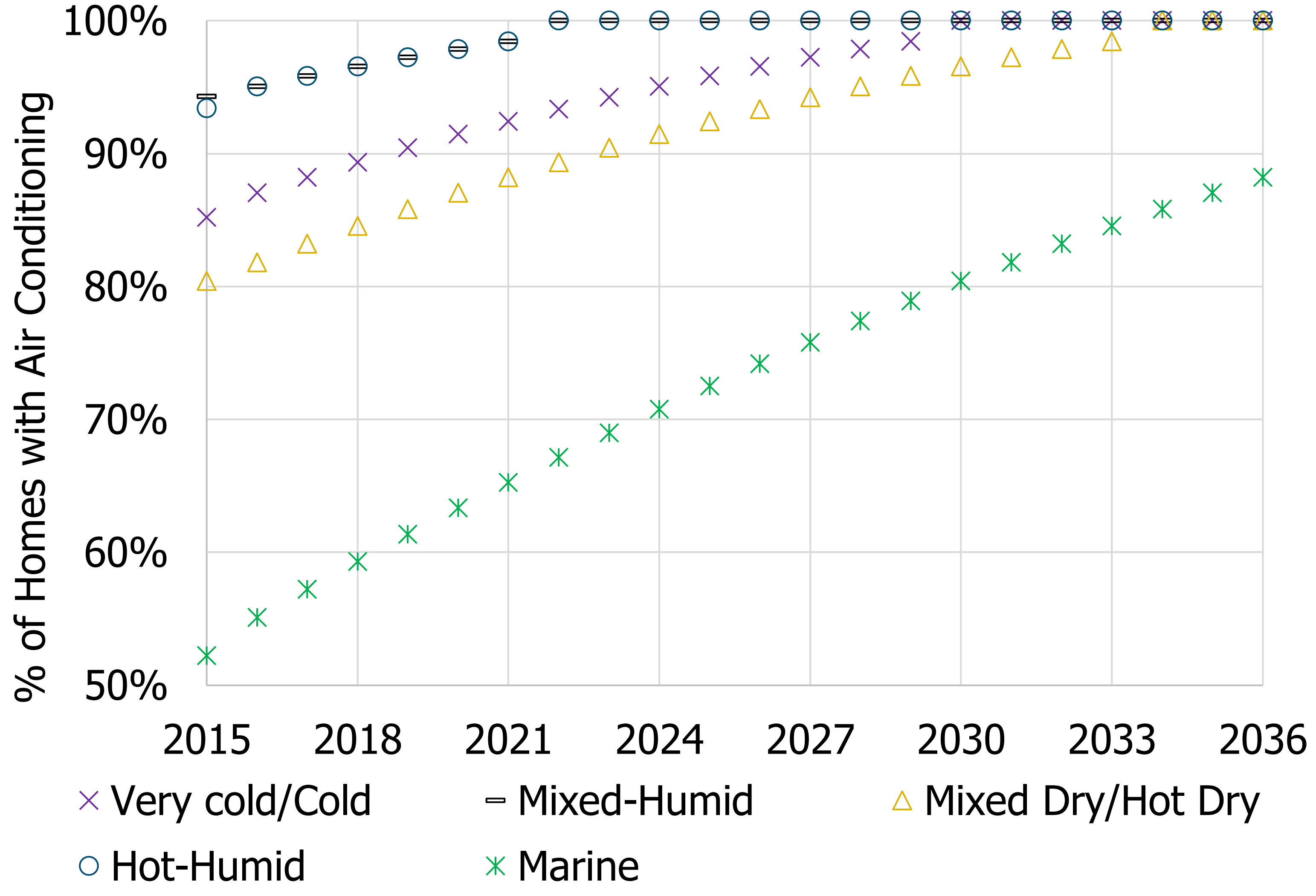
- 5.03 x 10^{-8} kg C02 per Joule natural gas burned [12]

[12] U.S. Energy Information Administration, "Natural gas explained," 24 9 2020. [Online]. Available: https://www.eia.gov/energyexplained/natural-gas/natural-gas-and-the-environment.php#:~:text=Natural%20gas%20is%20a%20relatively,an%20equal%20amount%20of%20energy.. [Accessed 3 2 2021].

Air Conditioner (AC) Adoption by Climate

- » Account for refrigerant leaks for the fraction of homes not expected to otherwise have AC as well as additional charge required for heat pumps
- » AC adoption forecast from 2015 data [13]
- » Forecast increased adoption over time in all regions based on adoption rate in South which has nearly 100% penetration [14]

Heat Pump Adoption	DOE/2015
Very cold	85.2%
Cold	85.2%
Mixed-Humid	94.3%
Mixed-Dry	79.5%
Hot-Dry	79.5%
Hot-Humid	93.4%
Marine	52.2%



[13] U.S. Energy Information Administration, "Residential Energy Consumption Survey. Table HC7.6 Air conditioning in U.S. homes by climate region, 2015," 05 2018. [Online]. Available: https://www.eia.gov/consumption/residential/data/2015/hc/php/hc7.6.php. [Accessed 8 2 2021].

[14] U.S. Energy Information Administration, "Residential Energy Consumption Survey: Air conditioning in nearly 100 million U.S. homes," 19 08 2011. [Online]. Available: https://www.eia.gov/consumption/residential/reports/2009/air-conditioning.php. [Accessed 8 2 2021].

