# Energy modeling and analysis of dual fuel heating systems in single-family homes

## Gas emerging technologies program (GET)

ET23SWG005: Final Presentation for GET Outreach Event

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# Our Team

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# Agenda

- Introduction
- Research objectives
- Literature review and subject matter expert interview findings
- Energy models and methodology
- Annual operating cost vs emissions trade-off
- Simulation results: Hourly trends
- Parametric analyses
- Key parameter correlations
- Findings

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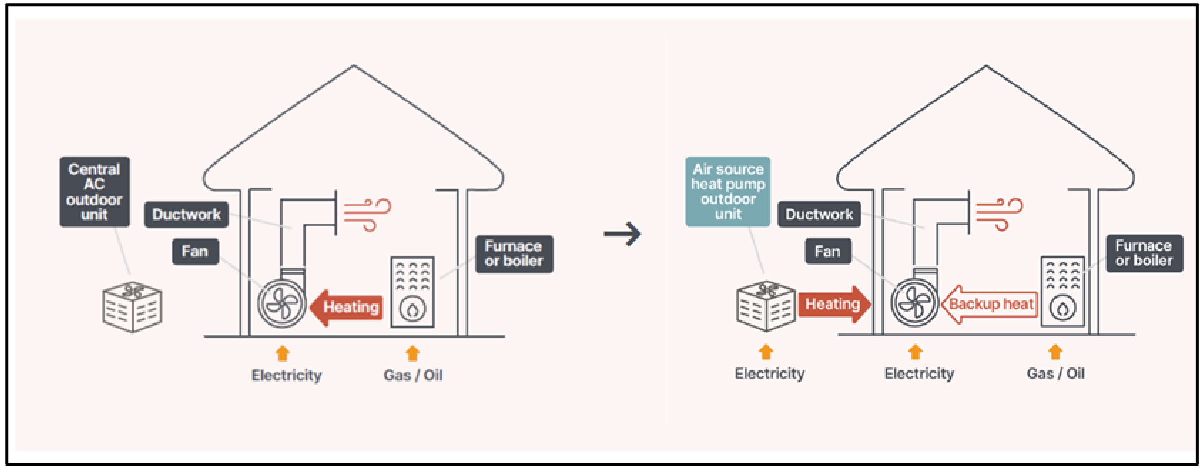
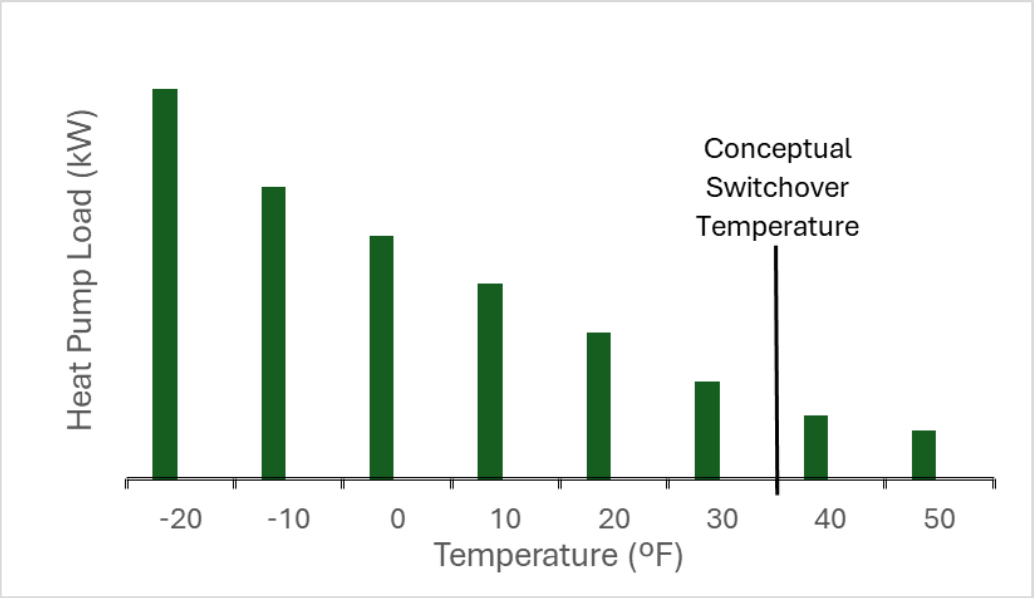
# Introduction: Dual fuel heating technology and configurations

- Introduction to dual fuel heating systems
- Configurations
- Switchover temperature and associated factors
- Emissions and economic balance point




House A: Central AC outdoor unit and gas furnace
House B: Air source heat pump and gas furnace




[1] Combating High Fuel Prices with Hybrid Heating, Report by CLASP and RAP, July 2022

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# Research objectives

- To determine the technical feasibility of dual fuel heating technology for single-family homes using EnergyPlus and spreadsheet analysis
- To determine the potential for emissions reduction from dual fuel space heating in single-family homes in California
- To analyze the impact of switchover temperature on total energy consumption and operating costs
- To determine the cost effectiveness of installing dual fuel heating system based on TRC and TSB tests (Metrics of cost effectiveness in CA)

