This Thousand Home Challenge webinar series is brought to you by the Pacific Gas & Electric Company's Energy Training Center & Affordable Comfort, Inc. (ACI).

Spring 2012 Case Study Webinar Series

WEBINAR 1: Do Deep Energy Retrofits Achieve Deep Energy Reductions?

LBNL Monitored Results of 10 California Case Studies

April 18, 2012 10-11:30 a.m. Pacific Time

Presented by: **Brennan Less & Jeremy Fisher,** LBNL, Berkeley, CA
Facilitated by: **Linda Wigington**, Affordable Comfort, Inc.
Respondent: **Don Fugler,** Ottawa, Ontario

www.1000HomeChallenge.org www.affordablecomfort.org

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ecoffman@affordablecomfort.org

Content Related Questions or Comments?

Use comment box; send to organizers

ACI Resources

MARK YOUR CALENDAR!

ACI California – Sacramento, CA – June 4-6, 2012

ACI National 2013 – Denver, CO – April 29-May 3, 2013

Past Handouts & Upcoming ACI Events

www.affordablecomfort.org

Information about the Thousand Home Challenge

www.ThousandHomeChallenge.org

Introduction to the Thousand Home Challenge Webinar

- May 17 10-11:30 AM Pacific time
- June 14 10-11:30 AM Pacific time

ACI Archives

www.1000HomeChallenge.org/resources

Past THC/ETC Webinars

- **High Performance Hot Water: On the Path to Deep Energy Reductions (2-part)** - *Gary Klein*
- **Analyzing Electricity Usage: A Critical Step Toward Deep Energy Reductions** - *Chris Hunt*
- **Ductless Heat Pumps: Recent Research & Applications for Low Energy Homes (2-part)** - *Mark Jerome, Bob Davis, & Marc Rosenbaum*
- **Ducted & Ductless Mini-splits for Cooling Existing Homes** - *Danny Parker & Dave Robinson*
- **Dense Pack for Insulation & Air Sealing California Homes (2-part)** - *Jim Fitzgerald*

PG&E's 2012 Classes – Free!

Sampling of Offerings (from mid April - June)
Related to Deep Energy Reductions in Existing Homes

For the full class schedule, visit **www.pge.com/energyclasses**

Deep Energy Reductions – The Thousand Home Challenge - *Linda Wigington*

Go Ductless California, Try Mini-Splits! - *Dick Rome*

Ventilate Right, Build Tight - *Judy Roberson*

Window Selection for New and Existing Homes - *Steve Easley*

The Passive House Approach to Zero Net Energy Homes - *Graham Irwin*

Balanced Ventilation for High Performance Homes - *Dan Perunko & Gavin Healy*

Auditing Electricity Use in Existing Homes - *Chris Hunt*

Integrating Energy Efficiency & Renewables in Home Retrofits - *Pete Shoemaker, +*

PG&E's ZNE Homes Class Series (Parts 4, 5, & 6) – *Rick Chitwood & Ann Edminster*

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Spring 2012 Case Study Remaining Webinars

- April 23 - Webinar 2: **First CA Home to Meet the THC - Beeler**: Phased Reductions Include Seismic Retrofit
- May 2 - Webinar 3: **First US Passive House Retrofit - O'Neill**: The PH Approach to Deep Energy Reductions
- May 9 - Webinar 4: **Second CA Home to Meet the THC - Bergamaschi:** Focus on Plug Loads & PV

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Learning Objectives for Today

By attending this webinar, participants will be able to:

1. Learn how a variety of approaches can be used to achieve deep energy reductions in homes

2. Understand which elements of the projects were successful, and which ones may have been detrimental to success

3. Explore different ways to define success in a deep reduction project and discover what drives it

Webinar Outline Today

Linda Wigington

- Intro & Thousand Home Challenge

Brennan Less & Jeremy Fisher

- Project descriptions
- LBNL monitoring results

Don Fugler

- Comments

Discussion & Questions

- Post comments & questions under “Questions” or send to (lwigington@affordablecomfort.org)

Deep Energy Retrofits

(Asset Performance

MPG Rating)

Vs. Deep Energy Reductions

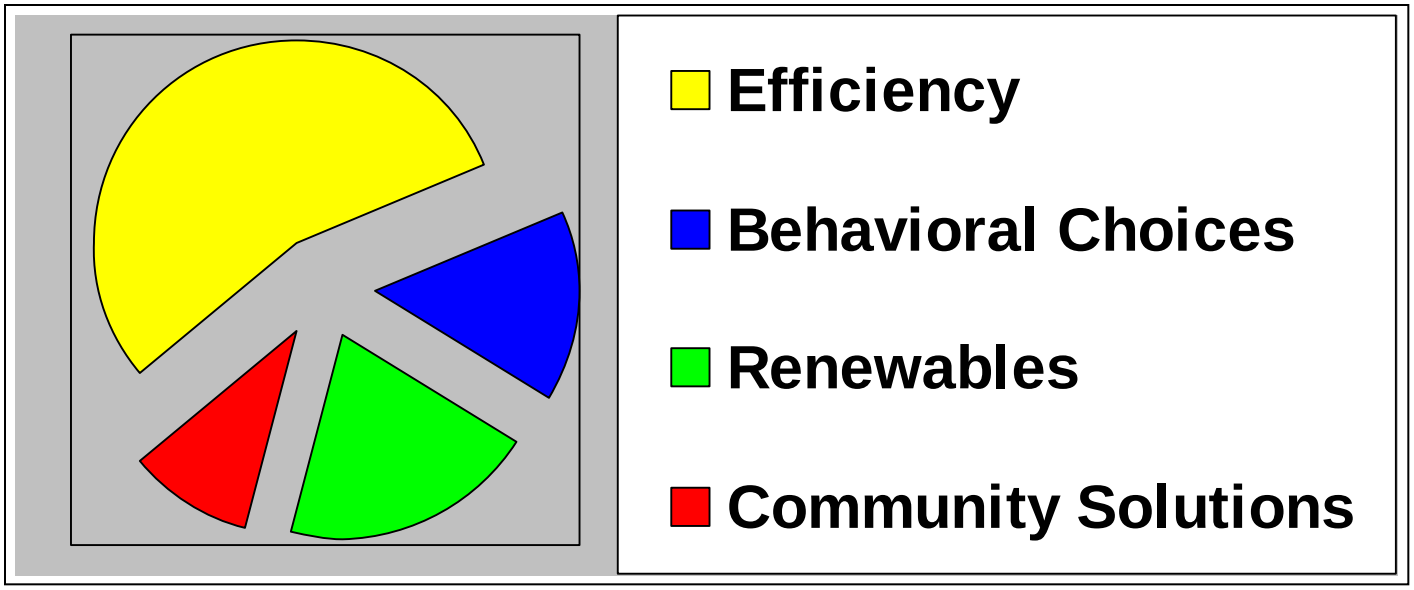
(Operational Performance

Actual Utility Bills)

The Thousand Home Challenge

70%+ Deep Energy Reductions

Access & Integrate



What is the Thousand Home Challenge (THC)?

- A new vision for what's possible
- Integrates human & technical solutions
- Stimulates innovation
- Builds capacity

Each household has its unique threshold of performance to meet or exceed.

Key Metric

Transparent & Direct

Include Occupants

Net Annual Household Site Energy

Credits/offsets: Solar & onsite renewables

Wood counts!

Thousand Home Challenge Threshold Determination

OPTION A

- 75% reduction in actual annual site energy use

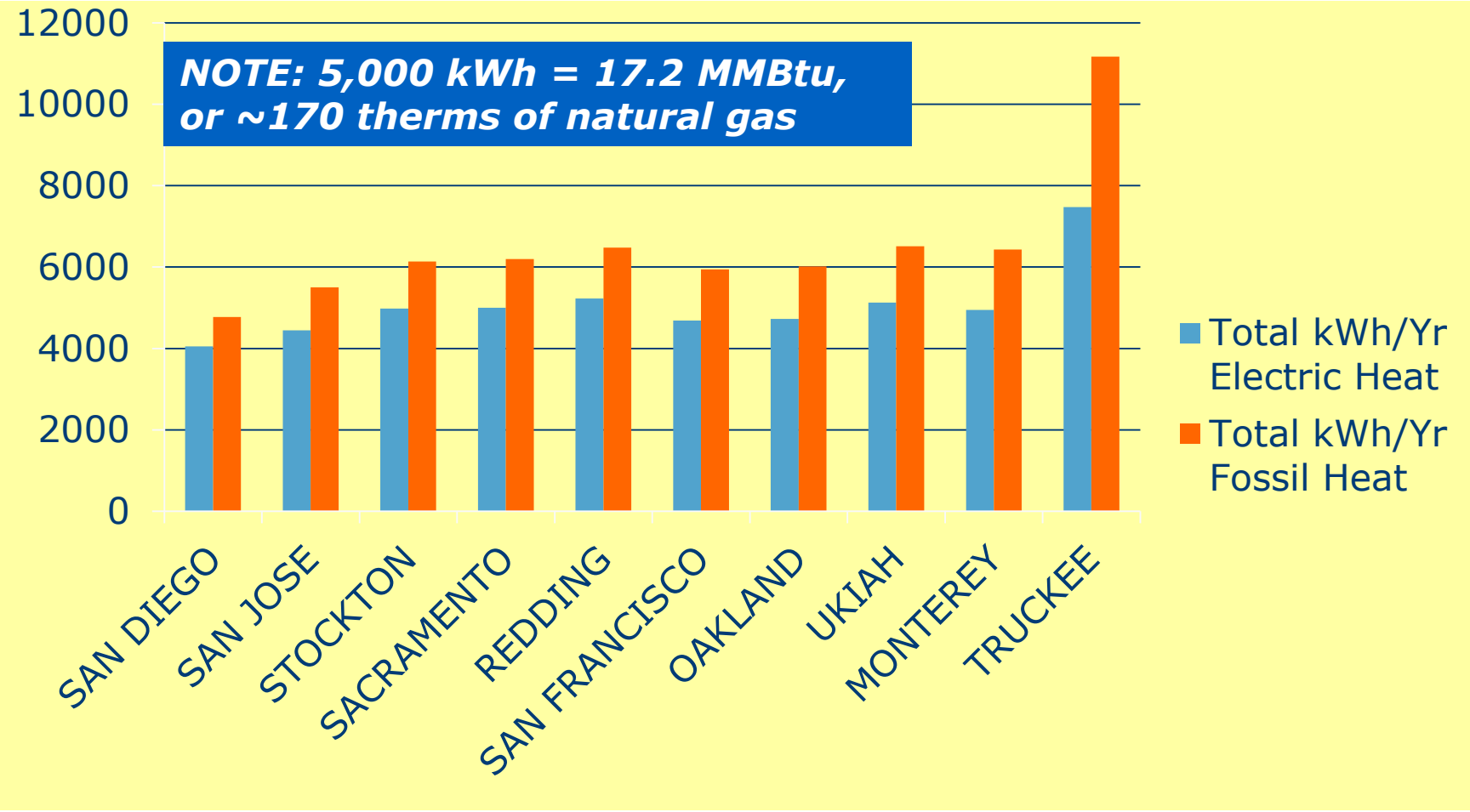
OPTION B

- **Climate** (ZIP Code or best match weather station)
- **House size** (FFA), converted to surface area (5 sides)
- **Detached or attached**
- **Electric heat allowance** = ½ fossil fuel or wood heat allowance
- **Number of occupants** (including partial occupancy)

THC OPTION B Household Threshold

Comparing electric vs. fossil/wood heated home)