Refrigerant Leak Amounts/GWP

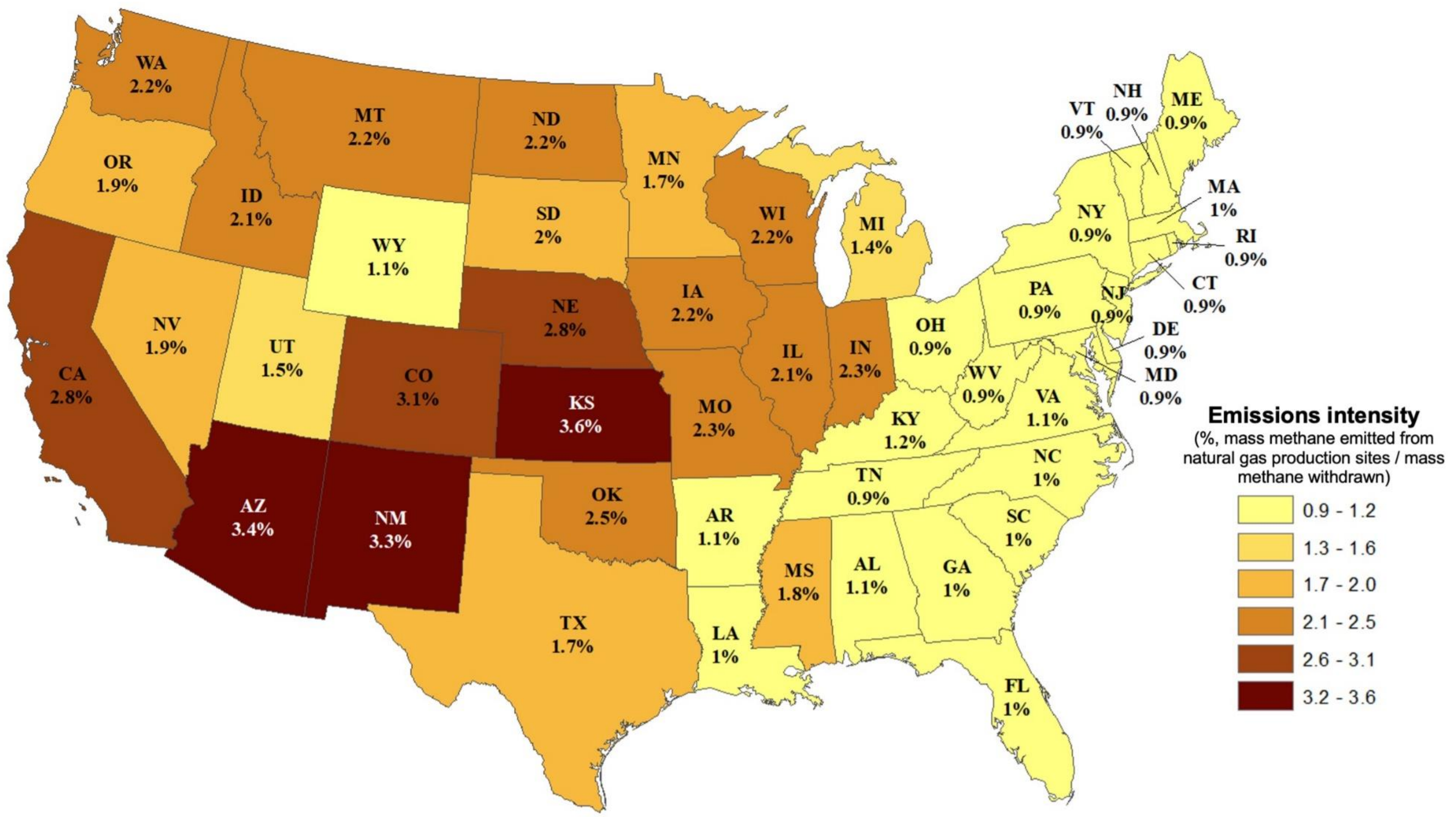
- Refrigerant amount
  - 0.28 kg/kW cooling capacity in AC
  - 0.34 kg/kW cooling capacity in HP
- Refrigerant charge based on Trane split systems (3, 4, 5 ton) with 14, 16, and 18 SEER ratings
- Annual Refrigerant Emissions Rate (%)=$7.5e^{-.045t}$ [16]
  - Where t is the number of years after 2020.
  - Includes all emissions (including end of life)
- Leak rate is not a function of refrigerant type
- Assume R-410A used until 2025
- Assume R-32 used 2026 and later

[15] F. Poggi, H. Macchi-Tejeda, D. Leducq and A. Bontemps, "Refrigerant charge in refrigerating systems and strategies of charge reduction," International Journal of Refrigeration, vol. 31, pp. 253-370, 2008.
[16] United States Environmental Protection Agency, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018," 2020.

Methane Leak Amount/GWP

- Methane Emissions [17] [18]
  - 0.9-3.6% Production emissions by State (Georgia Tech)
  - 0.5% (post-meter, leaks, incomplete combustion, pilots) (CEC)
  - Transmission and local distribution not included
  - Total – 1.4 - 4.1%
- Emissions from production applied to natural gas used for furnace and end-use electricity production
- Applied to all natural gas used over 15-year period

Estimated consumption-normalized production-stage methane emissions for natural consumed in each state



Diana Burns *et al* 2021 *Environ. Res. Lett.* in press https://doi.org/10.1088/1748-9326/abef33

[17] R. A. Alvarez and et al, "Assessment of methane emissions from the U.S. oil and gas supply chain," Science, vol. 361, pp. 186-188, 2018.
[18] M. Fischer, W. Chan, S. Jeong and Z. Zhu, "Natural Gas Methane Emissions from California Homes," California Energy Commission, Sacramento, 2018.