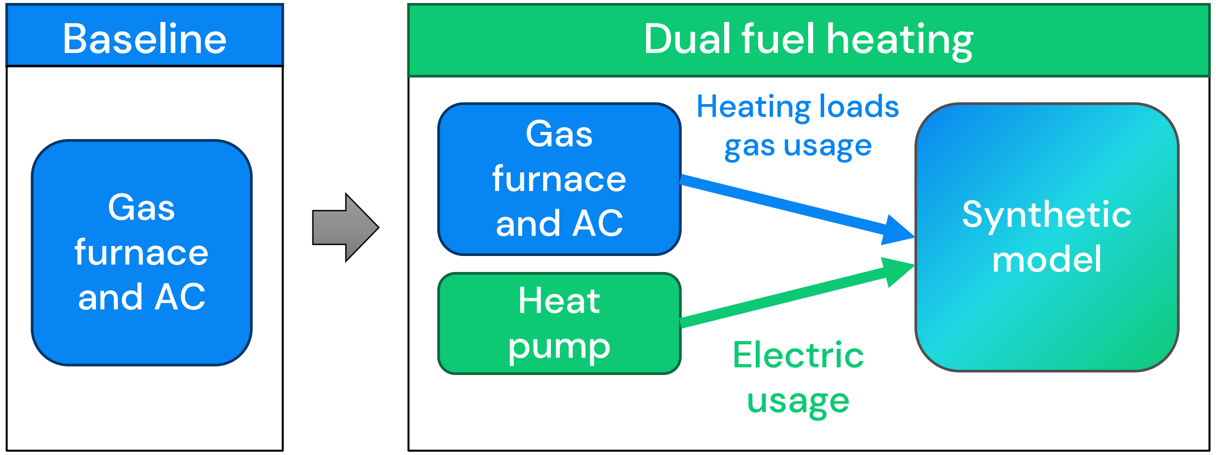
# Literature review and subject matter expert interview findings

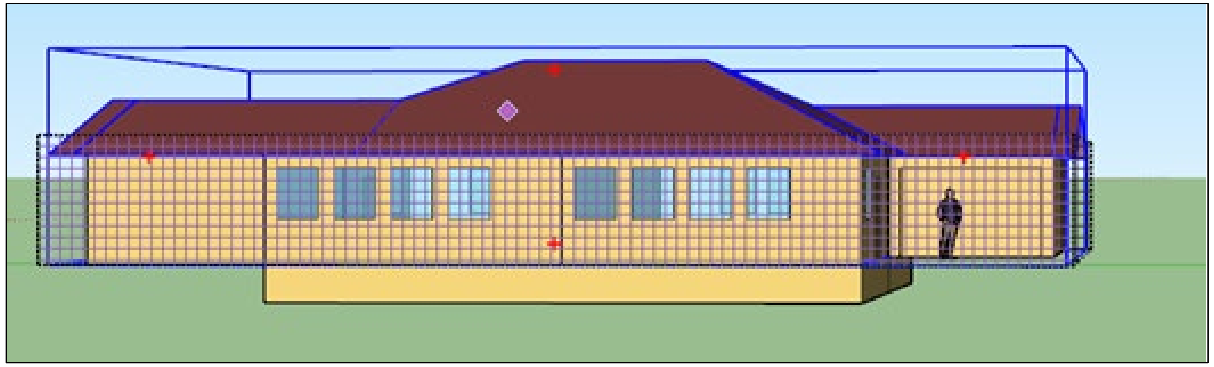
- About 47% of the U.S. homes are good candidates for retrofit of AC with a heat pump. (CLASP and RAP Report, July 2022)
- About 62% of the total homes in California have natural gas furnaces as their main heating equipment. (RECS Survey, 2020)
- Stronger market demand for dual fuel technology in residential sector. (NEEA Study 2023)
- Adoption of dual fuel heating systems is common in Northeast and Mid-Atlantic regions.
- Potential barriers of adoption of dual fuel technology.
- Pre-qualifications required for installing dual fuel heating systems.

# Energy models and methodology

- Synthetic model for dual fuel heating combines two otherwise identical models for gas furnace and heat pump
- Calculations are end-use specific, using time series outputs for heating and fans during heating mode

| Model assumption | Value |
|---|---|
| Building energy model | DEER EnergyPlus Single Family |
| Vintage | Median existing (circa 1975/1985 building energy code) |
| Size | Small (1-story / 1,400 ft$^2$) |
| Gas furnace efficiency | 95% AFUE |
| Heat pump efficiency | 15.2 SEER2 / 16 SEER<br>7.7 HSPF2 / 9.0 HSPF |
| Simulation time step | 10 minutes |
| Cost and emissions calculation granularity | Hourly |
| Emissions sources | California Avoided Cost Calculator (ACC 2022) |



| Climate zone | Gas tariff | Electric tariff for flat-rate analysis | Electric tariff for TOU analysis |
|---|---|---|---|
| CZ 16 | SCG GR | SCE D | SCE TOU-D-4-9PM |
| CZ 11 | PG&E G-1 | PG&E E-1 | PG&E E-TOU-C |