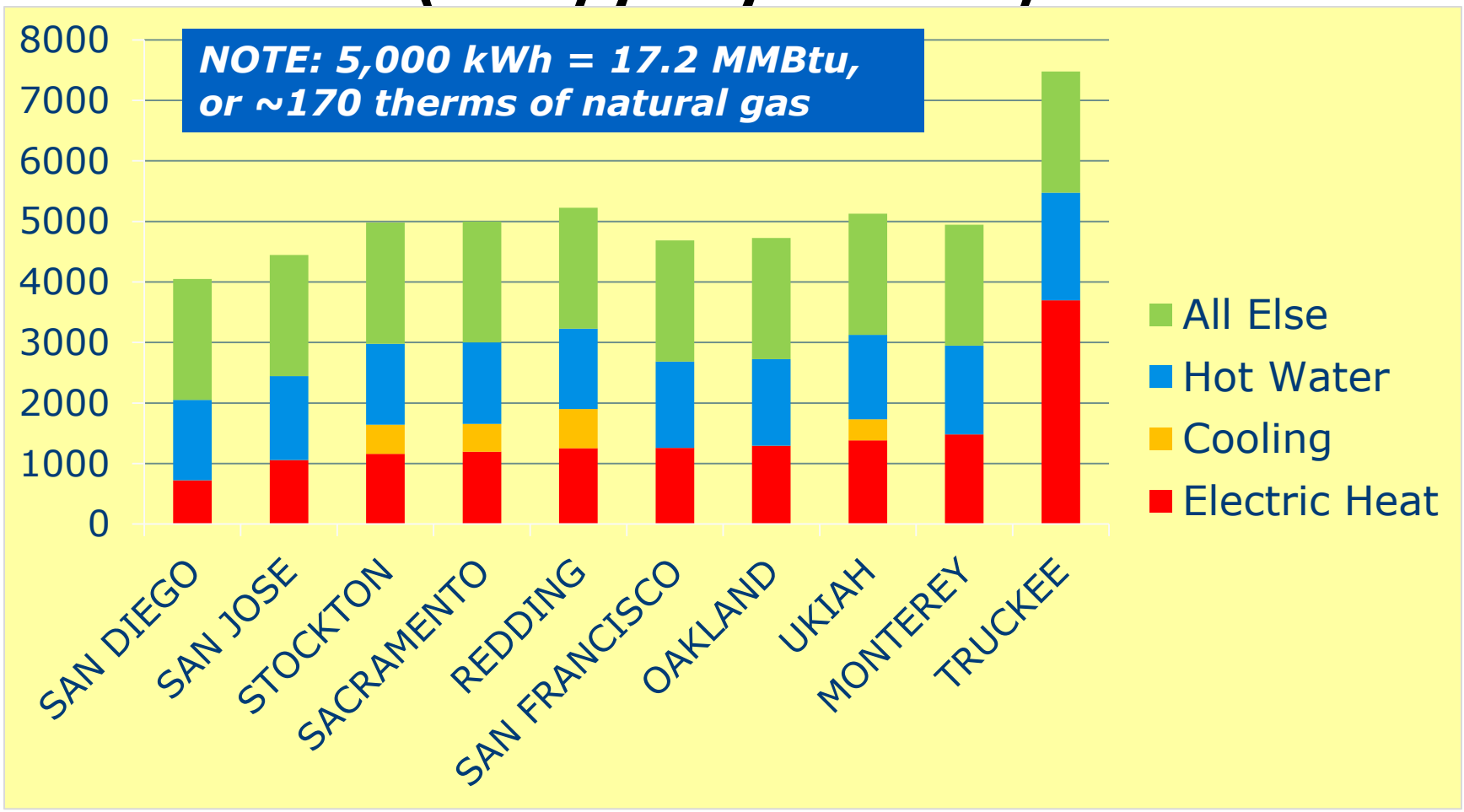
(kWh/yr. all end uses)



OPTION B Inputs: Detached; 3 in household; 2,000 ft^2 finished floor area (FFA)

THC OPTION B Household Threshold

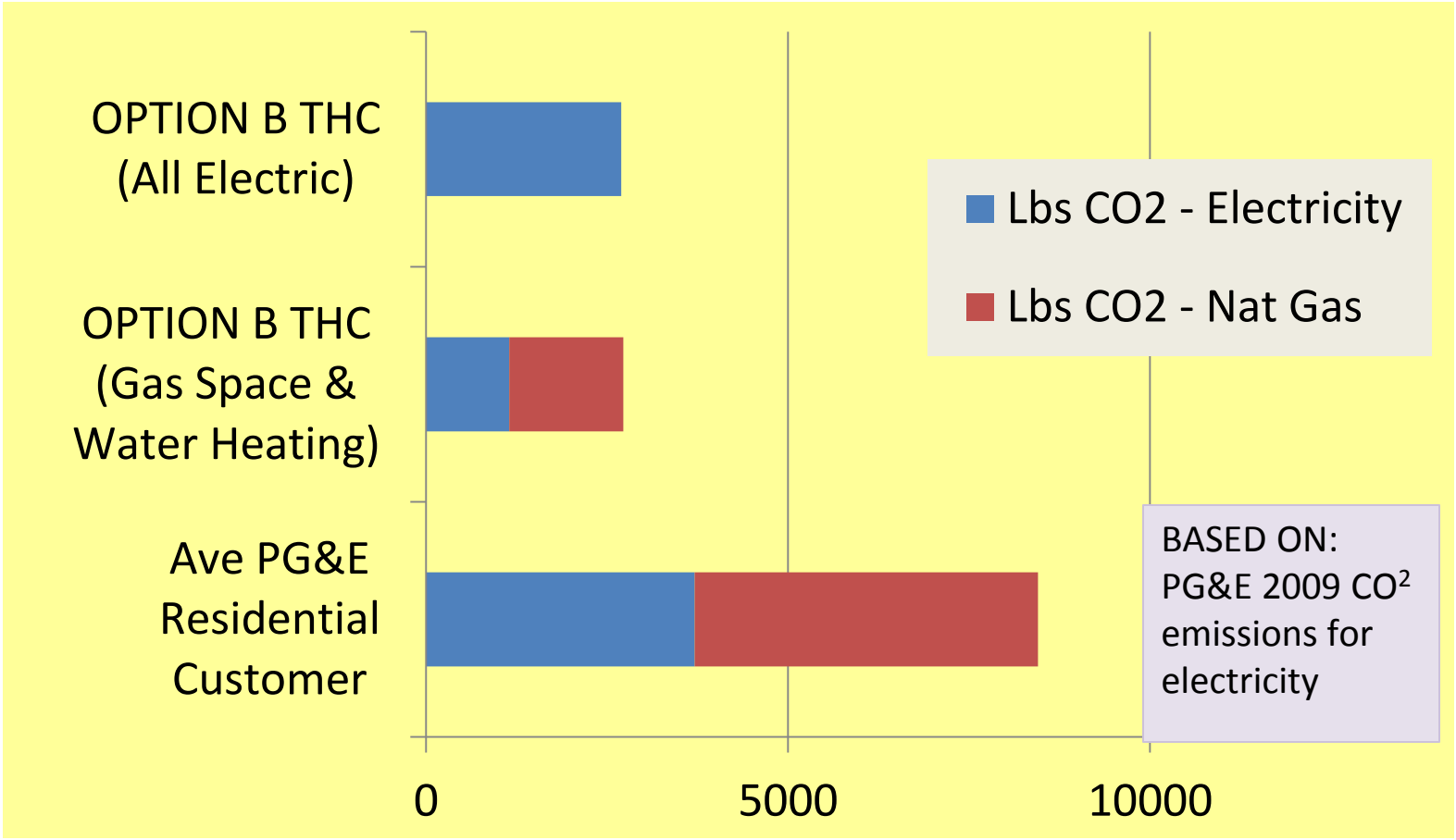
(kWh/yr. by end use)



OPTION B Inputs: Detached; 3 in household; 2,000 ft^2 finished floor area (FFA); electric heat

Comparing CO^2 Emissions

http://www.pge.com/mybusiness/environment/calculator/



OPTION B Inputs: Detached; 3 in household; 2,000 ft² finished floor area (FFA)
CA Average Residential Customer Annual Use (includes multis): 405 therms
6,456 kWh

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Brennan Less & Jeremy Fisher

Brennan Less, a researcher in the Residential Building Systems Group at Lawrence Berkeley National Laboratory, focuses on deep energy retrofits and indoor air quality in high performance homes. He co-manages a Department of Energy (DOE) research project monitoring the energy performance of ten California deep retrofits. Brennan also currently co-manages a study of indoor air pollutants in high-performance California homes.

Jeremy Fisher is a research associate at Lawrence Berkeley National Laboratory with the Residential Building Systems Group. He has 16 years of experience in the construction industry, is a LEED AP and a certified green builder. Jeremy's research is **focused on residential deep energy retrofits, energy monitoring, and the effects of construction quality on energy performance.**

Don Fugler, Respondent

Don Fugler was trained as a mechanical engineer and **spent 25 years doing housing research for Canada Mortgage and Housing Corporation (CMHC).** He managed research projects on topics such as combustion spillage, home energy use, wet basements, ventilation, indoor air quality, contaminated lands, and straw bale housing. **One of his last projects was the performance monitoring of the CMHC EQuilibrium homes, houses designed to be net zero and healthy.** He retired from CMHC in 2011, and currently undertakes contract research into ventilation, IAQ, energy retrofitting, and other issues.

DO DEEP ENERGY RETROFITS ACHIEVE DEEP ENERGY REDUCTIONS?

LBNL MONITORED RESULTS OF 10 CALIFORNIA CASE STUDIES

Jeremy Fisher, Brennan Less – 4/18/2012

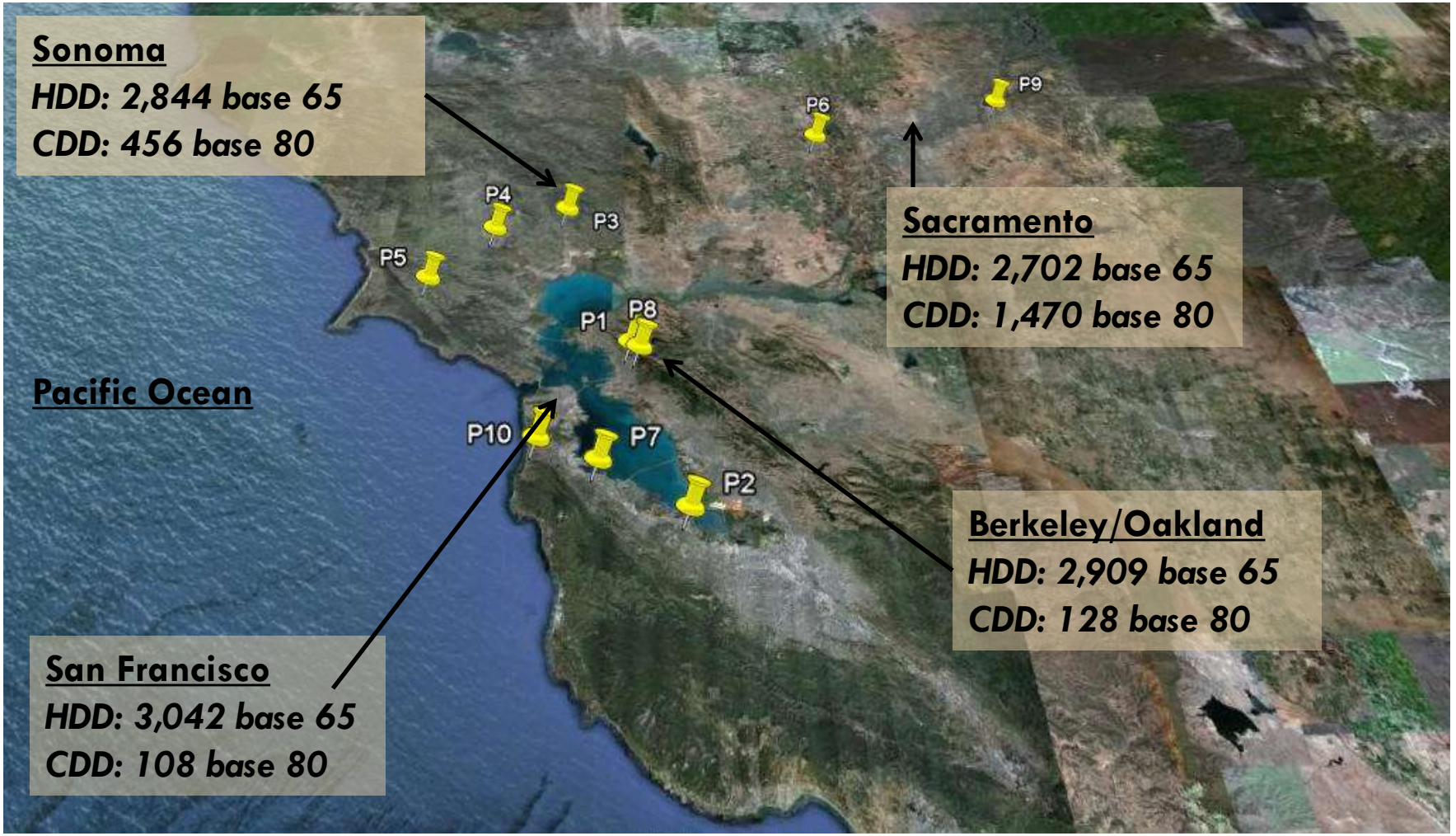
Overview

- Introduction to Deep Energy Retrofits (DER)
- Description of energy monitoring equipment & protocols
- 10 case studies funded by DOE Building America Program
  - Project descriptions
  - Annual energy savings
  - Energy end uses
- Comparison between projects
- Exploration of energy metrics & their impact on assessment of performance
- Cost of DER