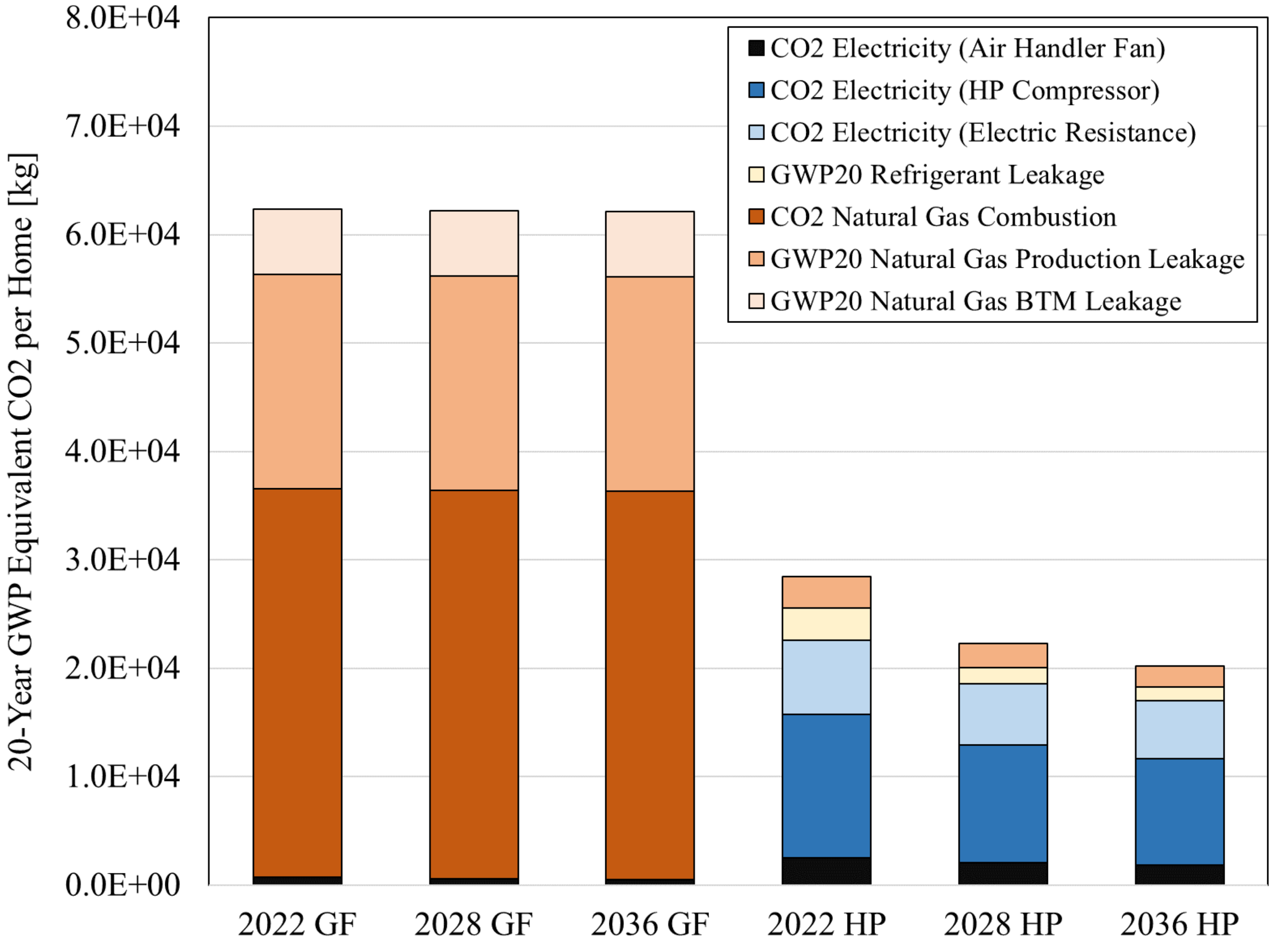
Natural Gas Used by Power Plants

- Hourly Cambium data forecasts fraction of electricity generated by three natural gas power plant configurations
- Average efficiencies to each type applied
- Methane emissions for natural gas production leaks estimated for end-use electricity consumed each hour

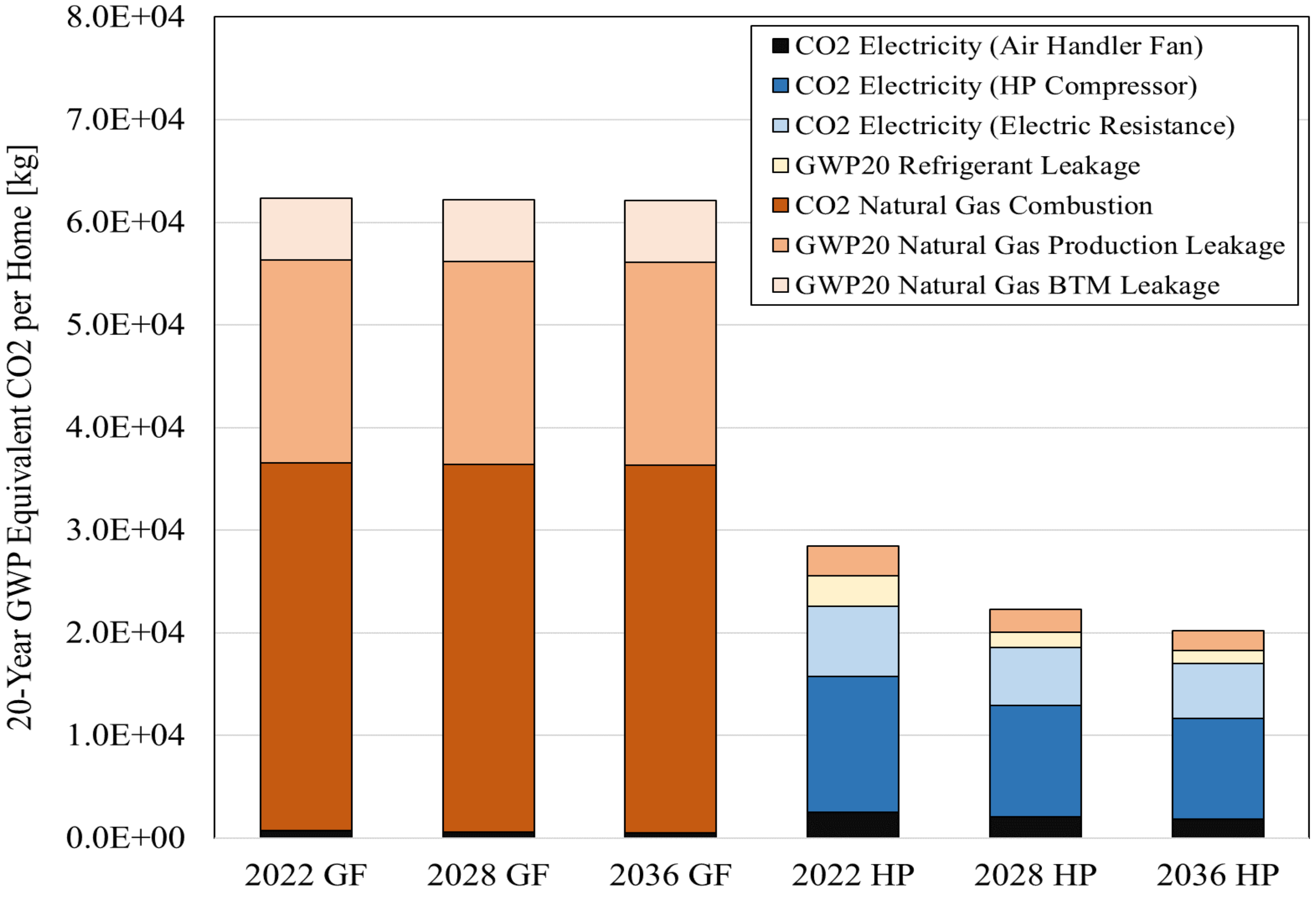
Natural Gas Power Plant Type	Modeled Efficiency
Combined Cycle	58%
Combined Cycle with Carbon Capture and Storage	49%
Combustion Turbine	35%

https://www.sciencedirect.com/science/article/pii/S0360128505000626
https://www.sciencedirect.com/science/article/pii/B978184569728050001X
https://www.sciencedirect.com/science/article/pii/B9780857094155500147
https://www.energy.gov/sites/prod/files/2016/09/f33/CHP-Gas%20Turbine.pdf

