ELECTRIC HEAT PUMP WATER HEATER PERFORMANCE SIMULATION

NRDC

PIERRE DELFORGE

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Research Question

Significant questions/confusion about heat pump water heater (HPWH) performance:

- Has evolved dramatically over last 10 years
- Varies by air and water temperature, tank size, technology, installation location…

➢ **What performance should policy makers expect from HPWH?**

Project Overview

Inputs

- 50-state TMY data
- Water draw profiles

Simulation

- HPWHsim* (HPWH performance model)
- SEEM (whole house energy model)

Outputs

- Annual coefficient of performance (aCOP)
  - By state / CA climate zone
  - By tank size
  - By household size
  - By technology

HPWHsim Validation:
https://github.com/EcotopeResearch/HPWHsim/blob/master/Documentation/updatedCalibrationReport.docx

Project Overview

Water Heater Type	Details
Conventional electric resistance (baseline)	• **Generic electric resistance** (ER) • EF=0.96 • 50 gal. and 80 gal.
Hybrid heat pump	• **GE GeoSpring 2014**, EF=3.25 • 50 gal. and 80 gal. tank sizes • Hybrid HP-ER • Unitary form factor
Pure heat pump	• **Sanden SanCO2 2016**, EF=3.35 • 39.6 gal. and 83.2 gal. tank sizes • CO2 refrigerant, pure HP • Split system

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Project Overview

Water Heater Type	Details	Modeled Installation Locations			
		Indoor	Garage	Basement	Outdoor
Conventional electric resistance (baseline)	• **Generic electric resistance** (ER) • EF=0.96 • 50 gal. and 80 gal.	✓			
Hybrid heat pump	• **GE GeoSpring 2014**, EF=3.25 • 50 gal. and 80 gal. tank sizes • Hybrid HP-ER • Unitary form factor		✓	✓	✓
Pure heat pump	• **Sanden SanCO2 2016**, EF=3.35 • 39.6 gal. and 83.2 gal. tank sizes • CO2 refrigerant, pure HP • Split system	✓ (tank)			✓ (evaporator)

* Did not model hybrid HPWH indoor due to interactive effects with HVAC

More on Methodology

- **Typical Meteorological Year (TMY)**:
  - Simulations run for all TMY locations, then aggregated by population across each state (and by climate zone in CA)
- **Water draw profiles**:
  - Representative weekly draw profiles with event clusters, from NEEA HPWH validation study (100 households)
  - Specific to household size (1 to 5+)
  - Scaled down to CA building code draws for drought states (CA, AZ, NM, NV)
- **3 temperature variables:**
  1. Evaporator air temperature
  2. Tank air temperature (different for split system)
  3. Inlet water temperature (generated from outdoor air temperature, per NEEA HPWH validation study)
- **Tank set point**:
  - Default settings: 125F for GeoSpring, 149F for Sanden + mixing valve