Introduction to DER

- Upgrading/remodeling existing homes to reduce energy consumption by 70%
- Combination of envelope upgrades, high-efficiency equipment, appliances & lighting, plug load reduction, adding renewables, & occupant conservation
- Current DER efforts
  - ACI Thousand Home Challenge
  - DOE Building America
  - NYSERDA
  - National Grid
  - Other efforts by utilities & national labs
  - IEA Task 37 - Advanced Housing Renovation with Solar & Conservation
  - Retrofit for the Future - England's Technology Strategy Board
  - EnerPHIT - Passive House Retrofit Standard
- The 10 homes in this research were not supported, monetarily or in design, by the research team

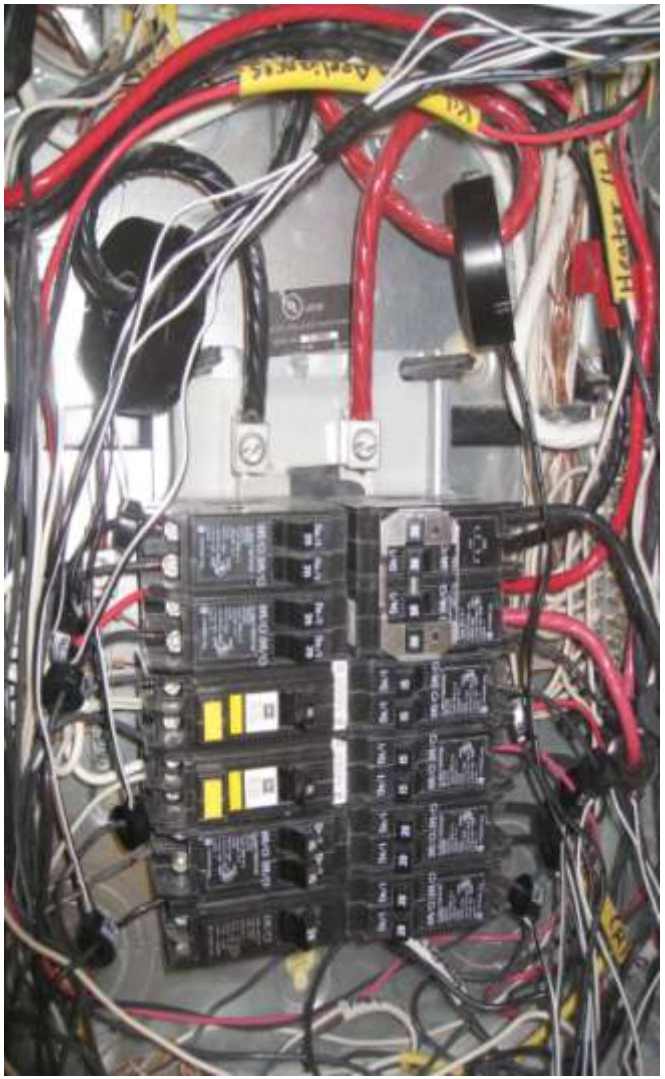
Project Locations, Varied Micro-climates in the Bay Area



Energy Monitoring Goals

- Monitor all significant end uses at the electrical panel & gas appliance, avoiding any intrusion on living space
- Provide real-time feedback to occupants
- Real-time access to data to facilitate detection of faults, communication failures, changes in load profile, etc.
- Use of wireless communication system to avoid running wires in the home
- Current transformers must be small enough to fit one for every circuit inside the main electrical panel
- One minute resolution that allows precise characterization of load profiles
- Monitoring equipment averages 15 watts of power

Monitoring Equipment



Energy Unit Essentials

- 3,412 Btu per kWh
- 29.3 kWh per therm of natural gas. THINK 30 kWh per therm
- CA Average Single Family Site Energy Use
  - Total: 20,061 kWh
  - Electricity : 7,605 kWh
  - Natural Gas : 425 therms = 12,456 kWh
- Site Energy vs. Source Energy
  - Site energy is what the utility bills a customer, in kWh or therms
  - Source energy accounts for the primary fuel (natural gas, coal, etc.) required to deliver energy to a home, includes power plant inefficiencies, grid distribution efficiencies, etc.
  - National conversion factors assume power plant fuel mixes & distribution losses are same everywhere, which may not be the case (hydropower, renewable energy, natural gas power plants vs. coal combustion)
    - Source Natural Gas (kWh) = Site Gas (kWh) x 1.02
    - Source Electricity (kWh) = Site Electricity (kWh) x 3.16
- Electricity use is penalized in source energy calculations; source energy impact of natural gas may be greater than the 1.02 conversion factor would suggest (fracking?)
- Carbon impact is calculated in this presentation as CO_2 equivalent emissions in pounds per year using National US EPA published values for grid electricity & natural gas
  - Net CO_2e lbs. = (Net Site Elec. (kWh) x 0.775)+(Net Site Gas (kWh) x 0.4)
    - **Electricity in CA is significantly less carbon intensive than this national value**, due to more renewable, natural gas and hydro power.
    - 0.575 in CA versus 0.775 Nationally, 26% less carbon for a CA kWh versus a national kWh

P1 Project Description

1904 Craftsman Bungalow

Berkeley, CA

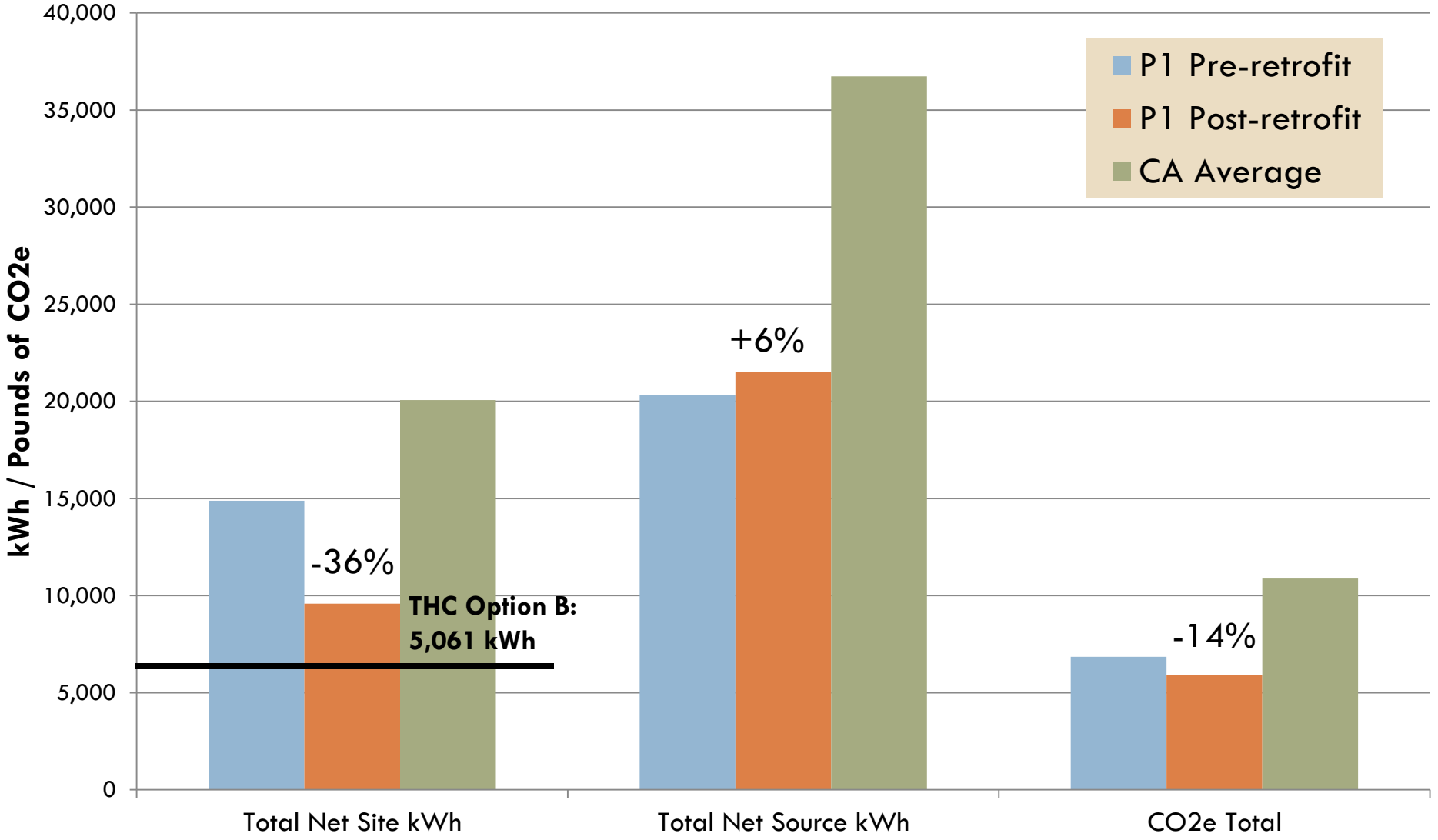
Pre: 960ft^2 ⟹ Post: 1,630ft^2

- Original home – no insulation, 1 natural gas floor heater on the 2nd level
- House raised, & the ground floor rebuilt to legal height
- Project guided by European *Passive House* principles
- 4 bedrooms, 2 baths, 4 occupants, home office

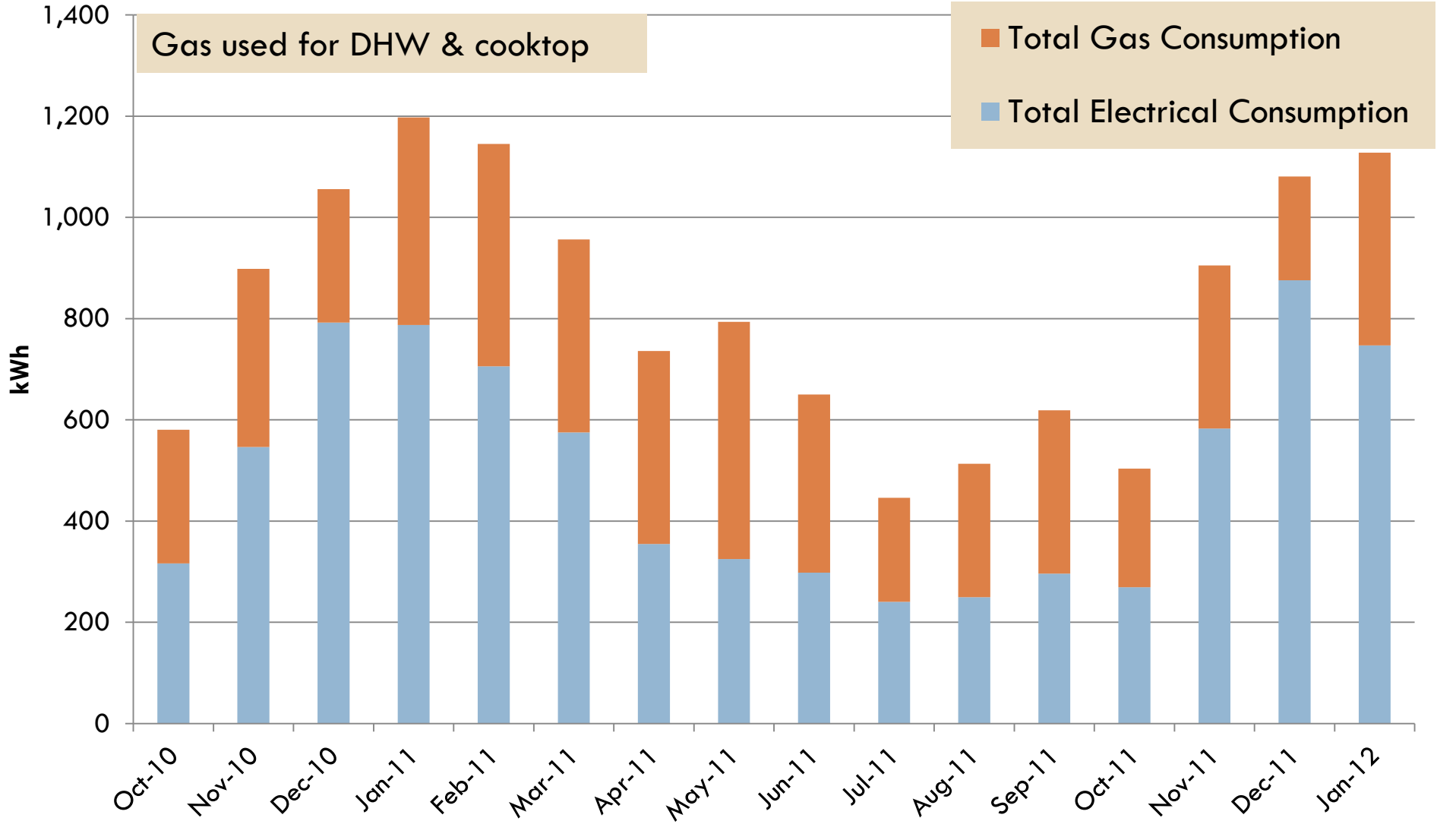
P1	Pre-retrofit	Post-retrofit
ENVELOPE		
Wall Insulation	None	1st floor: 5.5" cellulose - R19 2nd floor: 3.5" cellulose; 2" ext. XPS - R23
Attic/Roof Insulation	Some fiberglass	10" cellulose in attic floor- R38
Foundation Insulation	None	1" XPS slab perimeter - R5 3" polyiso over slab with thermally broken wooden sleepers - R21
Windows	Single pane wood frame, double hung	2-pane, Low E, argon, wood frame – U-0.3, SHGC-0.35, VT- 0.54
Air Leakage		271 CFM_{50}, 0.0634 CFM_{50}/SA, 1.1 ACH_{50}
MECHANICAL		
Cooling	None	None
Heating	Gas floor furnace, ~60% efficient, on 2nd floor, no dist.	Electric resistance baseboard heaters in each room
DHW	40-gal gas tank in garage	Gas tankless, 0.84 EF. 11-199 kBtu/hr.
Ventilation	Natural	ERV SER 81-83%, exhausts: bath & kitchen, supplies: living room & bedrooms
Distribution	None	R6, foil faced flex duct for ERV
LIGHTS/APP/MEL	All incandescent lights, old appliances	100% CFL lights, new Energy Star appliances, small home office