US Average – 20-Year Global Warming Potential (GWP)

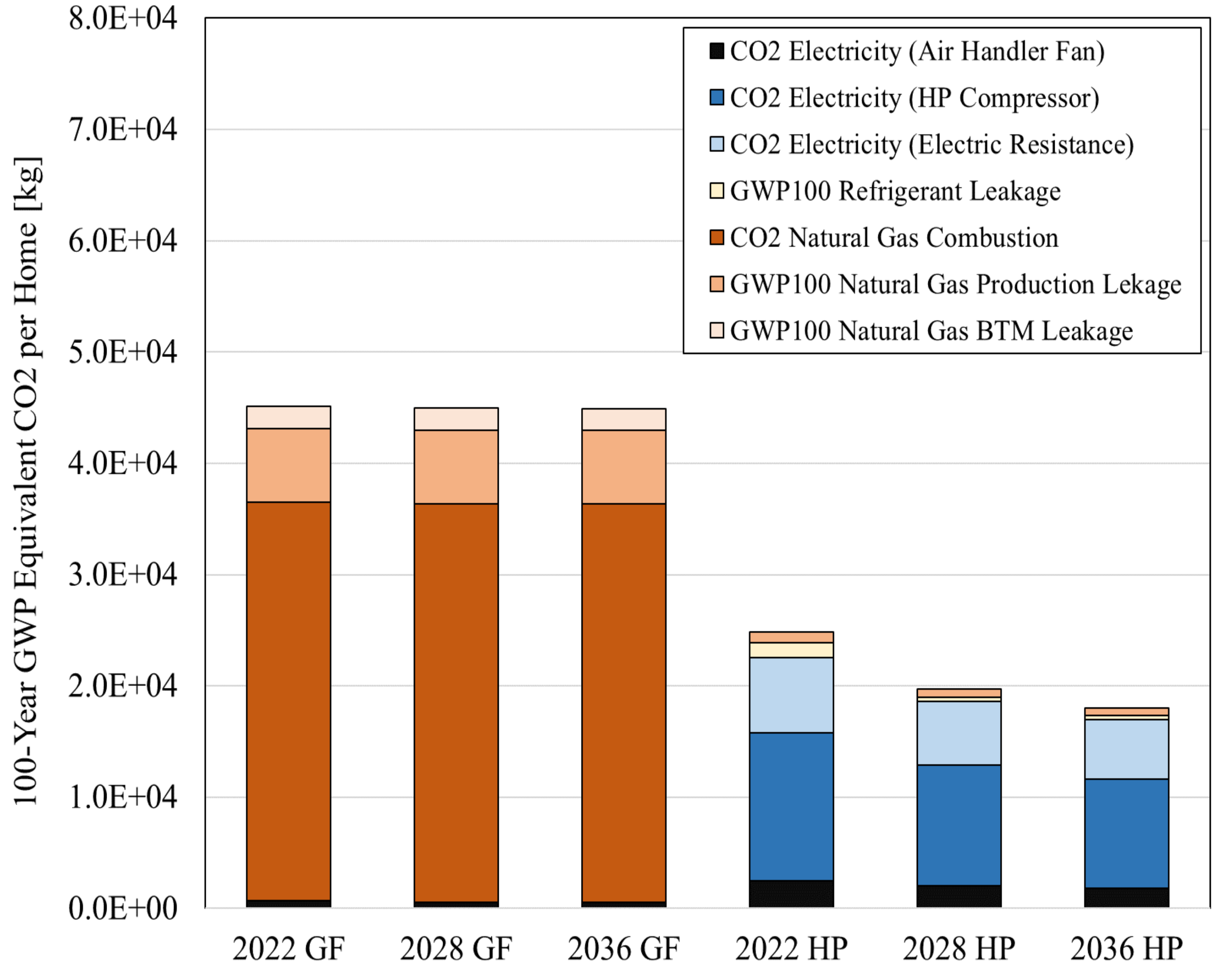


2006 Construction

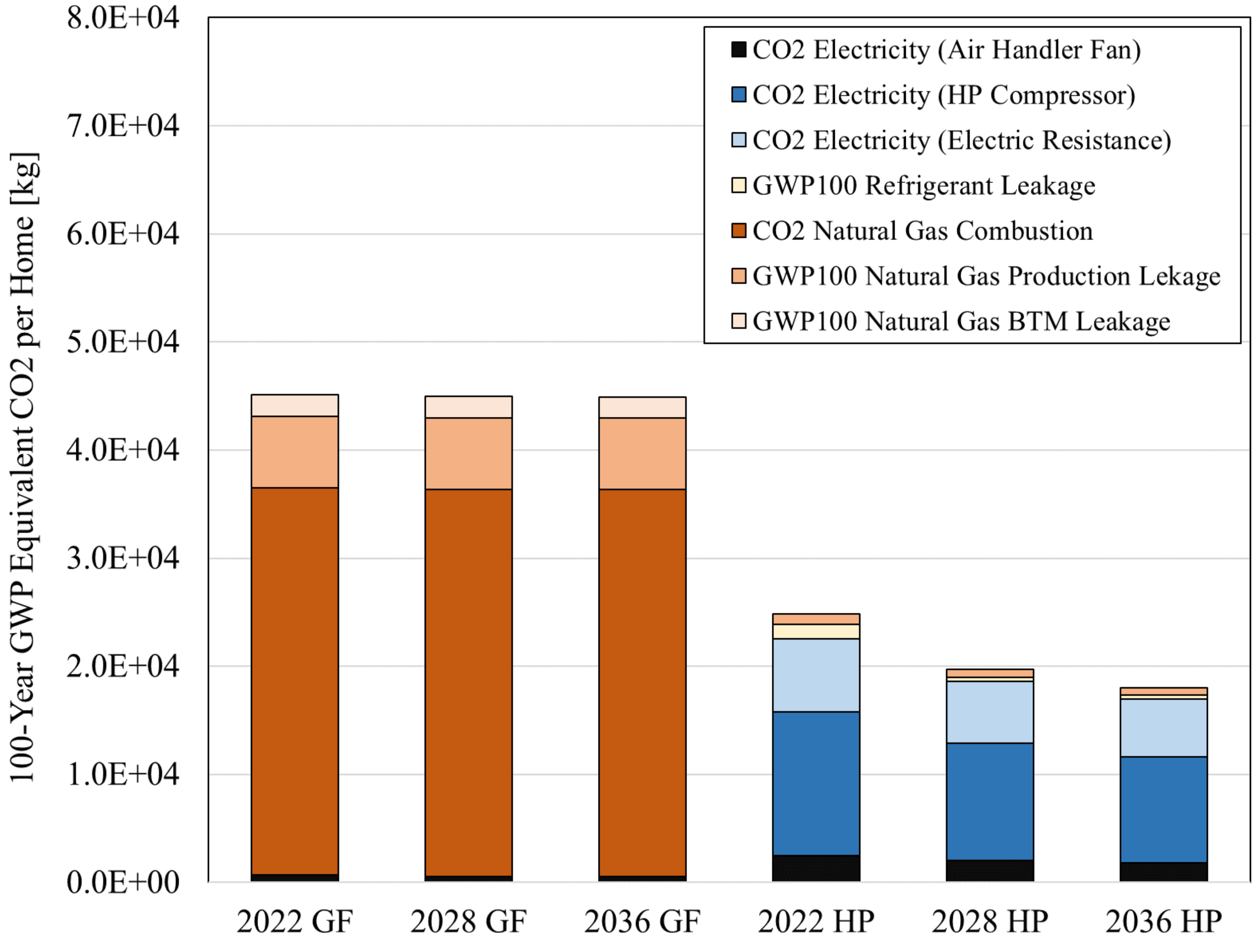


2018 Construction

US Average – 100-Year Global Warming Potential (GWP)