# Emissions Savings and Cost Increase

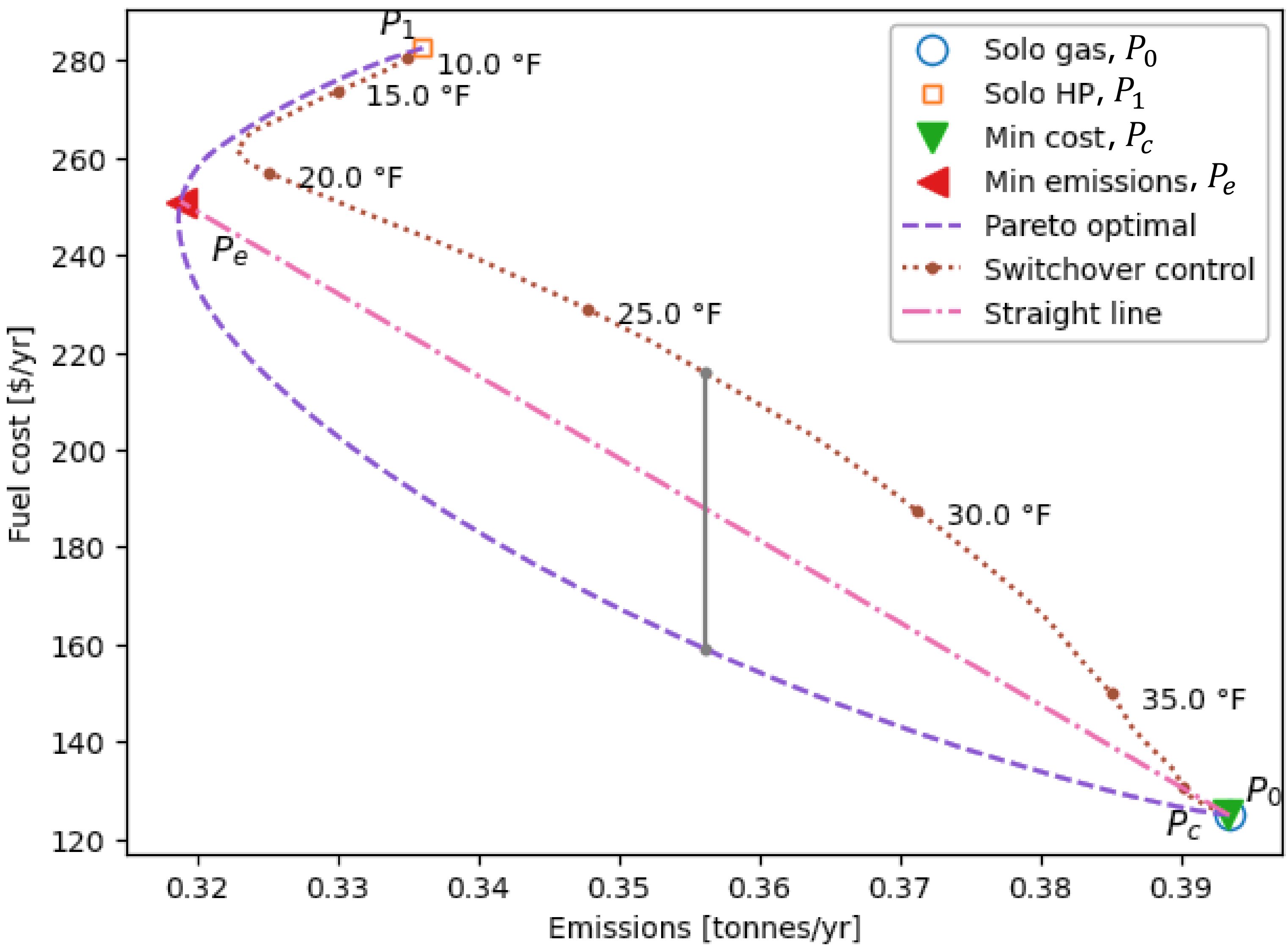
| Climate Zone | Annual HVAC Fuel Cost[3] [$] | | | | Annual HVAC Emissions [tonnes CO2] | | |
|---|---|---|---|---|---|---|---|
| | Gas Furnace | Heat Pump | Preferred System for Minimum Cost | Preferred System for Minimum Emissions | Gas Furnace | Heat Pump | Preferred System for Minimum Emissions |
| 1 | $166.28 | $446.25 | $166.26 | $405.20 | 0.497 | 0.414 | 0.408 |
| 2 | $317.68 | $728.43 | $317.67 | $709.34 | 0.918 | 0.708 | 0.705 |
| 3 | $249.01 | $543.89 | $249.01 | $540.91 | 0.701 | 0.509 | 0.509 |
| 4 | $222.76 | $485.60 | $222.76 | $482.07 | 0.631 | 0.470 | 0.470 |
| 5 | $263.16 | $587.02 | $263.16 | $584.98 | 0.745 | 0.547 | 0.546 |
| 6 | $145.37 | $268.53 | $145.37 | $268.01 | 0.434 | 0.310 | 0.310 |
| 7 | $214.19 | $360.88 | $214.19 | $360.64 | 0.425 | 0.287 | 0.287 |
| 8 | $147.95 | $250.76 | $147.87 | $249.64 | 0.427 | 0.287 | 0.286 |
| 9 | $163.66 | $294.76 | $163.66 | $294.43 | 0.493 | 0.348 | 0.348 |
| 10 | $89.24 | $205.47 | $89.24 | $186.16 | 0.281 | 0.248 | 0.244 |
| 11 | $222.63 | $518.13 | $222.62 | $462.14 | 0.620 | 0.523 | 0.514 |
| 12 | $221.58 | $521.02 | $221.57 | $475.46 | 0.620 | 0.527 | 0.519 |
| 13 | $229.93 | $501.86 | $229.93 | $480.80 | 0.627 | 0.510 | 0.506 |
| 14 | $233.61 | $458.06 | $233.57 | $441.93 | 0.698 | 0.541 | 0.539 |
| 15 | $73.07 | $134.03 | $73.04 | $126.23 | 0.219 | 0.165 | 0.162 |
| 16 | $124.83 | $282.56 | $124.81 | $247.45 | 0.393 | 0.336 | 0.319 |