P1 Retrofit Description

P1 Net Energy Annual Performance

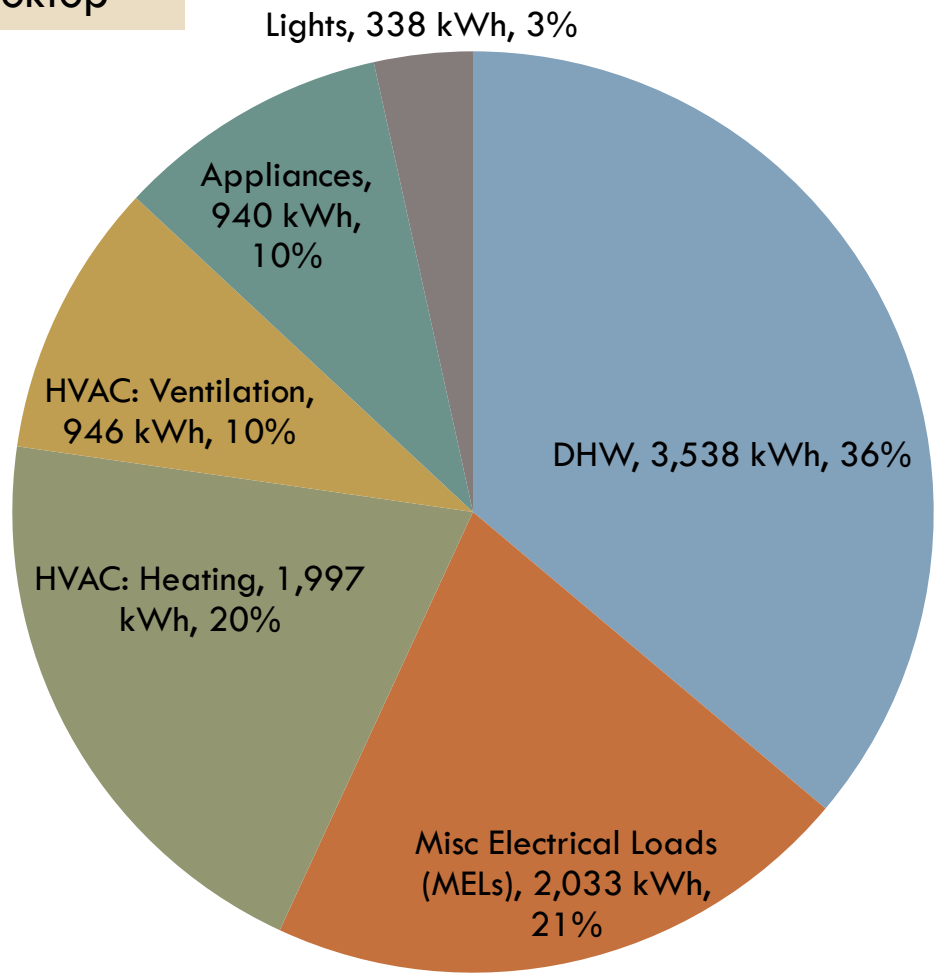


P1 Total Monthly Site Energy Use

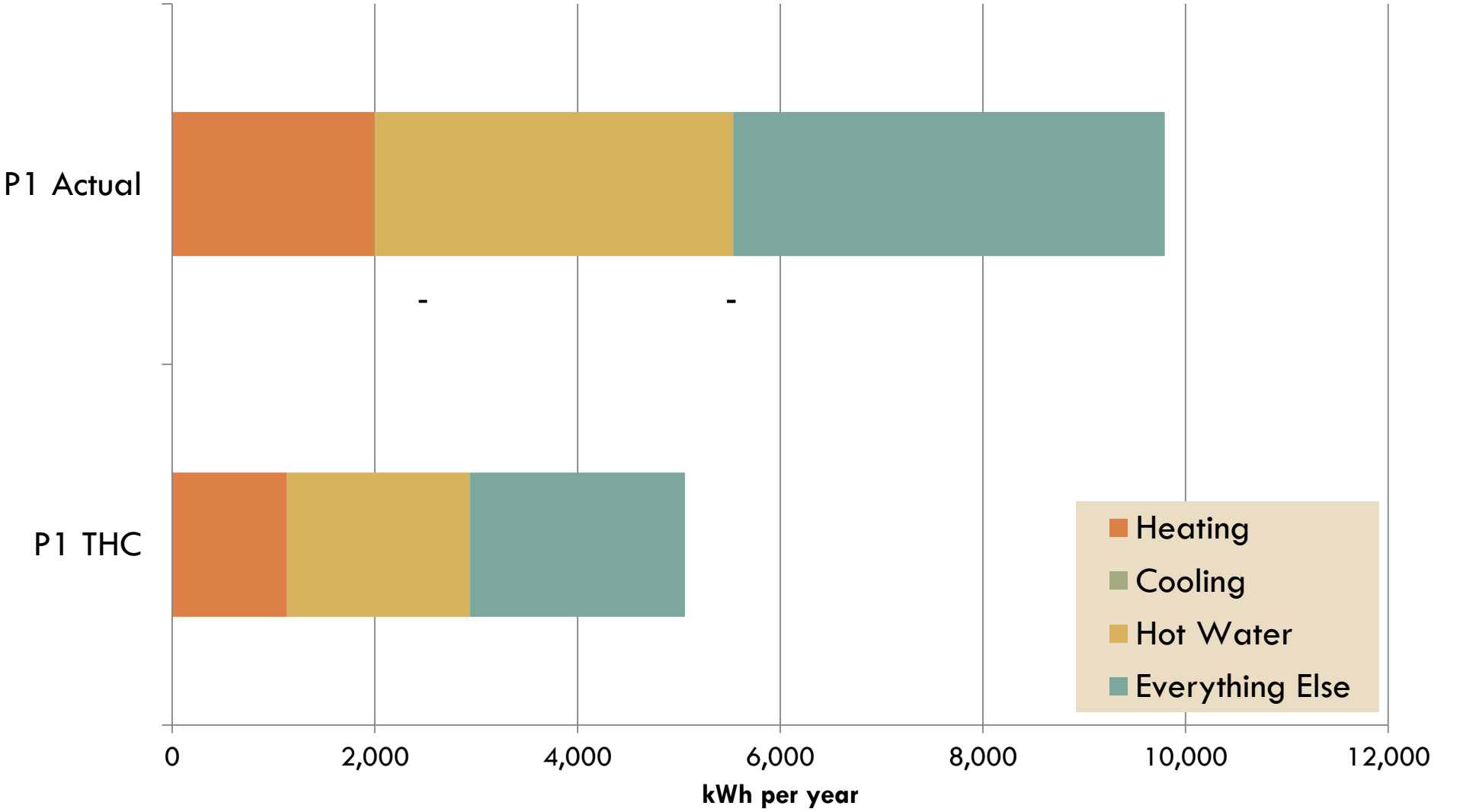


P1 Annual Energy End-Use

Gas used for DHW & cooktop



P1 THC Option B End Use Vs. Actual (kWh/yr.)



P2 Project Description

1936 English Tudor

Revival Style Home
Palo Alto, CA

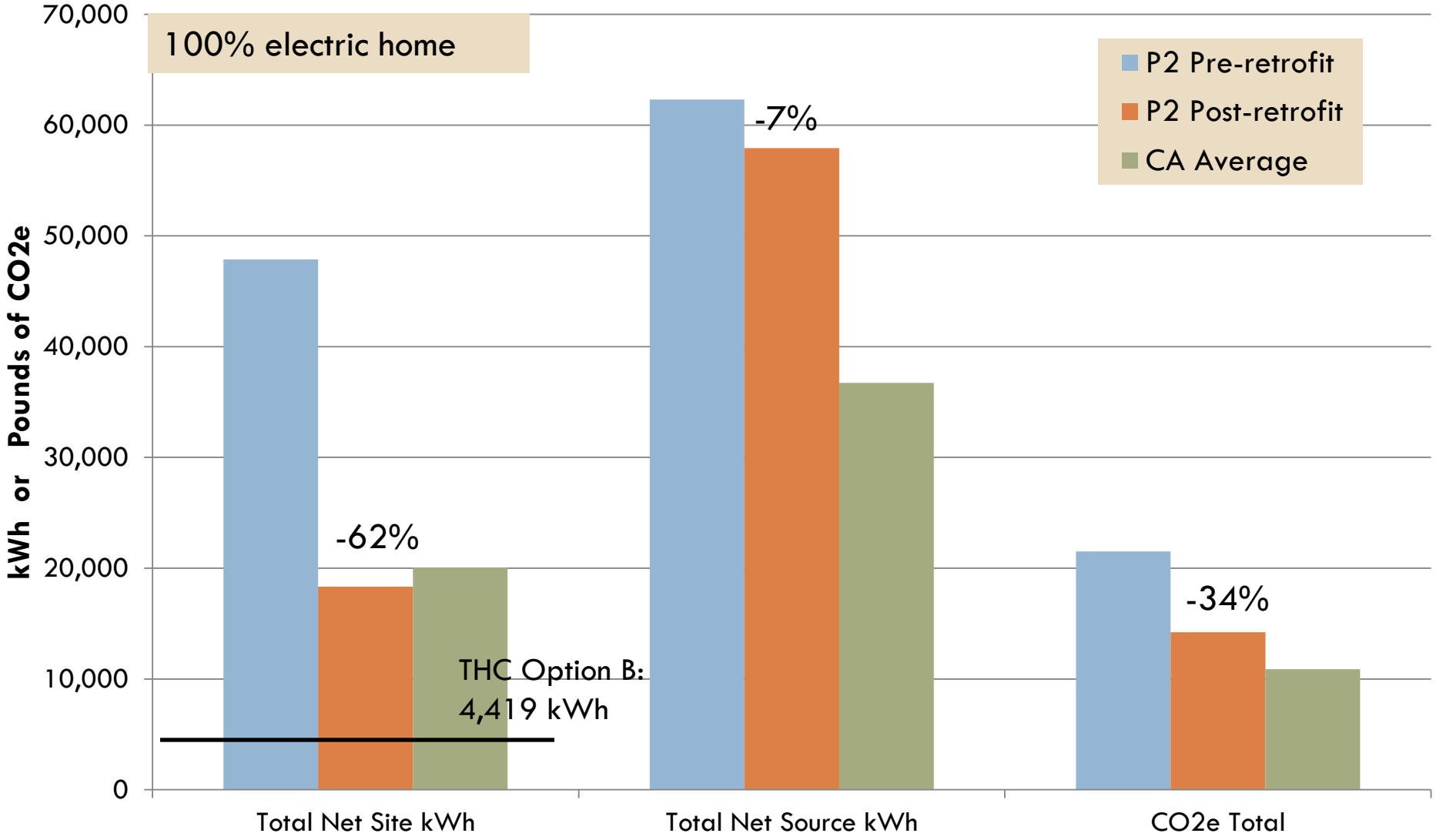
Pre: 2,780 ft^2 ⟶ Post: 2,780 ft^2

- Due to architectural significance, efforts made to maintain historical character throughout project
- 5 bedrooms, 3 baths, variable occupancy, home office