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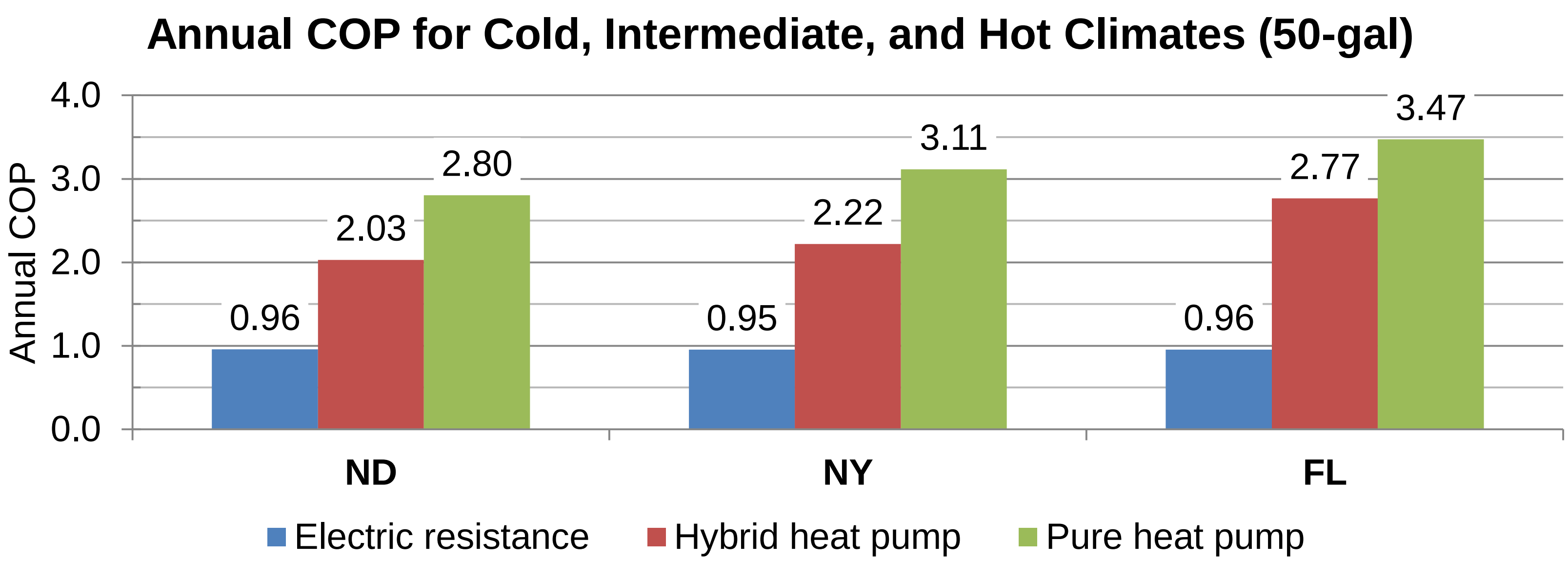
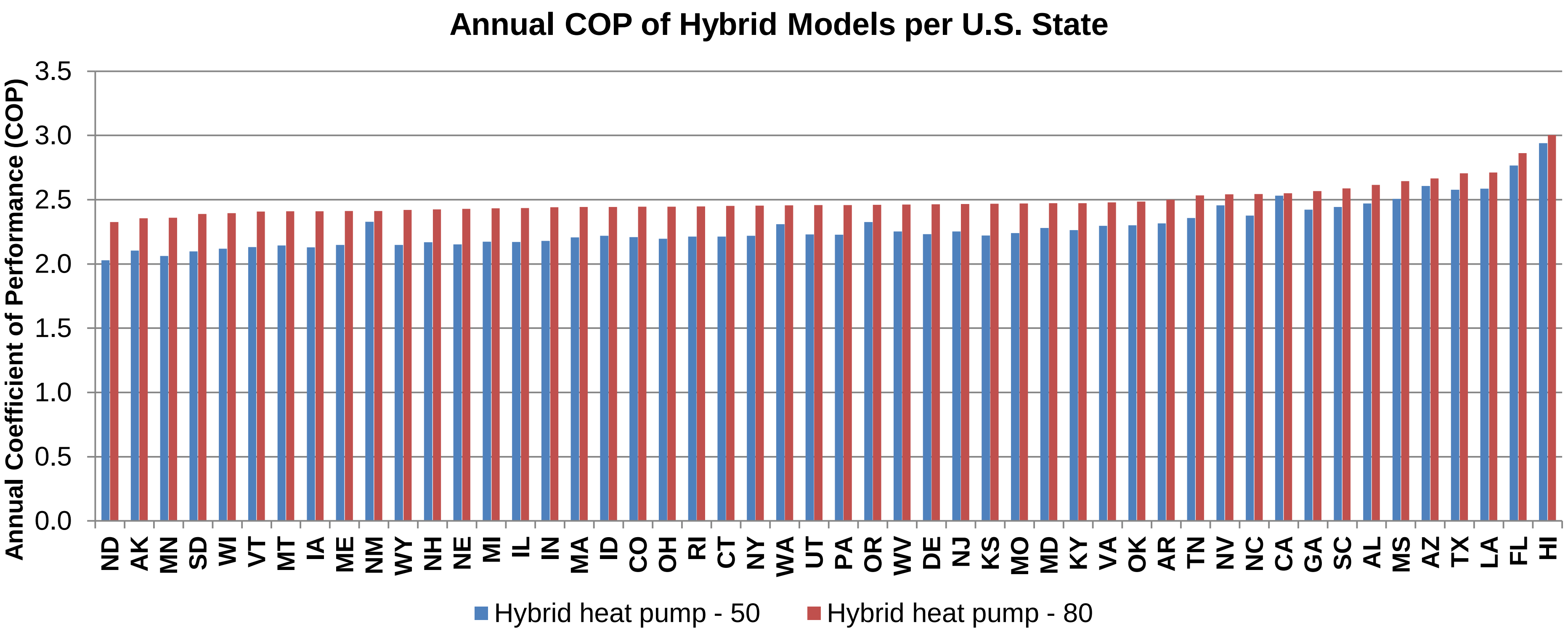
Key Findings