# Emissions Savings and Cost Increase, Continued

| Climate Zone | Emissions Savings: Dual Fuel Over heat Pump (MT $CO_2$) | Emission Savings as percent of Heat Pump Emissions (MT $CO_2$) | Cost Savings: Dual Fuel Over Heat Pump | Cost Savings (% of Heat pump Cost) | Cost Increase: Dual Fuel Over Gas Furnace | Cost increase (% of Gas Furnace Cost) |
|---|---|---|---|---|---|---|
| 01 | 0.0062 | 2% | $41.05 | 9% | $238.92 | 144% |
| 02 | 0.0035 | 0% | $19.09 | 3% | $391.66 | 123% |
| 03 | 0.0006 | 0% | $2.98 | 1% | $291.90 | 117% |
| 04 | 0.0007 | 0% | $3.54 | 1% | $259.31 | 116% |
| 05 | 0.0004 | 0% | $2.03 | 0% | $321.82 | 122% |
| 06 | 0.0002 | 0% | $0.52 | 0% | $122.64 | 84% |
| 07 | 0.0000 | 0% | $0.24 | 0% | $146.46 | 68% |
| 08 | 0.0002 | 0% | $1.12 | 0% | $101.69 | 69% |
| 09 | 0.0001 | 0% | $0.33 | 0% | $130.77 | 80% |
| 10 | 0.0036 | 1% | $19.31 | 9% | $96.91 | 109% |
| 11 | 0.0099 | 2% | $55.99 | 11% | $239.52 | 108% |
| 12 | 0.0084 | 2% | $45.56 | 9% | $253.88 | 115% |
| 13 | 0.0045 | 1% | $21.06 | 4% | $250.88 | 109% |
| 14 | 0.0024 | 0% | $16.13 | 4% | $208.32 | 89% |
| 15 | 0.0034 | 2% | $7.80 | 6% | $53.16 | 73% |
| 16 | 0.0174 | 5% | $35.11 | 12% | $122.63 | 98% |

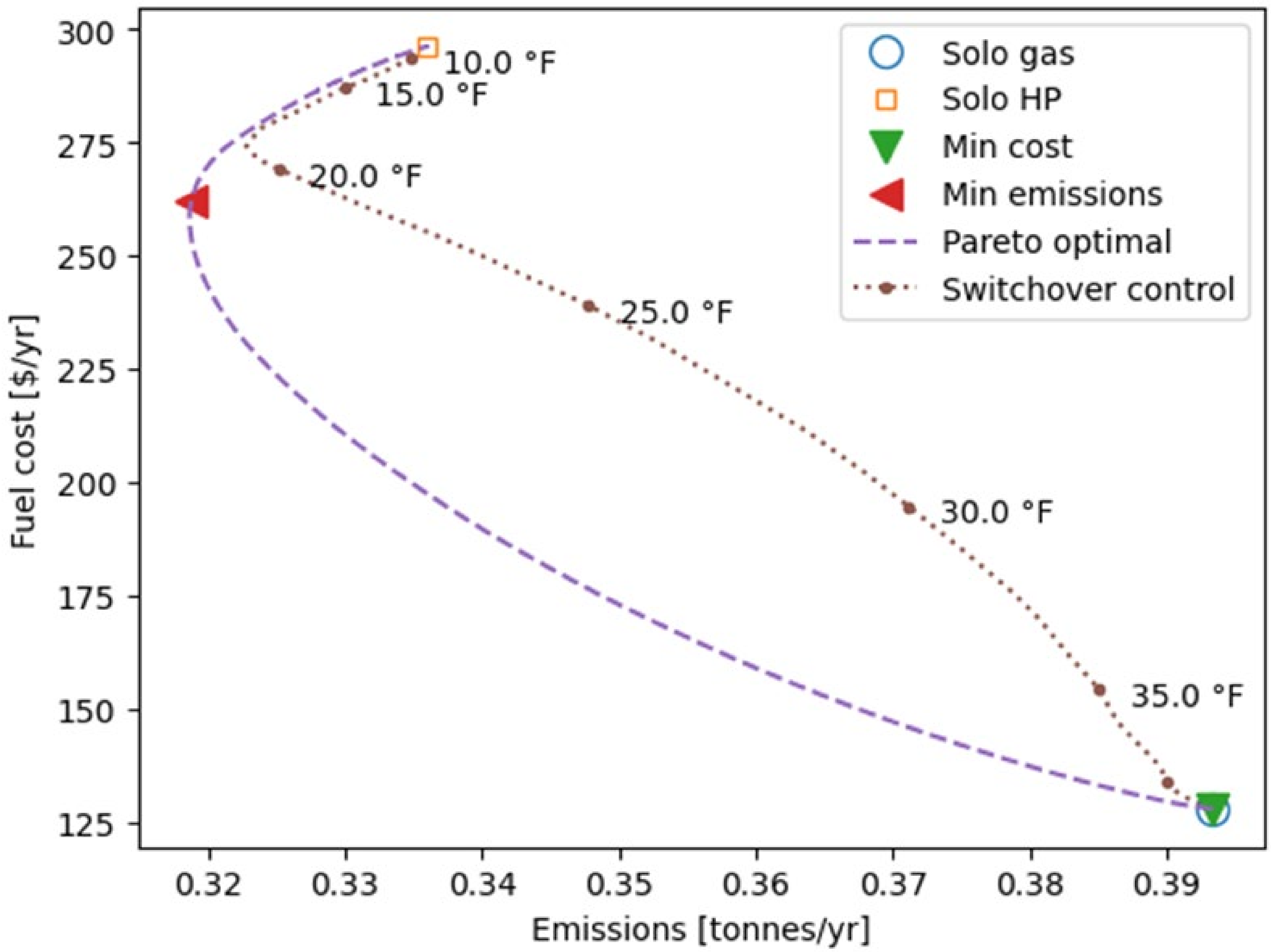
# Annual operating cost vs emissions trade-off