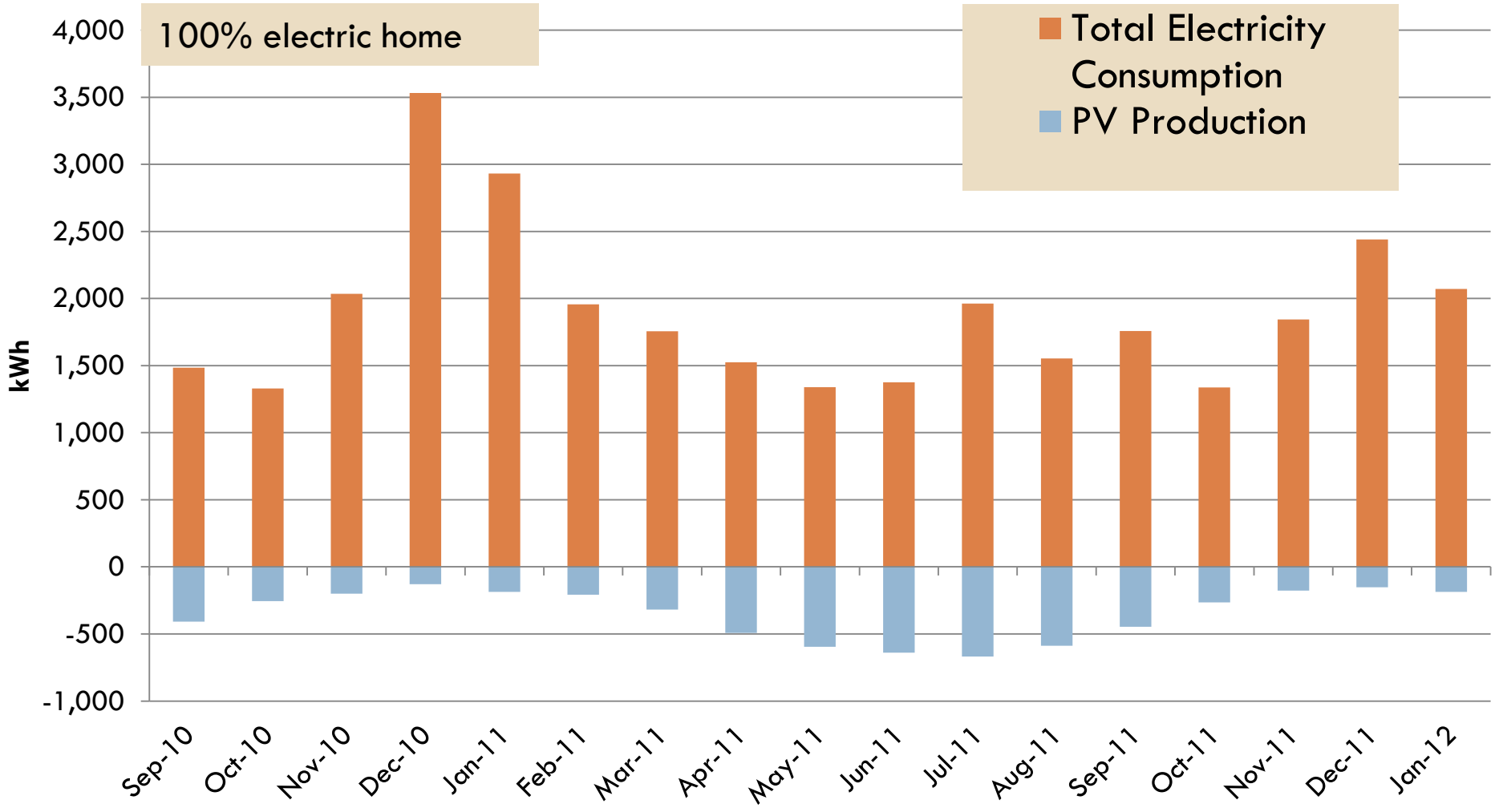
P2	Pre-retrofit	Post-retrofit
ENVELOPE		
Wall Insulation	None	3.5” cellulose - R13
Roof Insulation	None	6.5” open cell spray foam - R23
Foundation Insulation	None	6.5” open cell spray foam - R23
Windows	Single pane, steel frame	2-pane, Low E, argon - interior storm windows, values unknown
Air Leakage		2,260 CFM_{50}, 0.325 CFM_{50}/SA, 5.7 ACH_{50}
MECHANICAL		
Heating, Cooling, & DHW	Natural gas furnace, 40-gal gas tank DHW heater	3-ton air to water heat pump, EER 9-12, variable speed compressor
Ventilation	Natural	2 air handlers, integrated HRVs -continuous ventilation, bath exhaust fans
Distribution	None	R6, foil faced flex duct in sealed & conditioned attic & basement
LIGHTS/APPLIANCES/MEL	All incandescent lights, old appliances	CFL, halogen & LED lights, new Energy Star appliances
RENEWABLES	None	4.3 kW PV

P2 Retrofit Description

P2 Net Energy Annual Performance

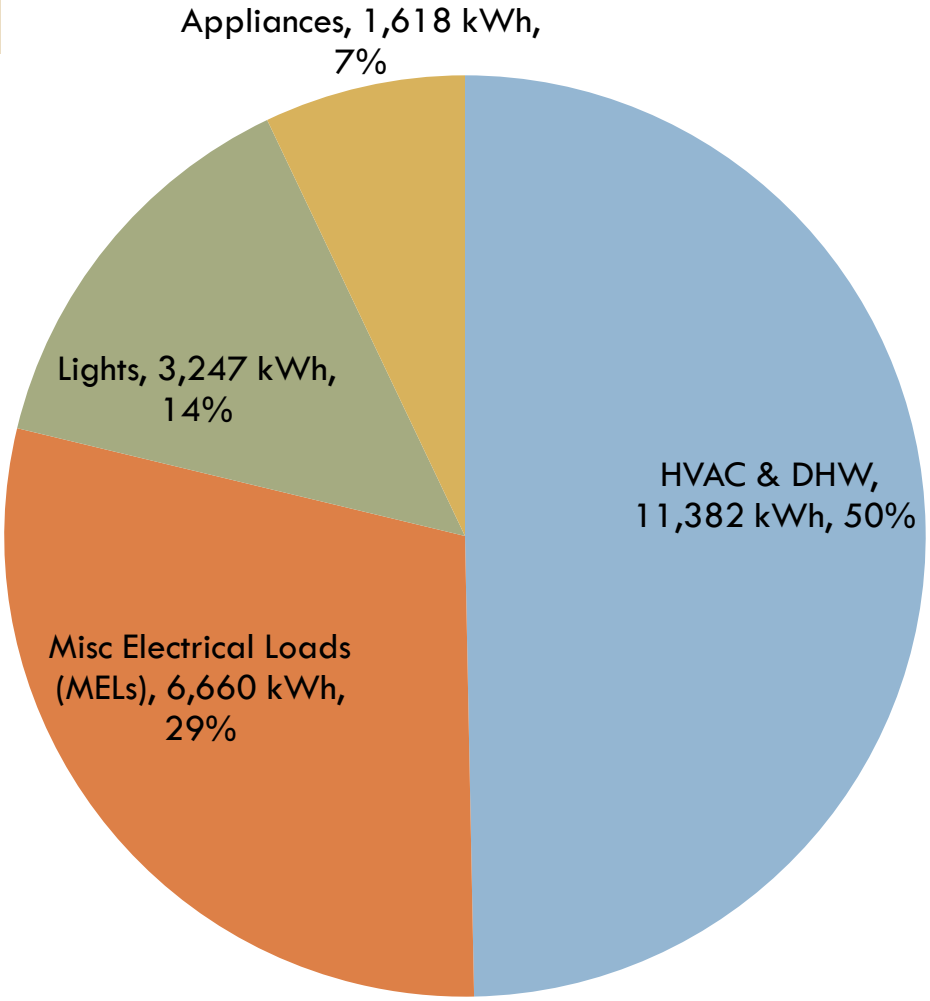


P2 Total Monthly Site Energy Use

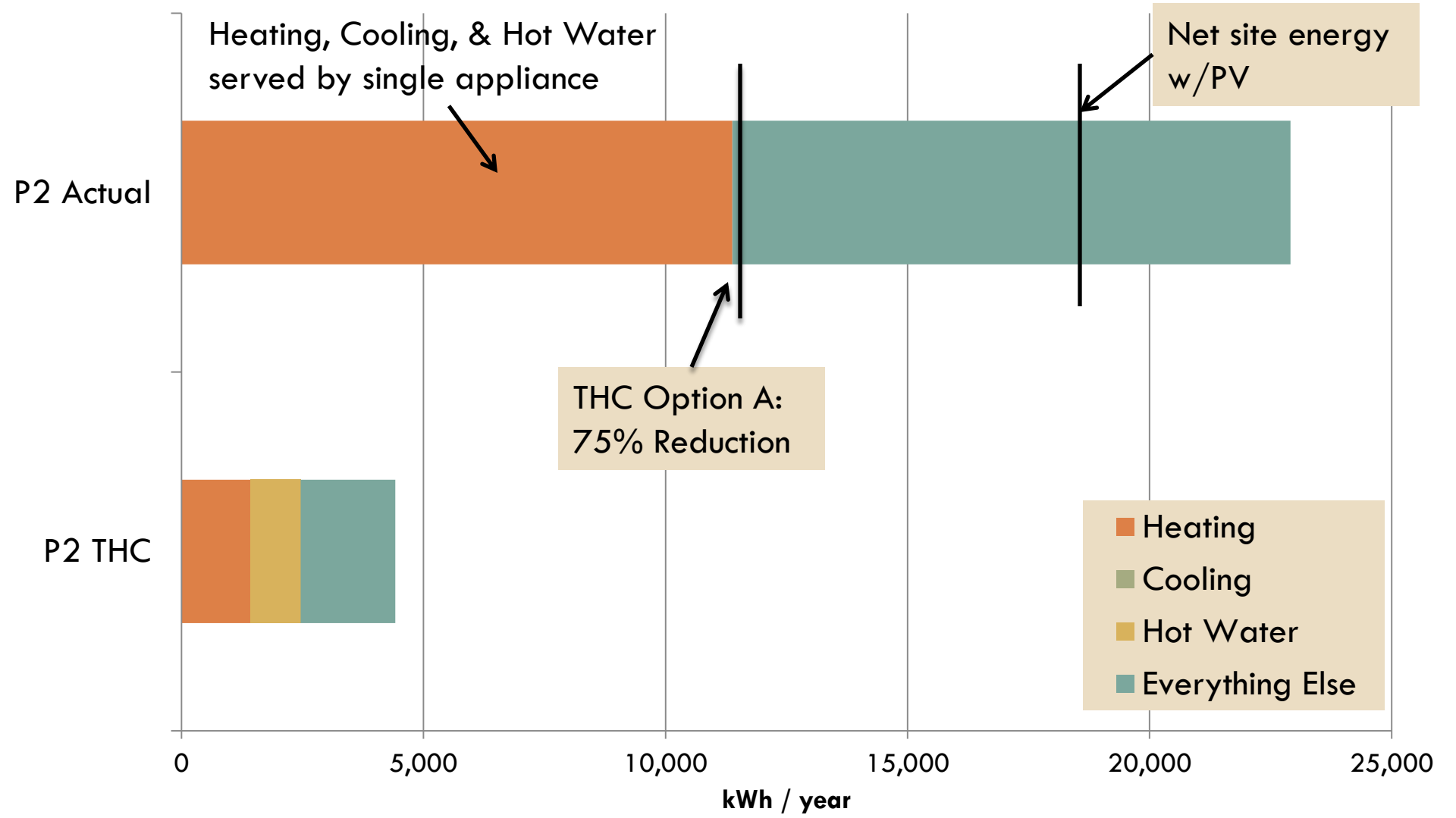


P2 Annual Energy End Uses

100% Electric home



P2 THC Option B End Use Vs. Actual (kWh/year)