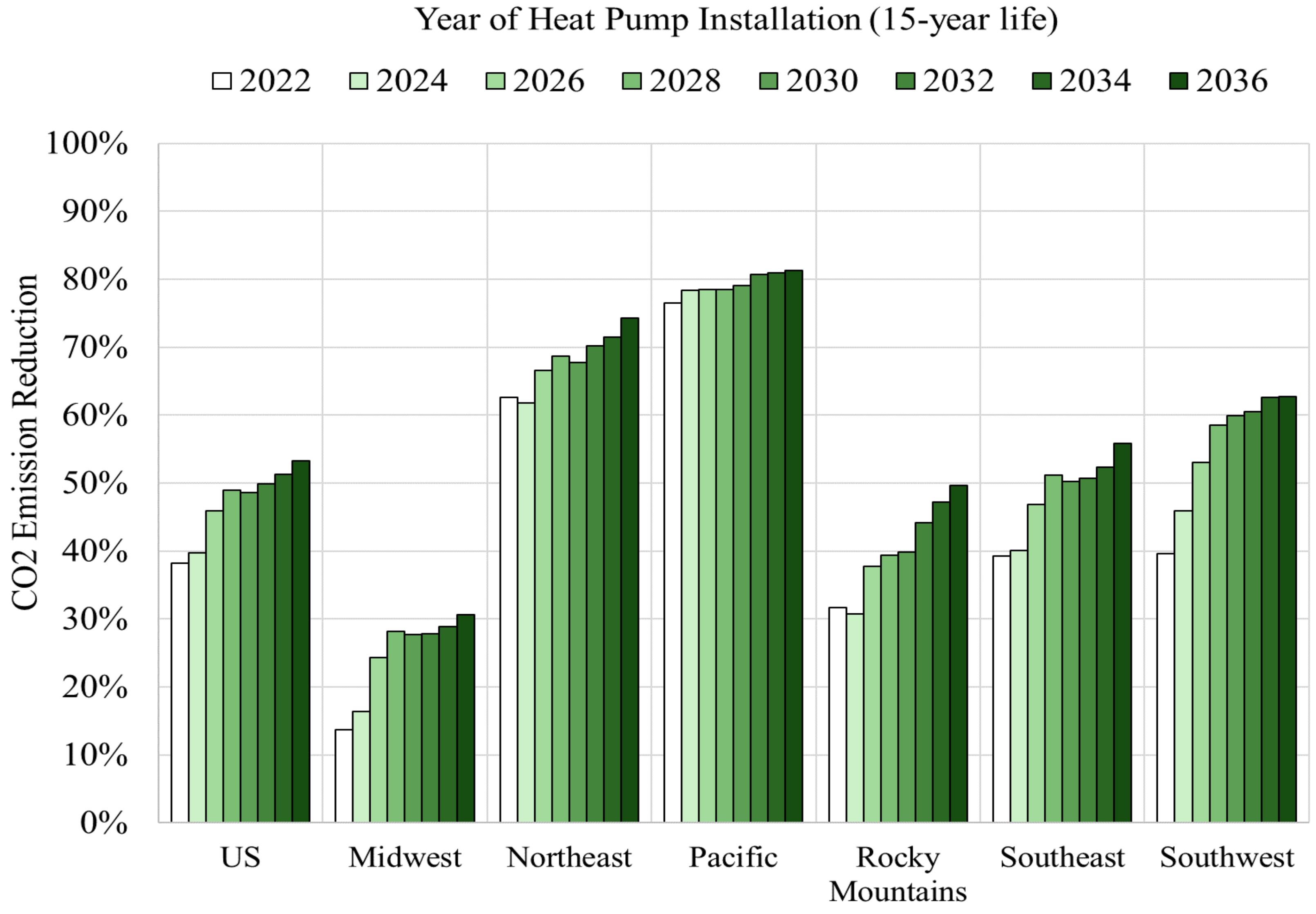
2006 Construction



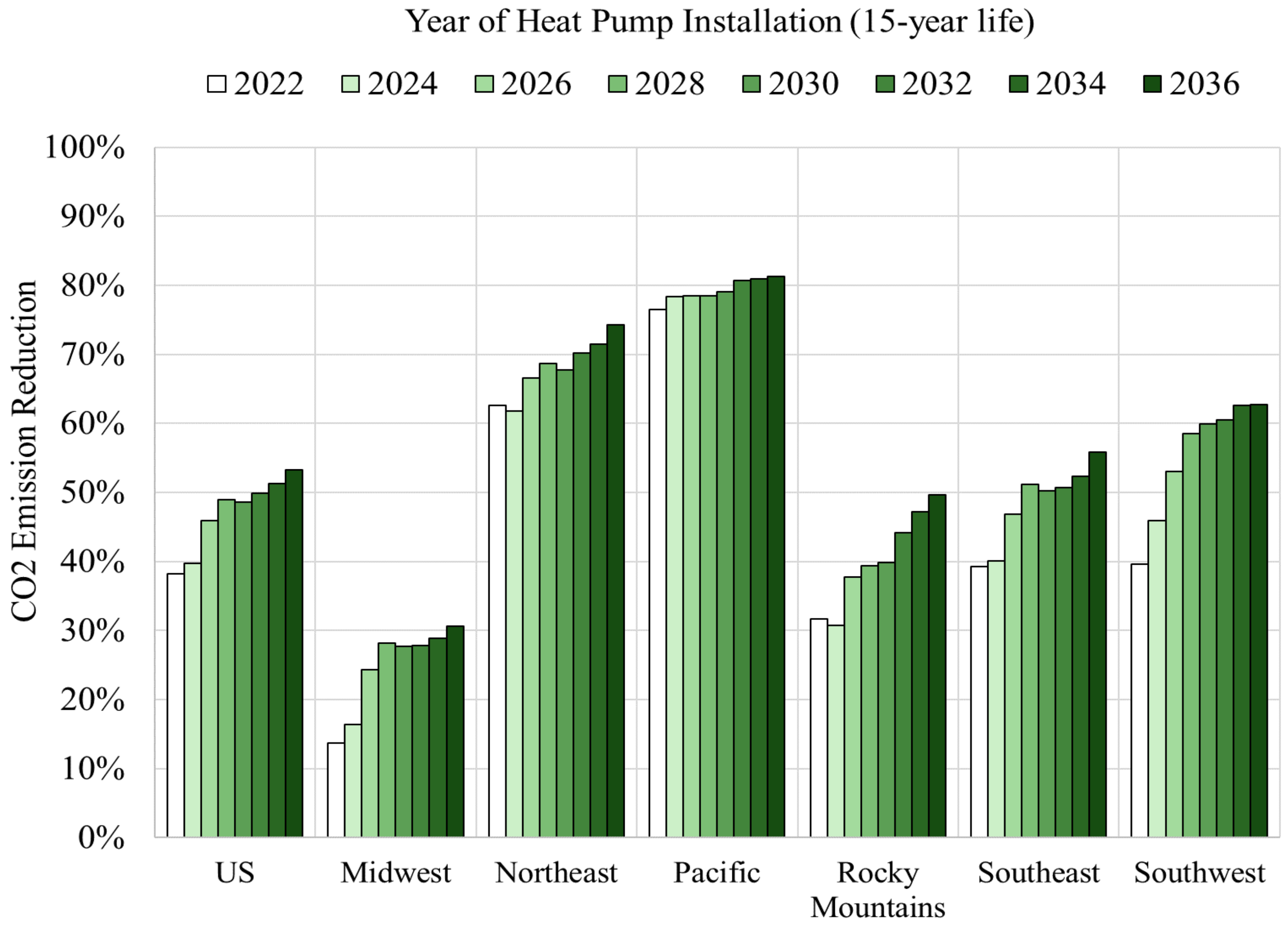
2018 Construction

C02 Emission Reduction % by Region

Does not include methane and refrigerant leakage

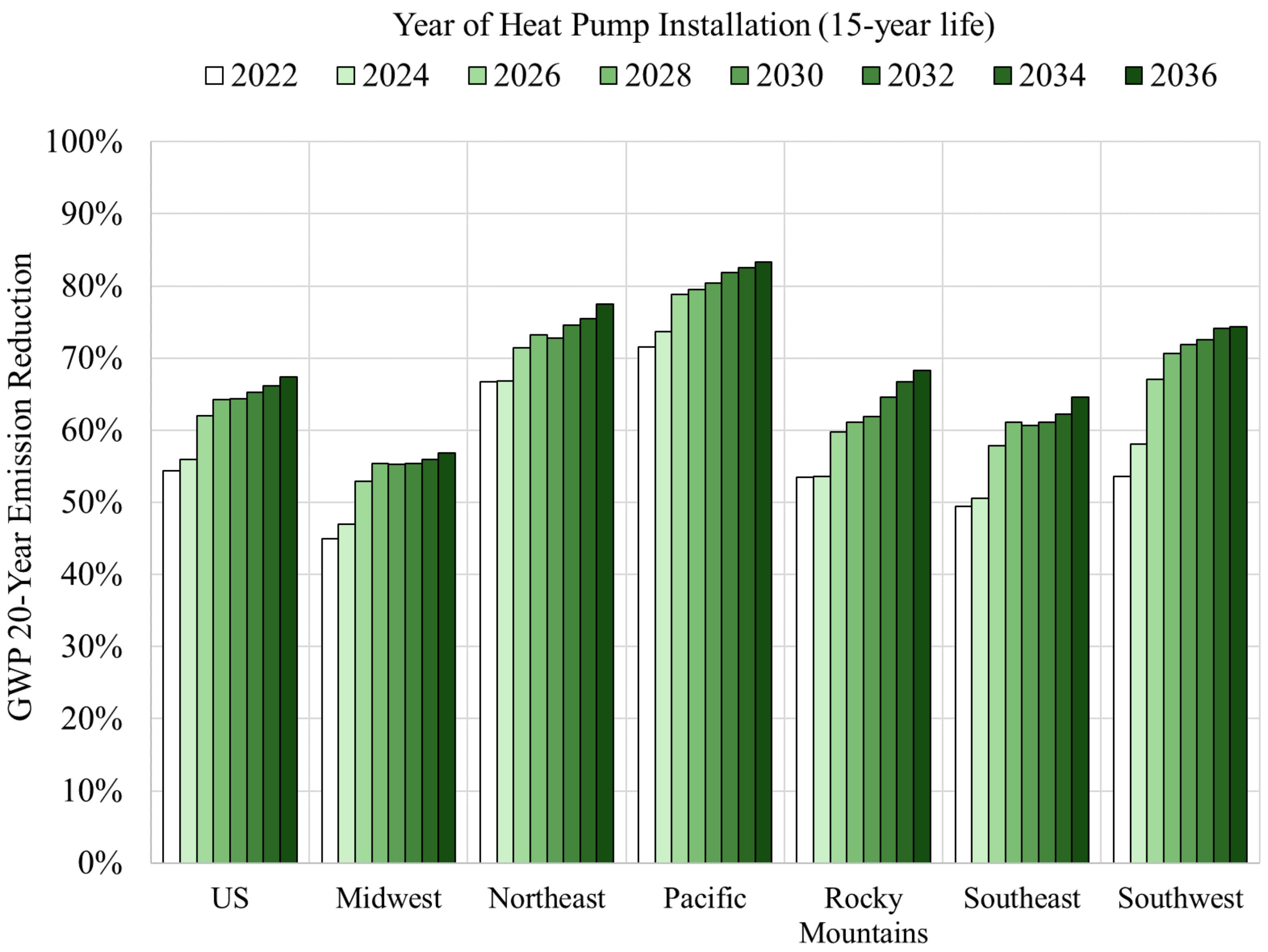


2006 Construction

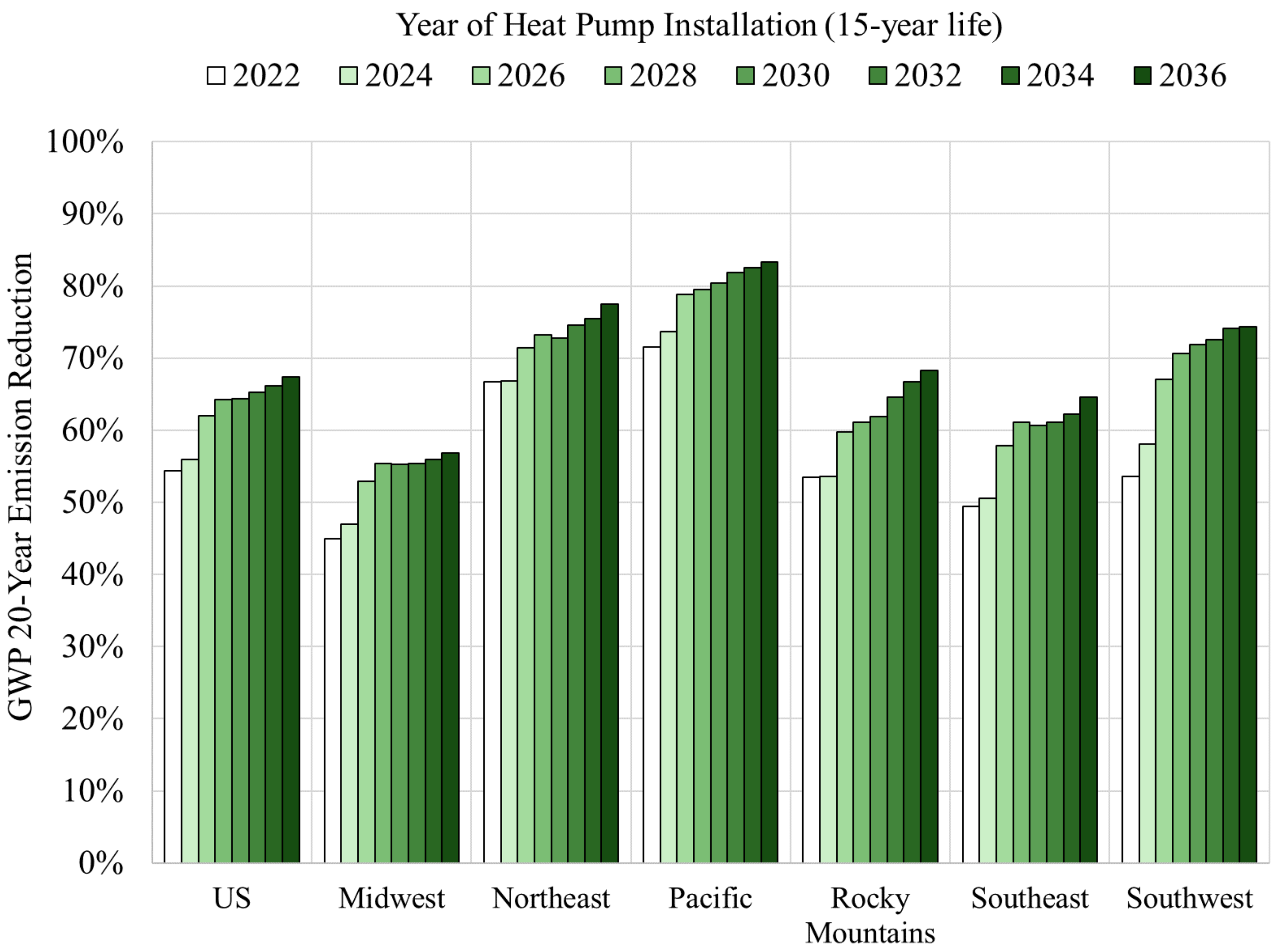