Pareto optimal front, CEC climate zone 16, flat rate electric tariff



# Annual operating cost vs emissions trade-off

Pareto optimal front, CEC climate zone 11, flat rate electric tariff

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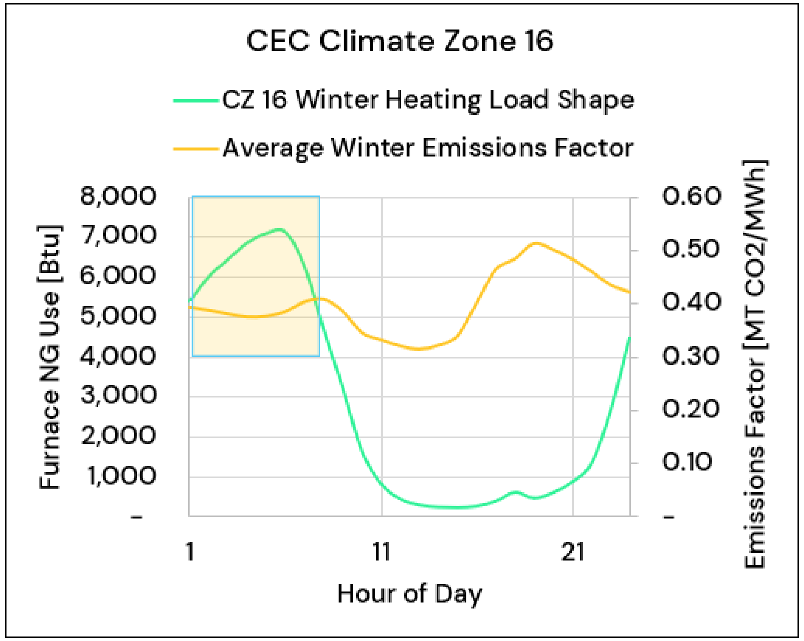
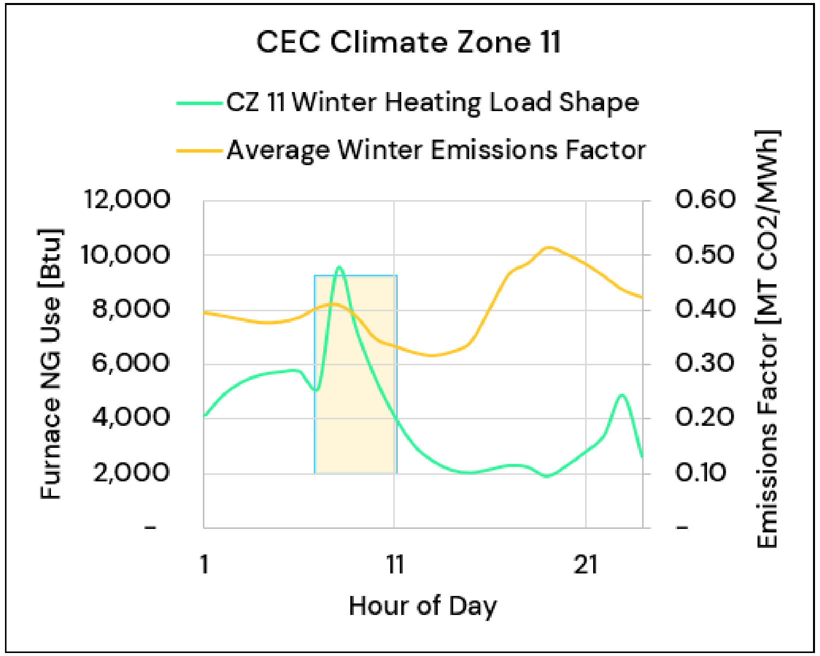
# Simulation results: Hourly trends

- Heating load peaks in winter mornings
- Emissions are at their secondary peaks for both climate zones
- Potential electric grid constraints in winter morning hours as more homes electrify