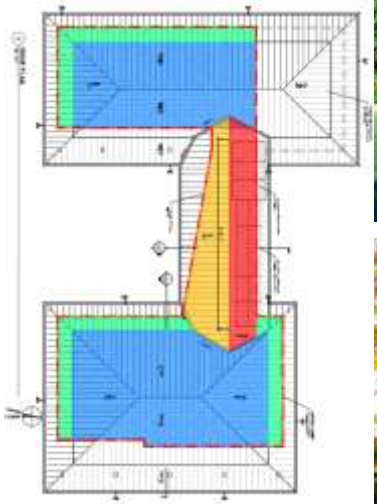


P3 Project Description

Check out the additional THC/ETC webinar about this project on 5/2/2012

Two 1958 ranch-style homes connected by a covered breezeway

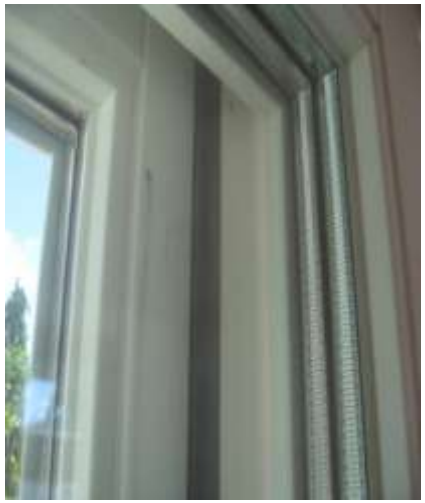
Pre: 1,933 ft^2 → Post: 2,342 ft^2



- The two structures were connected by forming a u-shaped home with a central courtyard
- 3 bedrooms, 2 baths, 1 occupant, home office

P3	Pre-retrofit	Post-retrofit
ENVELOPE		
Wall Insulation	None	1: 3.5” dense-pack fiberglass, 5” EPS - R38 2: 5.5” dense-pack fiberglass, 2.5” EPS - R33
Roof Insulation	Vented attic, R19 batt insulation	15” blown fiberglass, 2.5” EPS - R68
Foundation Insulation	None	Slab edge: 3.75” rockwool - R16 1: 4.5” EPS - R19 2: 1.5” EPS, .6” Aerogel - R12.5
Windows	U: 1.2 SHGC: 0.8	3-pane, wood frame U: 0.125; SHGC: 0.53
Air Leakage		151 CFM_{50}, 0.0186 CFM_{50}/SA, 0.48 ACH_{50}
MECHANICAL		
Heating & Cooling	Gas boiler, air handler with hydronic coil	Mini-split heat pump, solar hydronic coil on ERV
DHW	Gas tank, 0.58 EF	(3) 4’X6’ solar thermal panels, 80-gallon insulated storage tank, gas tankless backup 0.82 EF
Ventilation	Kitchen & bath exhaust	ERV SER 81-83%, exhausts from bath & kitchen, supplies living room & bedrooms
Distribution	R4 ducts in attic	Ducted ERV, all within thermal envelope
LIGHTS/APP/MELs	All incandescent lights, old appliances	CFL & LED lights, new Energy Star appliances, 2nd refrigerator
RENEWABLES	None	2.15 kW PV, 3 solar thermal panels

P3 Retrofit Description



P3 Retrofit Description

P3 Net-Energy Performance

Gas used for hot water & cooking

CA Average

P3 Post-retrofit

Where pre-retrofit data is not available, CA average (2009, RASS for statewide single family) is used.