2018 Construction

GWP20 Emission Reduction % by Region

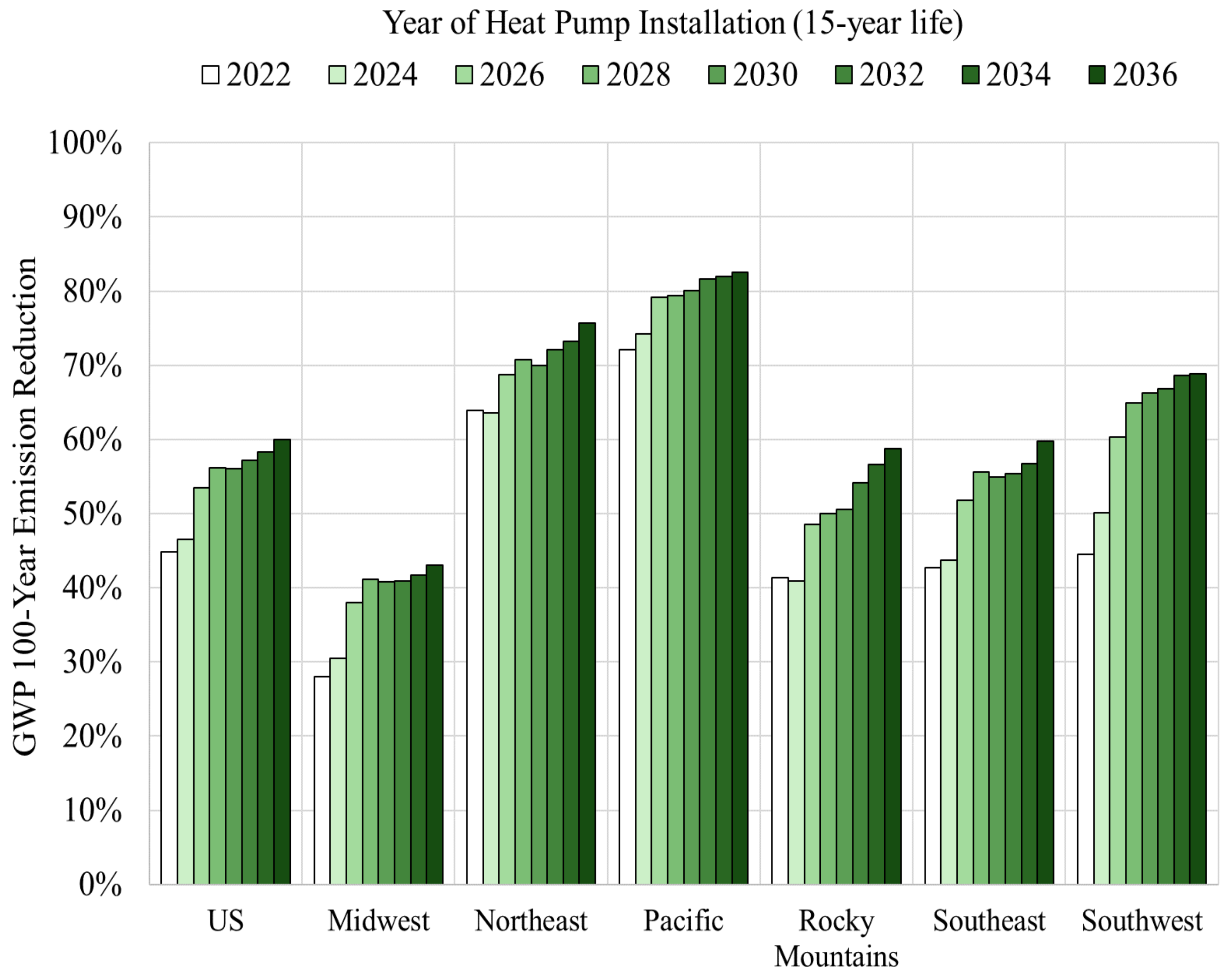


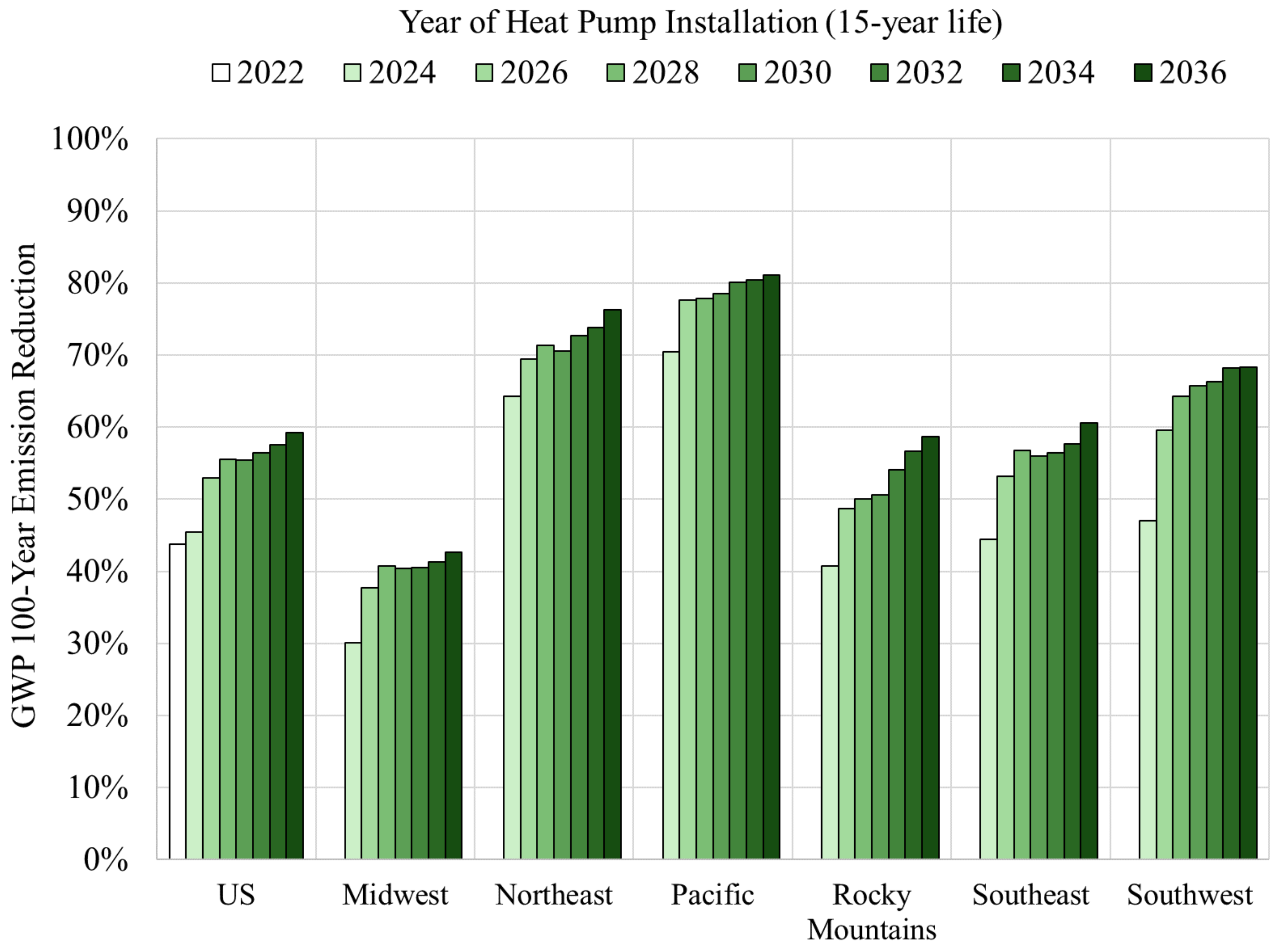
2006 Construction



2018 Construction

GWP100 Emission Reduction % by Region





Discussion and Limitations

» Significant emissions reductions forecasted in all regions
  - Regional averages may not apply to smaller cities – full data tables for all 99 cities will be made available

» Results are highly sensitive to forecasted emissions for end-use electricity generation (i.e. long-range vs short-range)

» Improvements to heat pump controls (load-shifting) would improve emissions reductions

» Heat pump vs air conditioner refrigerant charge widely varies and is not currently optimized by manufacturers

» Operational costs over lifetime have not been analyzed

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