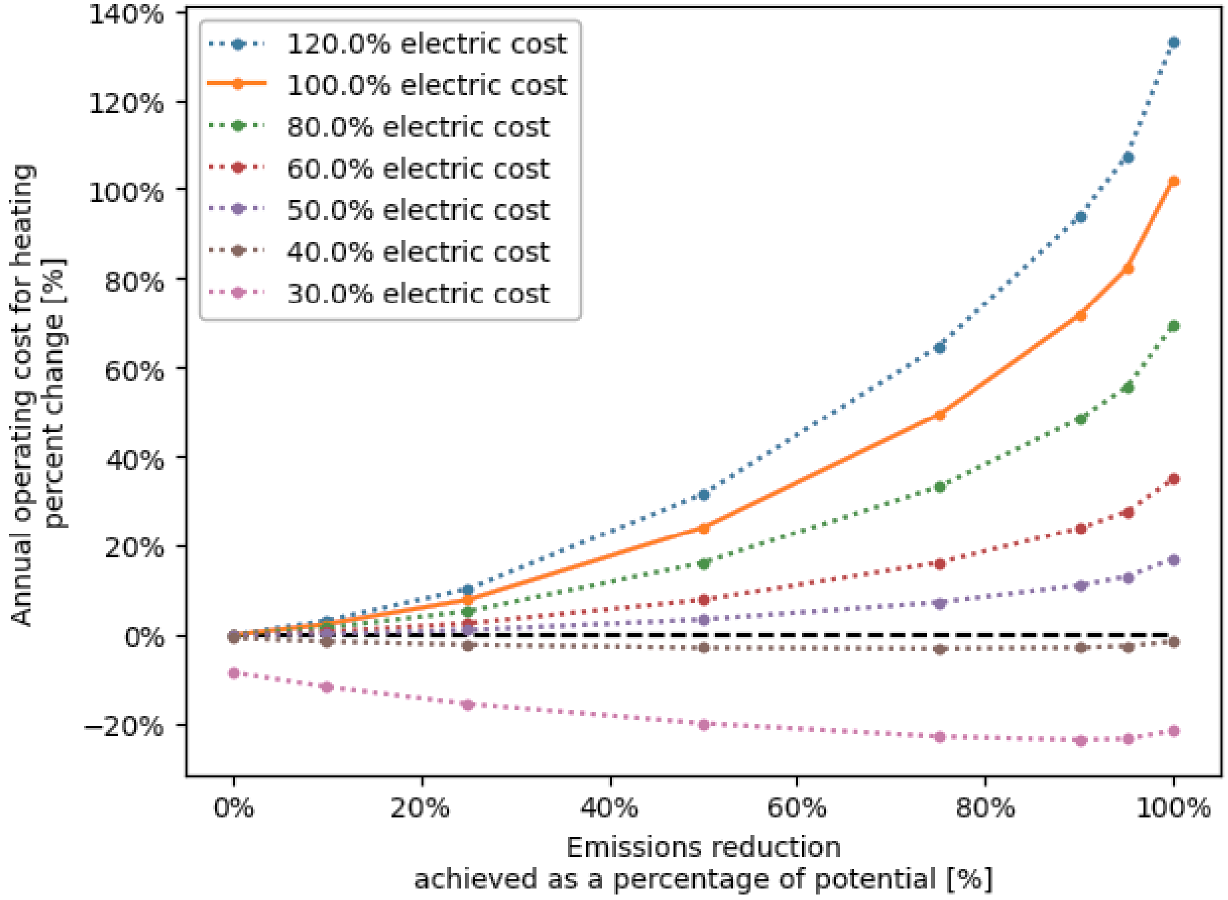


# Parametric analyses

- Scenario 1 : Customer electric cost varies from default assumption (equivalently, vary electric-to-gas cost ratio ([$/kWh] / [$/therm]) )

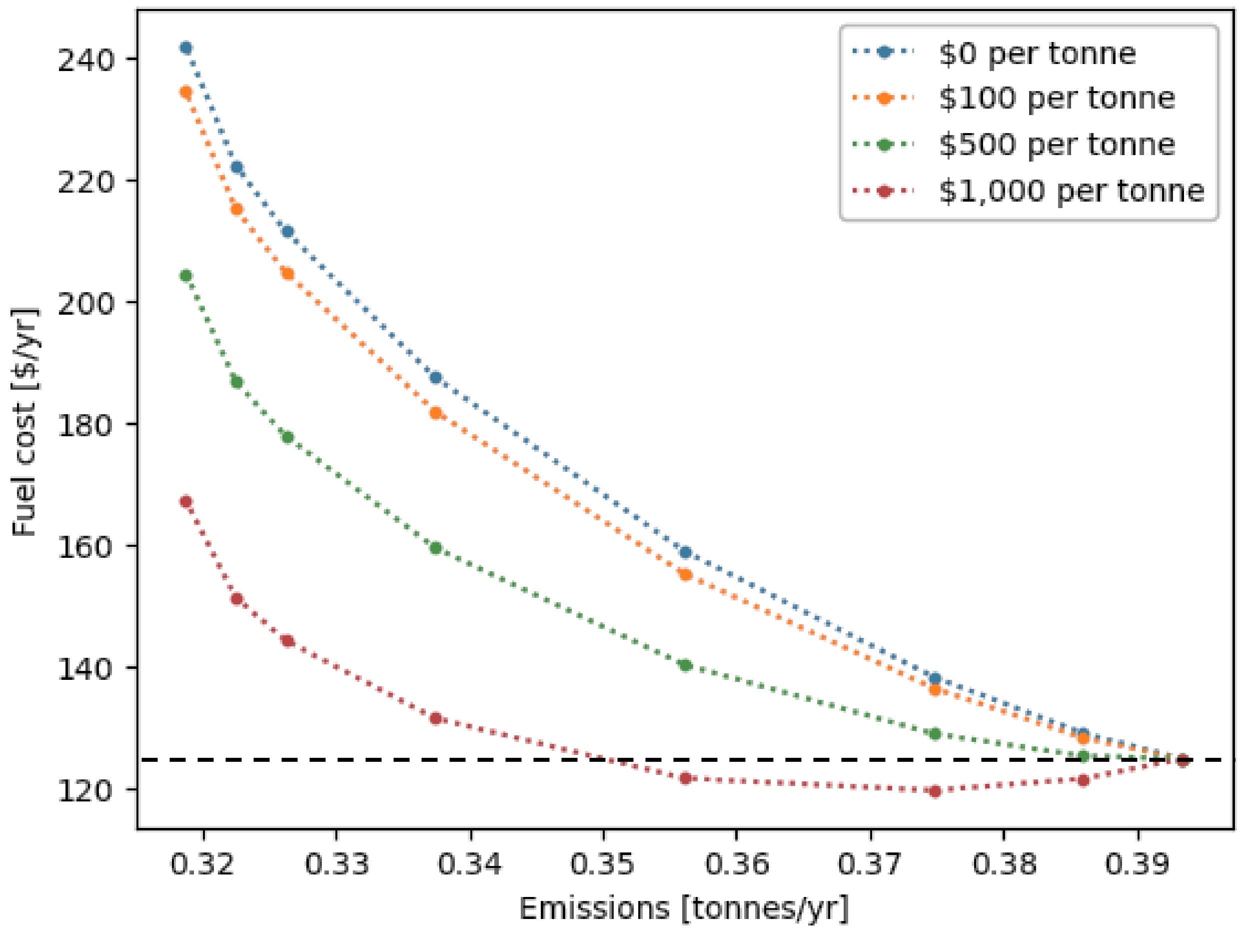
Percent change results for parametric variation of electric costs, CZ 11, flat rate electric tariff