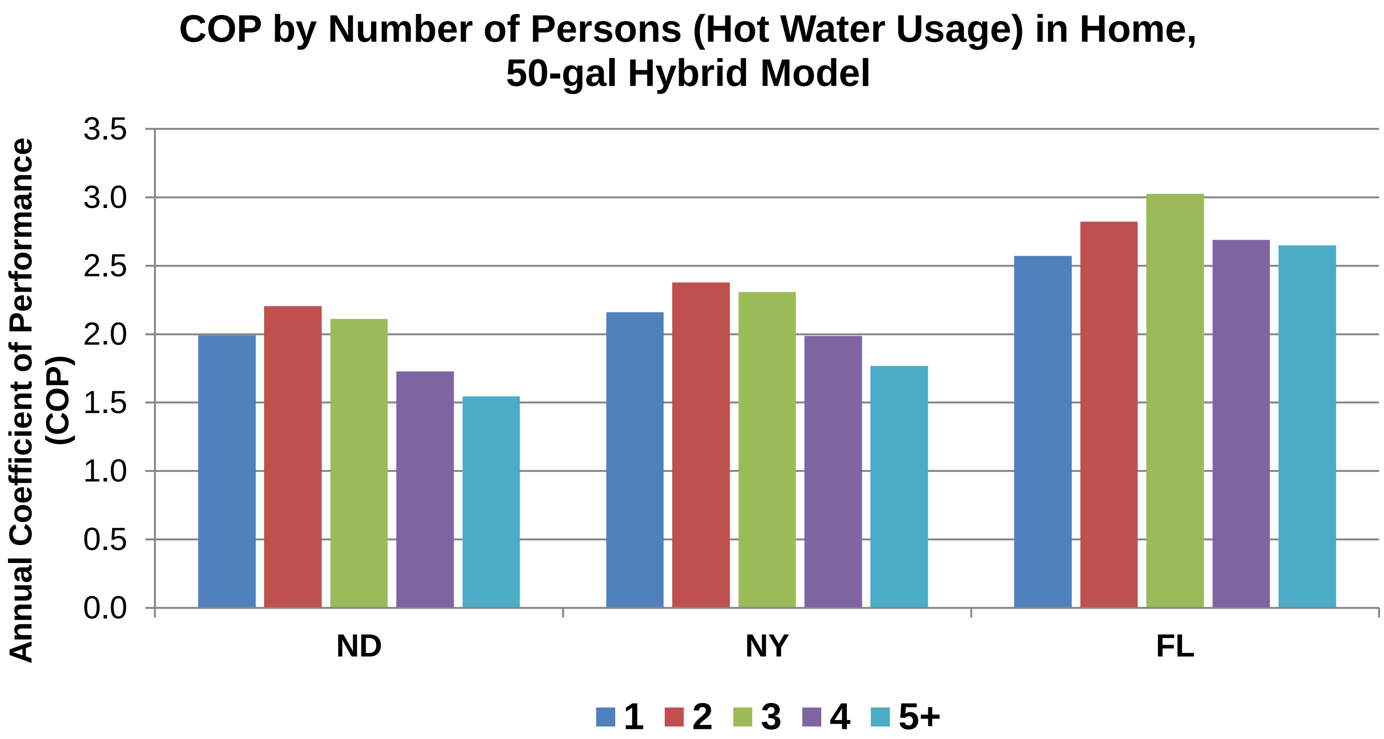
- Hybrid HPWH more than **2x** as efficient as electric resistance (ER) in coldest US climates, and up to nearly **3x** in warmest
- CO_2 heat pump **3x** to **3.5x** as efficient as ER
- Efficiency varies by household size, installation location, tank size