kWh / Pounds of CO2e

40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0

-74%

THC Option B: 4,797 kWh

-62%

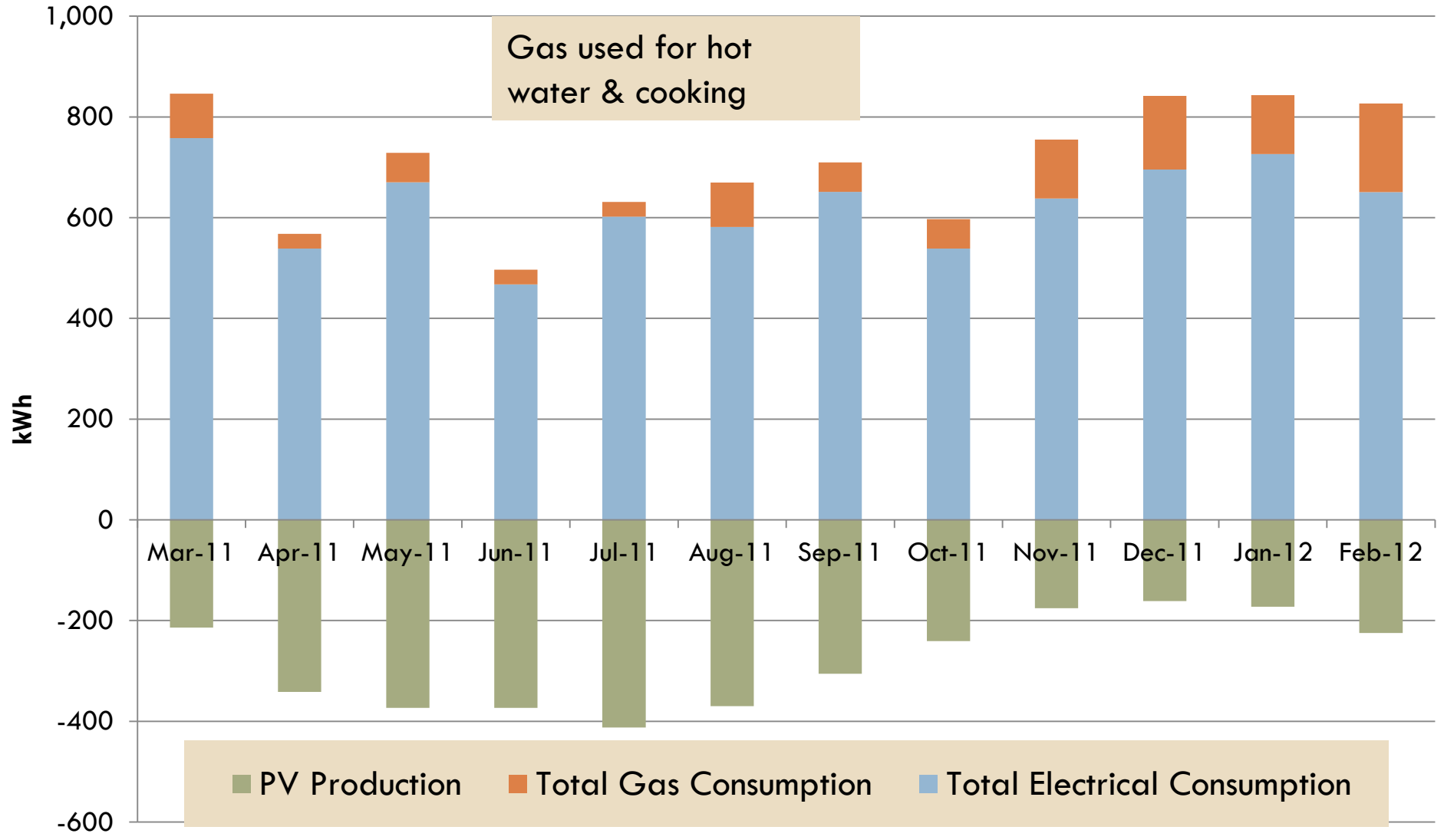
-67%

Total Net Site kWh

Total Net Source kWh

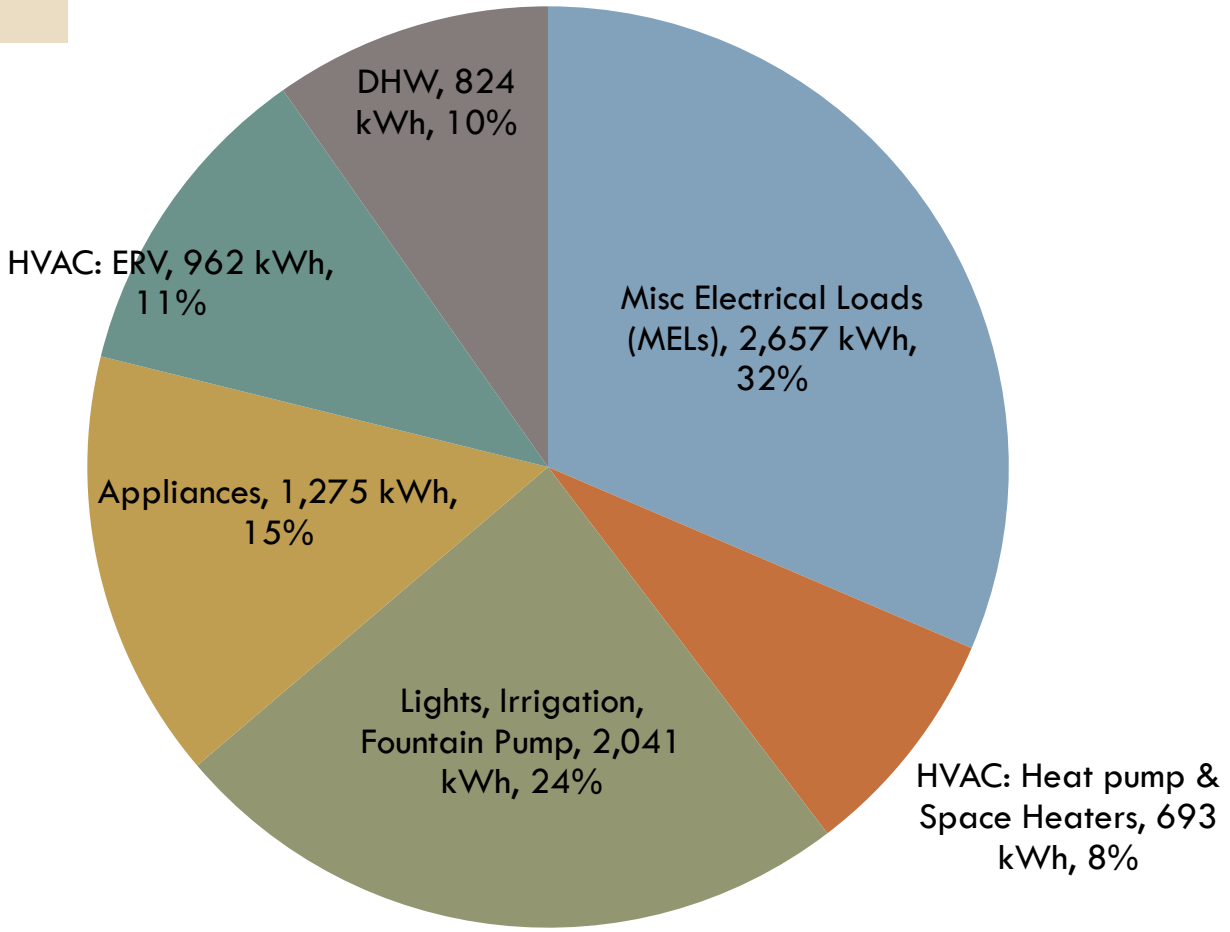
CO2e Total

P3 Total Monthly Site Energy Use

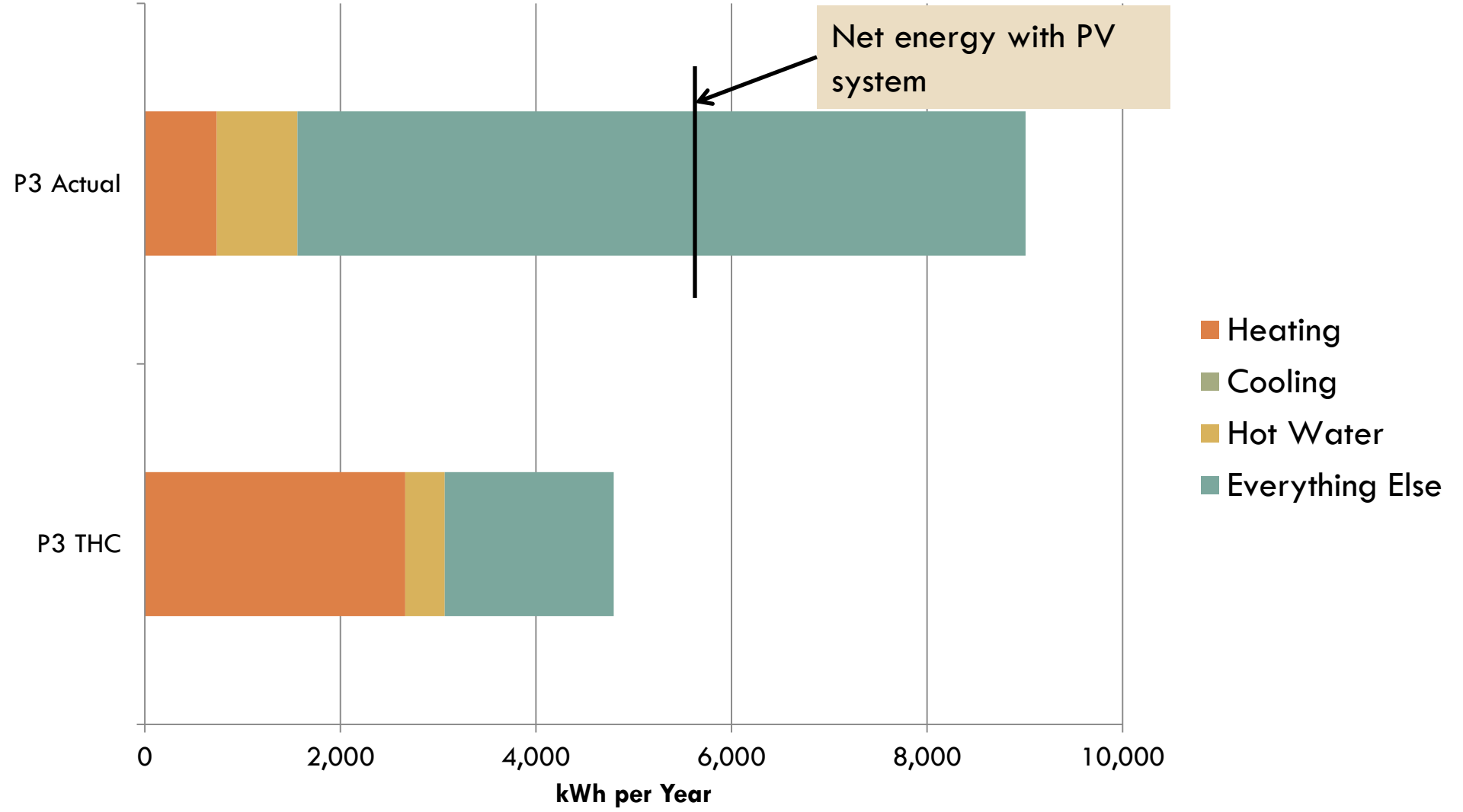


P3 Annual Energy End Use

Gas used for hot water & cooking



P3 THC Option B End Use Vs. Actual (kWh/year)



P4 Project Description

Check out the additional THC/ETC webinar about this project on 4/25/2012

1000 Home Challenge

1940's Bungalow
Petaluma, CA

Pre: 1,540 ft^2 ⟶ Post: 2,510 ft^2

3-phase retrofit

1 - 1998 prior to moving in

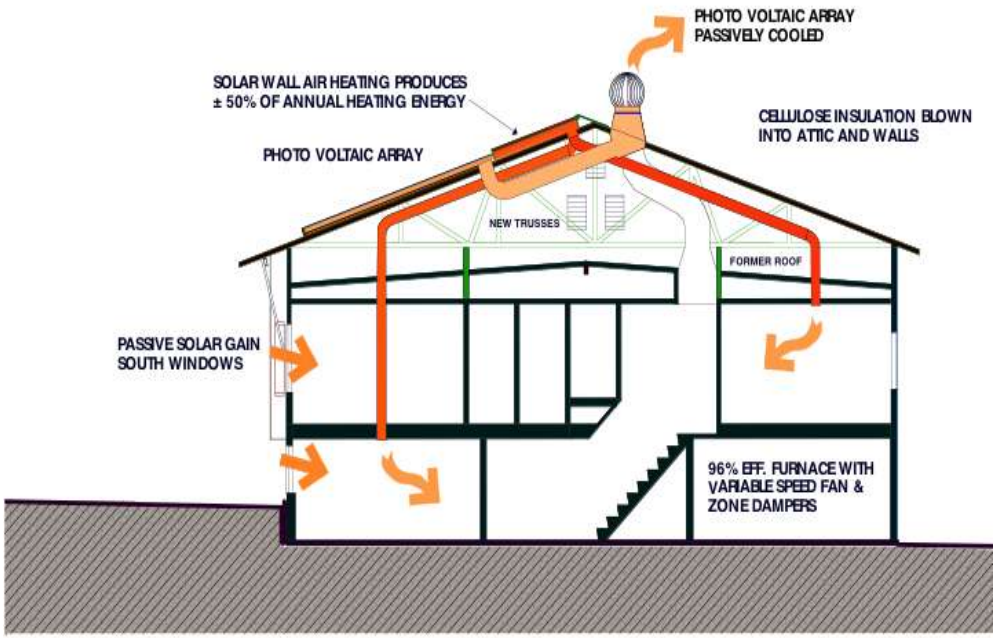
2 - 2004 added renewable energy

3 - 2010 a structural/seismic retrofit

- Phase 4 - Planning to reach net zero carbon
- 1st home to officially meet THC in CA!
- 2 bedrooms, 2 baths, 2 occupants, home office

P4	Pre-retrofit	Post-retrofit
ENVELOPE		
Wall Insulation	None	1: 5.5” dense pack cellulose - R19 2: 3.5” dense pack cellulose - R13
Roof Insulation	None	12” loose fill cellulose - R43
Foundation Insulation	None	Stem wall: 1.5” XPS - R7 exterior
Windows	1-pane aluminum frame	2-pane, Low E, argon filled, fiberglass frame U: 0.32
Air Leakage		1,983 CFM_{50}, 0.322 CFM_{50}/SA, 5.4 ACH_{50}
MECHANICAL		
Heating & cooling	Gas furnace, 40% eff	Condensing gas furnace, variable speed fan, 2-stage gas valve, 96.1 AFUE, 200 ft^2 of SolarWall with 500 CFM supply fan
DHW	Gas tank, 0.58 EF	Condensing gas tankless, .80 EF, demand recirc pump
Ventilation	Kitchen exhaust, vented to inside	Bath & kitchen exhaust, natural vent stack; SolarWall 500 CFM fresh air supply fan
Distribution	Sheet metal ducts	Manual central dampers added to ducts, supply leakage: 61 CFM; return leakage: 99 CFM
LIGHTS/APPLIANCES/ MELs	All incandescent lights, old appliances	CFL & LED lights, top 10% Energy Star appliances
RENEWABLES	None	2.5 kW PV