# Parametric analyses

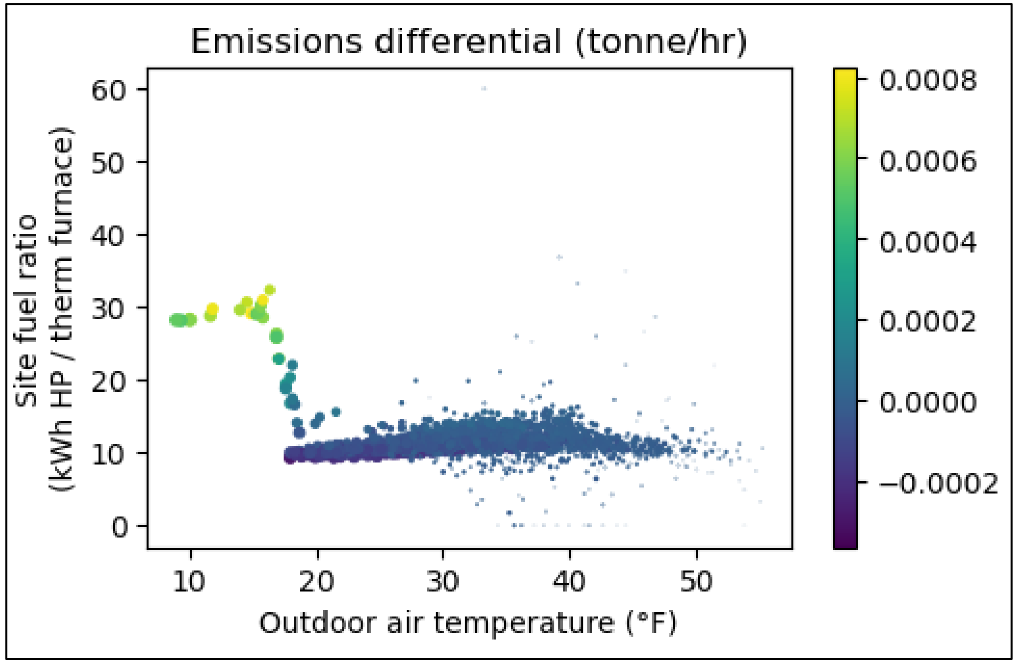
- Scenario 2 : Emissions reduction credit

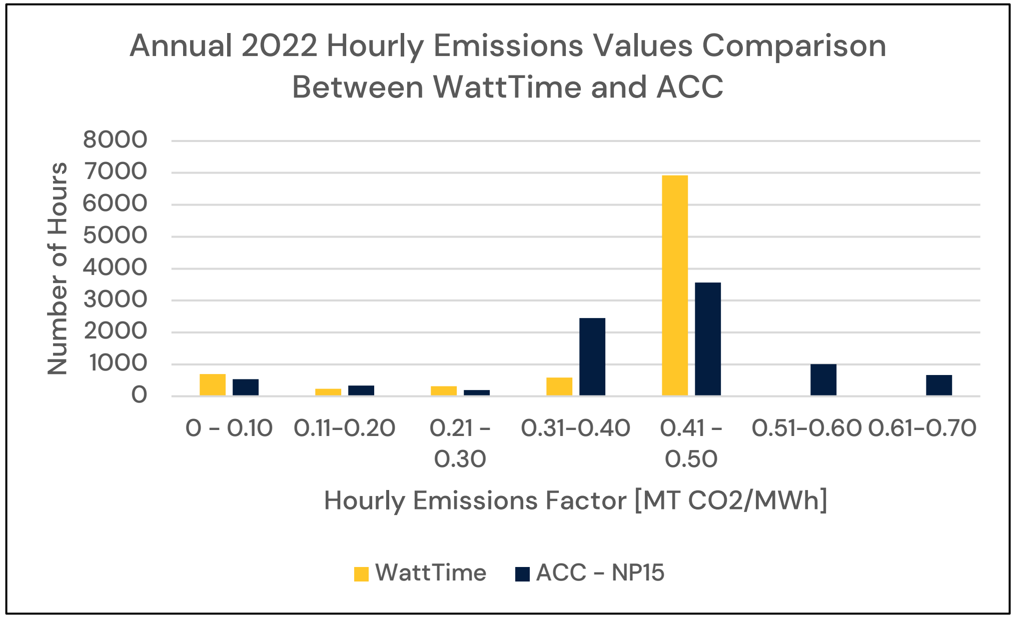
Parametric variation of emissions reduction credit, CZ 16, flat rate electric tariff



# Key parameter correlations

- Heating fuel usage differential correlates to outdoor air temperature and time of day
- Heating-related emissions differential correlates with real-time grid emissions factor (and data source)