All 50 States, Hybrid Models



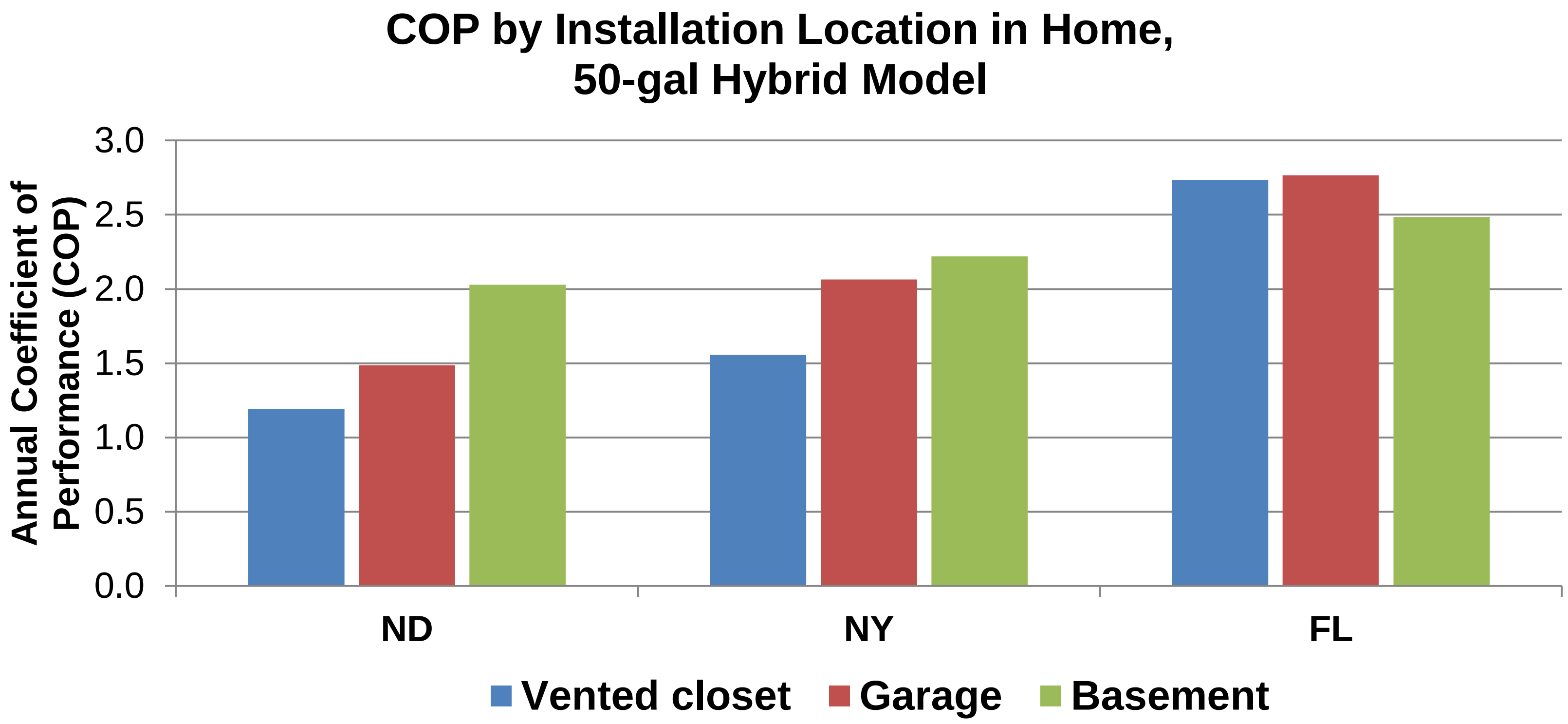
- Bigger is often better for HPWH, particularly in colder climates (and larger households)
- This chart is for all household sizes combined, best installation location for each state

Effect of Household Size (Hot Water Usage)