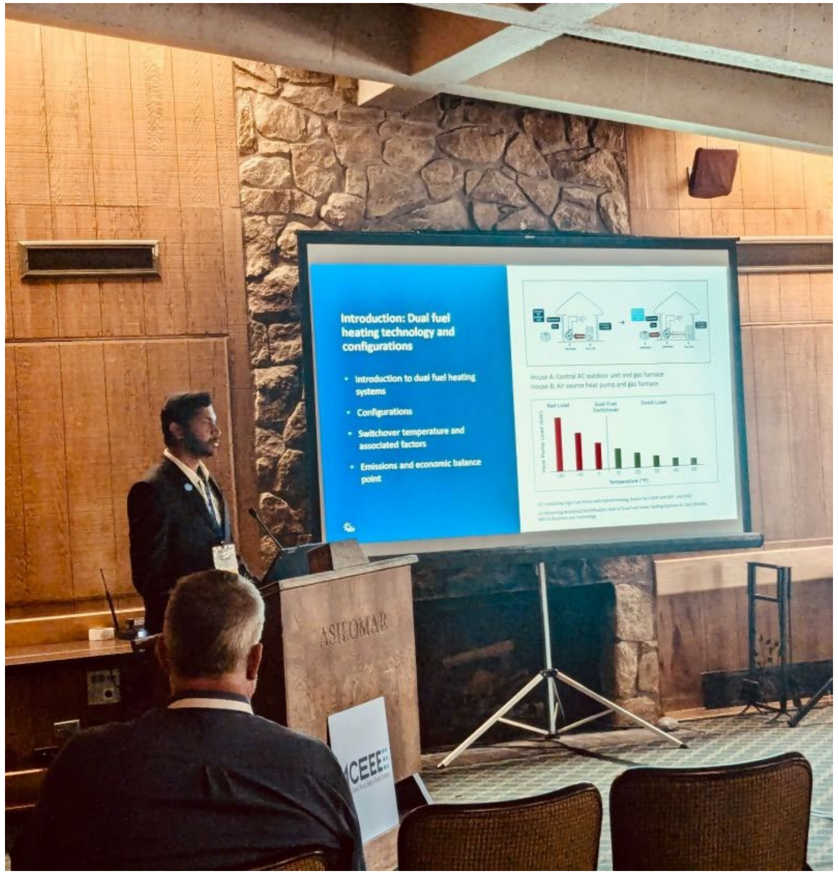



# Findings

- In California, no "emissions balance point" and "economic balance point"
- Heating peak in winter mornings could lead to potential electric grid constraints as more homes electrify
- Under California electric and gas rates considered in the study, the cost to operate the heating system in heat pump mode is nearly double when compared to solo gas furnace
- CZ 11 – The current rate ratio would need to be reduced by 55% to achieve 100% emissions reduction
- Significance of rate ratio and emissions credit ($/tonne) in making dual fuel systems cost effective
- Limited benefits of using static switchover temperature control strategy
- Cost effectiveness ranges in California (TRC/TSB)

# Presentation at conferences


ACEEE Hot Water and Hot Air Forum, Atlanta



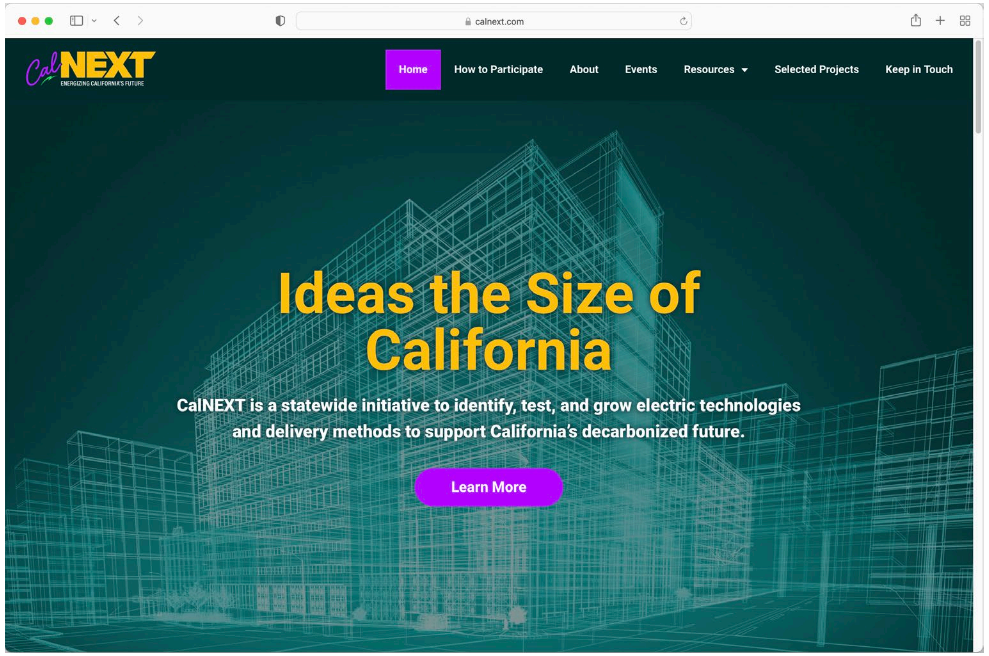

ACEEE Summer Study, California


ETCC Summit, California

# CalNEXT

CalNEXT's vision is to identify emerging electric technologies across six priority areas and bring them to the IOU energy efficiency programs portfolio.

To learn more and sign up for our email list, please visit **calnext.com**

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# Q&A

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