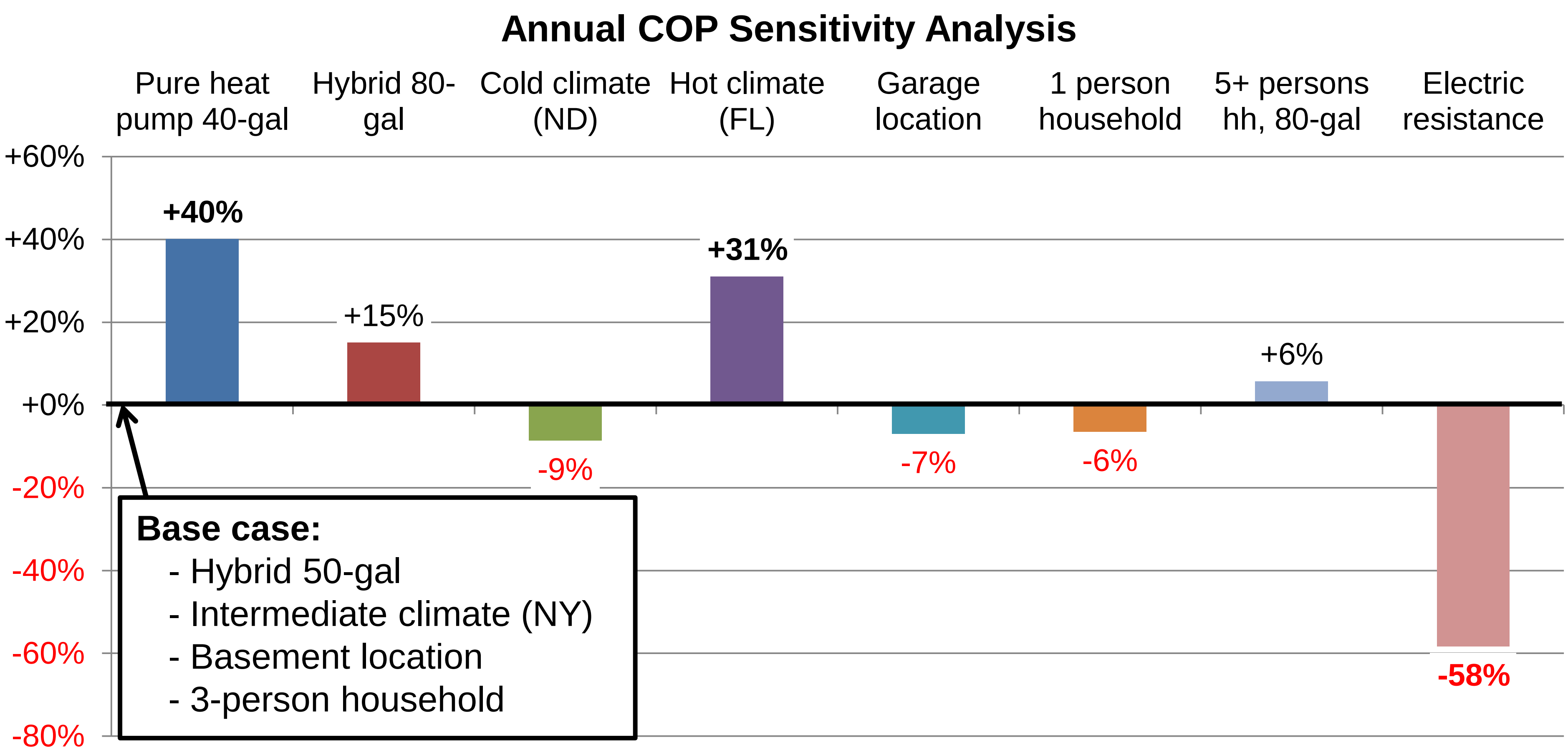
- Household size effects efficiency in two opposing ways:
  1. Increased use of electric resistance element by larger draws
  2. Increased relative standby losses for smaller draws

Effect of Installation Location



- Best installation location varies by climate:
  - Basements (unconditioned) are best in cold and intermediate climates
  - Vented closets and garages better in warm climates

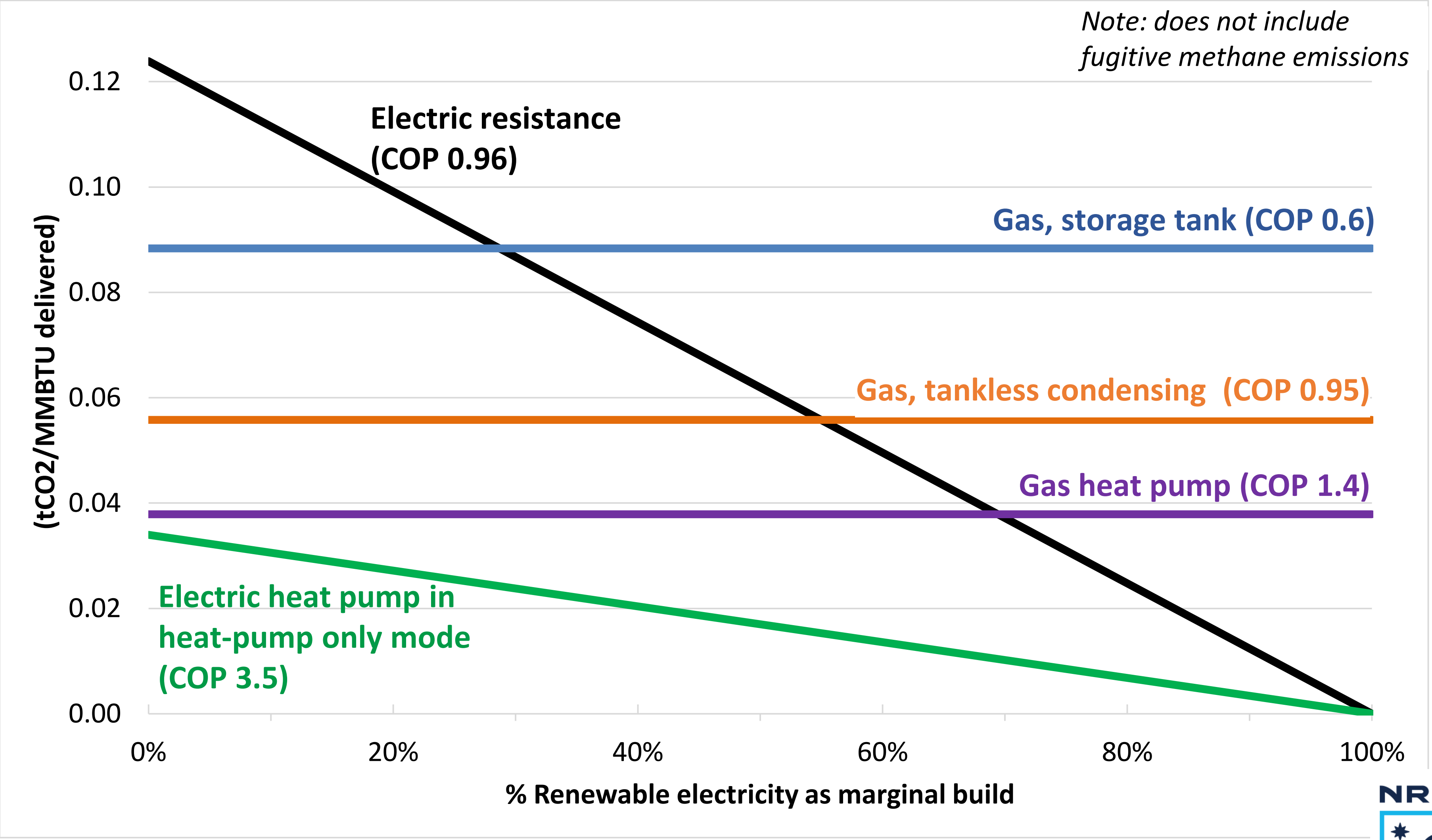
How Significant is Each Factor?



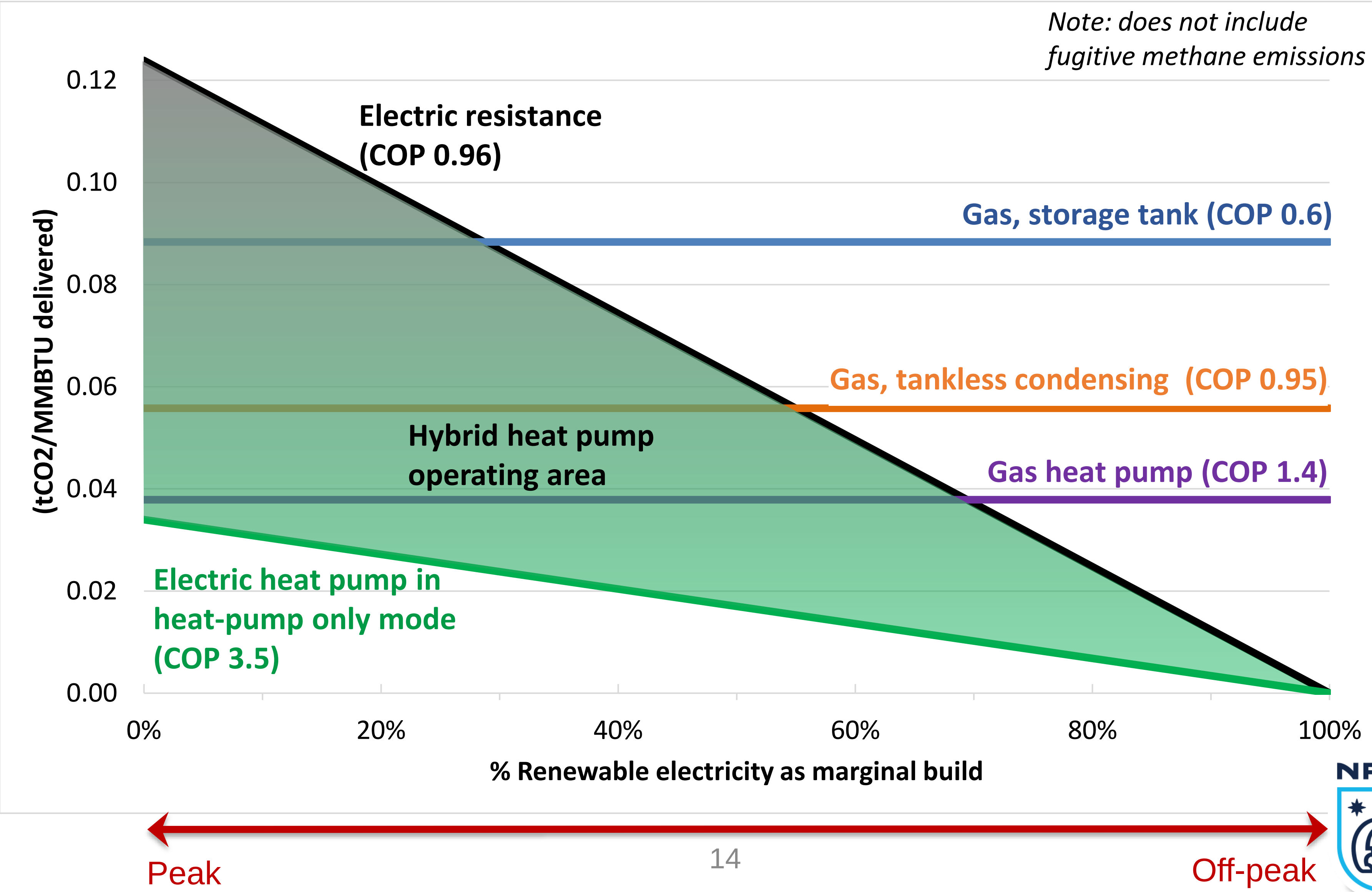
Limitations and Further Research Opportunities

- **Latest HPWH model** have a higher energy factor (3.5) than the 2014 GeoSpring used in this study (3.25)
- **Water draw profiles and inlet temperature** : improve accuracy
- **Superheating** (higher set point + mixing valve) would reduce use of electric resistance, but increase standby losses and affect heat pump efficiency. Needs further study.

How about gas water heaters?



Generally better, but it all depends on time of use (avoiding ER on peak) ➔ grid-connectivity is key!



THAN
K YOU! - QUESTIONS?

Full results and analysis available at https://www.nrdc.org/experts/pierre-delforge/very-cool-heat-pump-water-heaters-save-energy-and-money

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