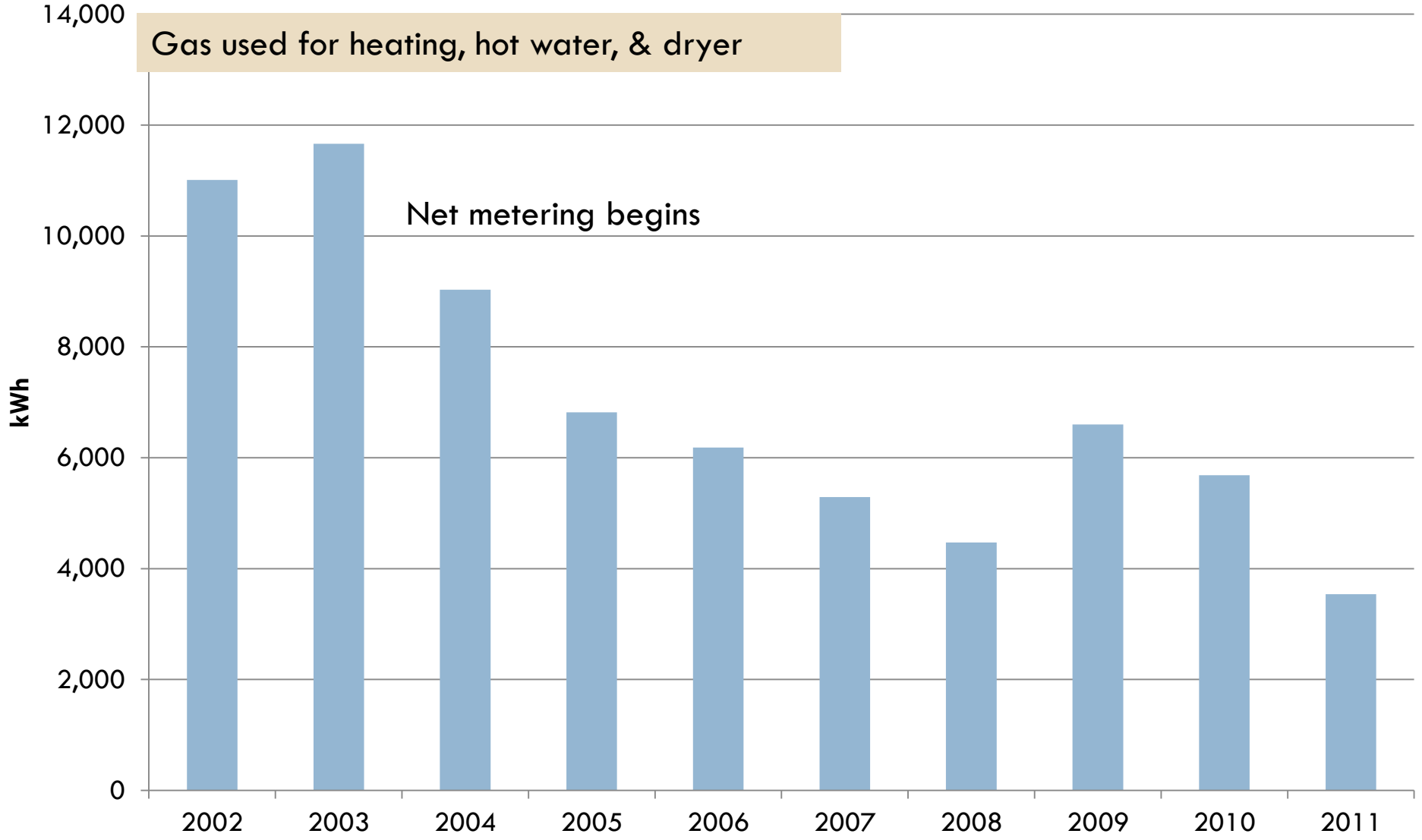
P4 Retrofit Description



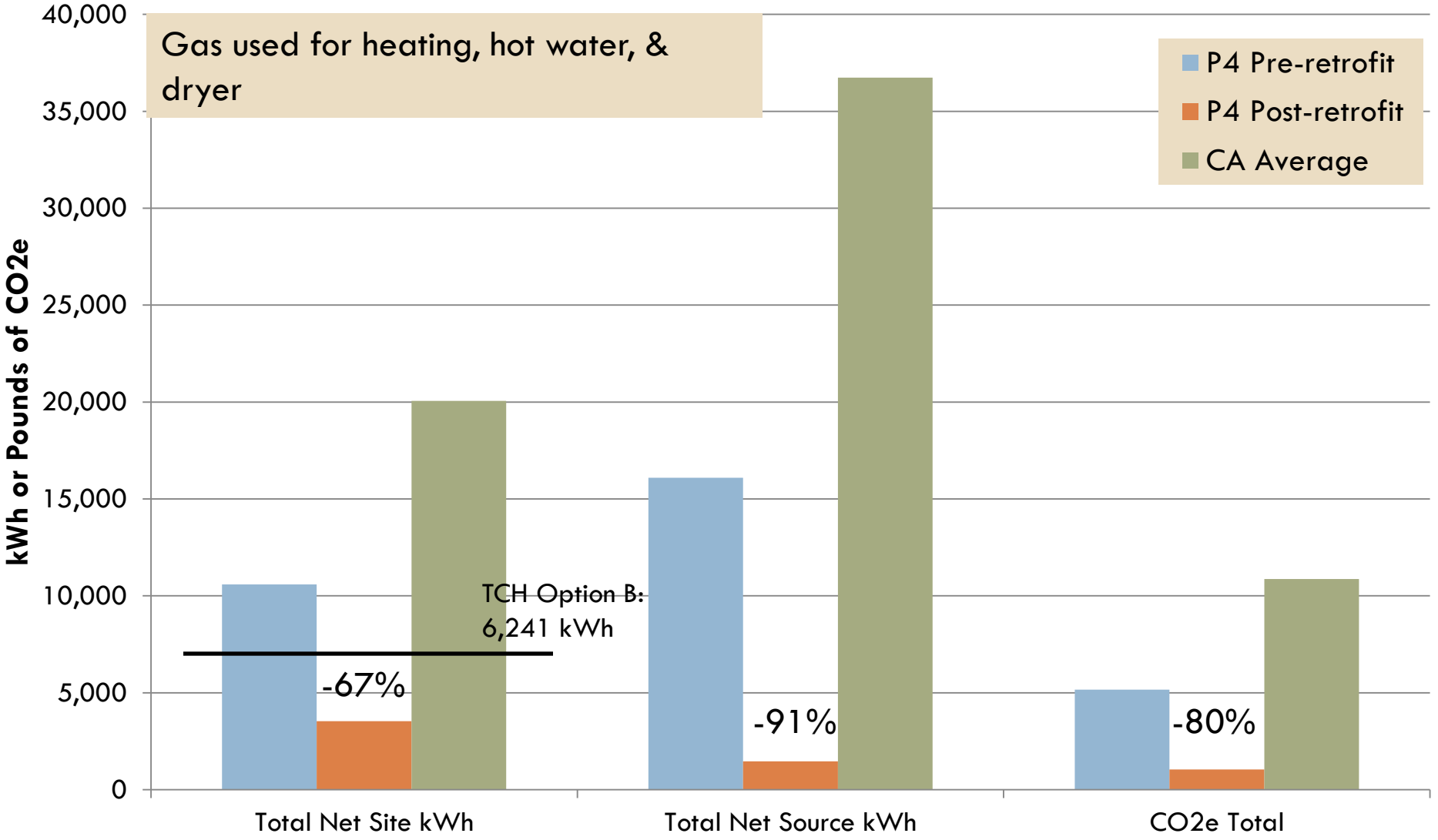
WINTER FEATURES · BUILDING SECTION

AIM ASSOCIATES
100 FAIR STREET, PETALUMA CALIFORNIA

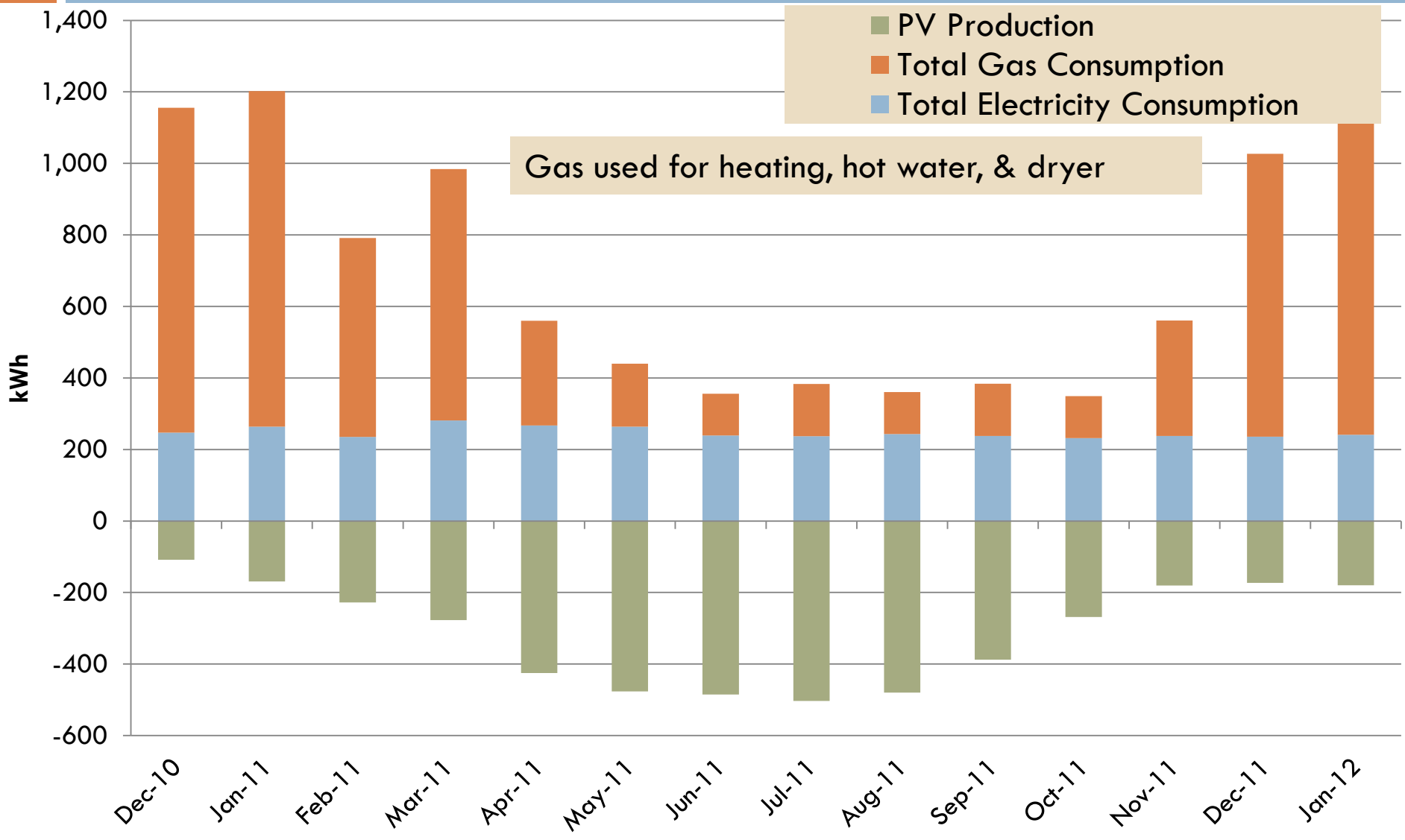
P4 Historical Utility Bill Data



P4 Net Energy Performance

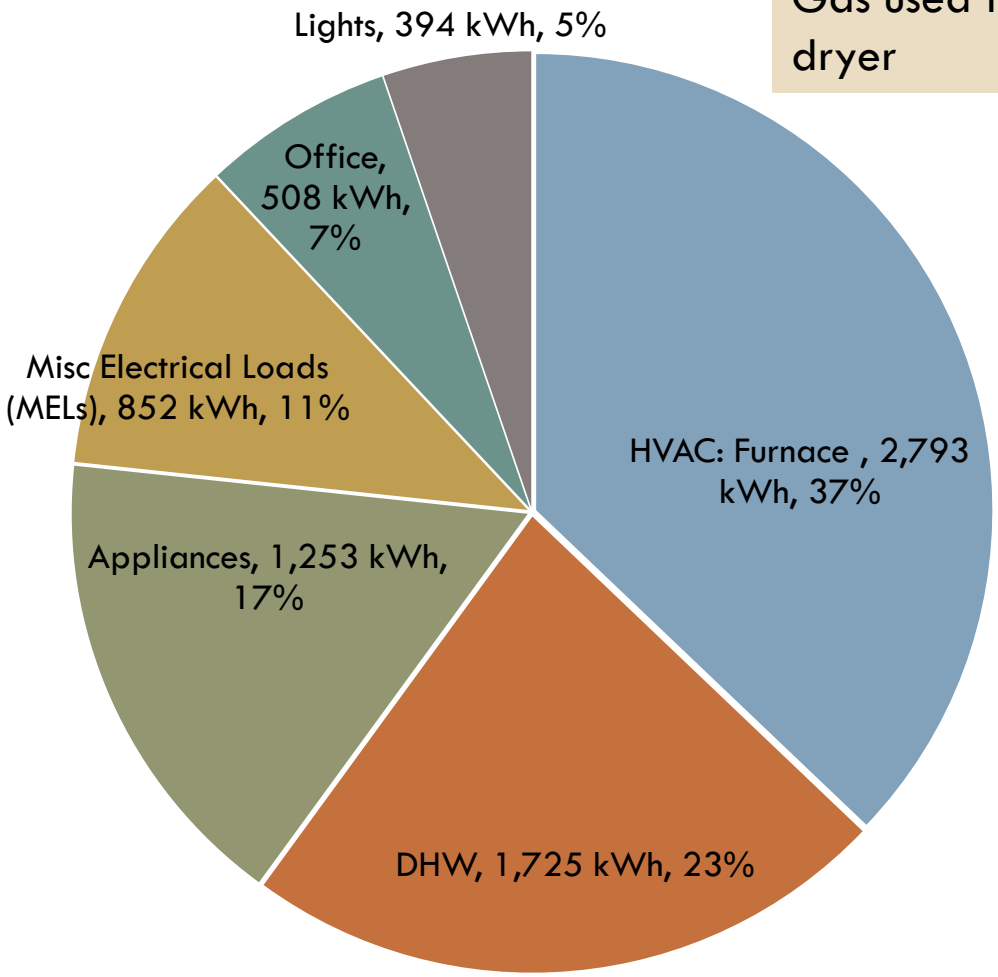


P4 Total Monthly Site Energy Use

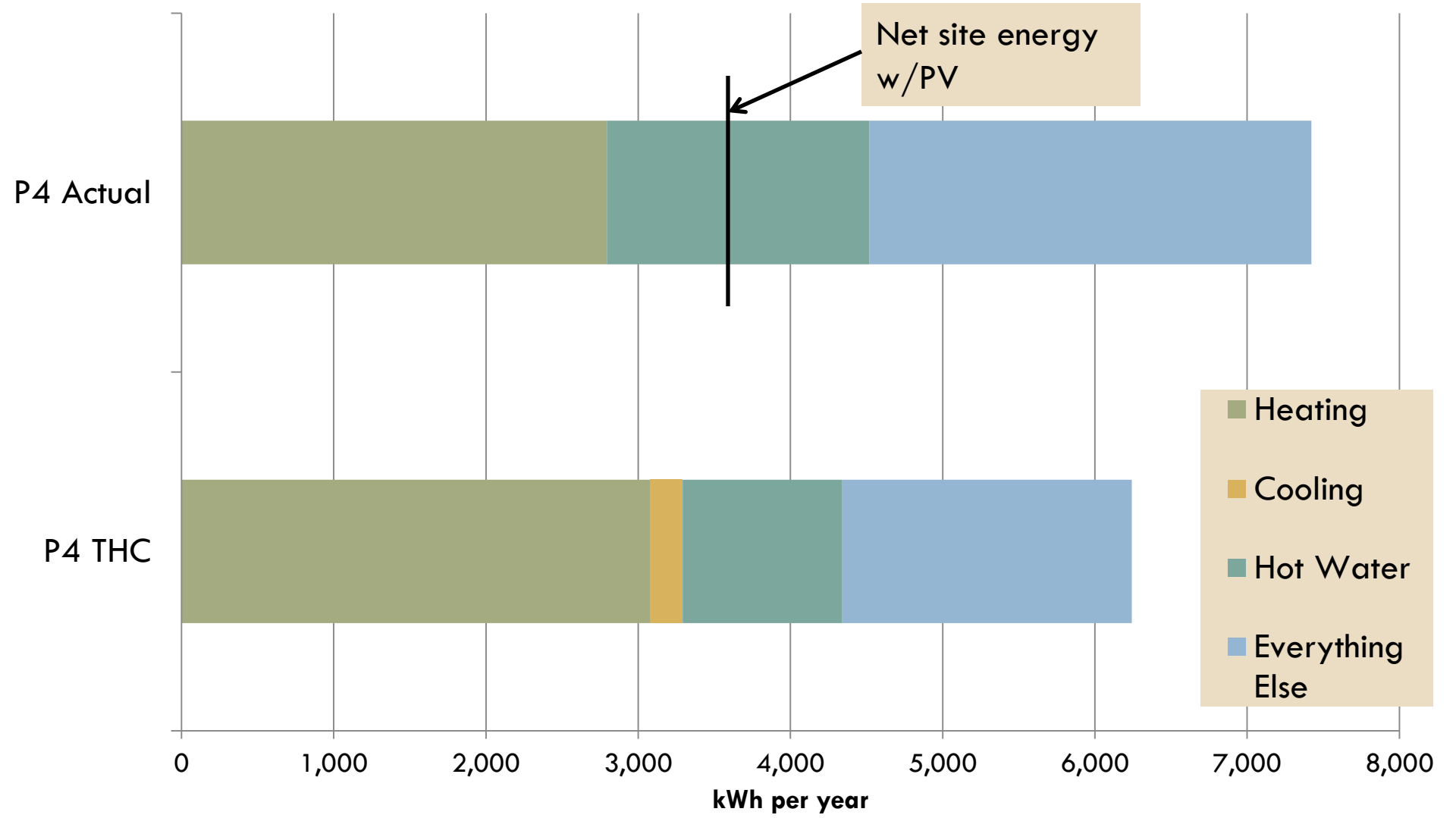


P4 Annual Energy End Use

Gas used for heating, hot water, & dryer



P4 THC Option B End Use Vs. Actual (kWh/year)



P5 Retrofit Description

1920's 2-bedroom house

Pt. Reyes Station, CA

Pre: 800 ft^2 ⟶ Post: 905 ft^2

- Community Land Trust Association of West Marin (CLAM) bought the property & funded the retrofit to rent to "very low-income households"
- 2 bedrooms, 1 bath, 3 occupants

Most images sourced from: http://www.clam-ptreyes.org

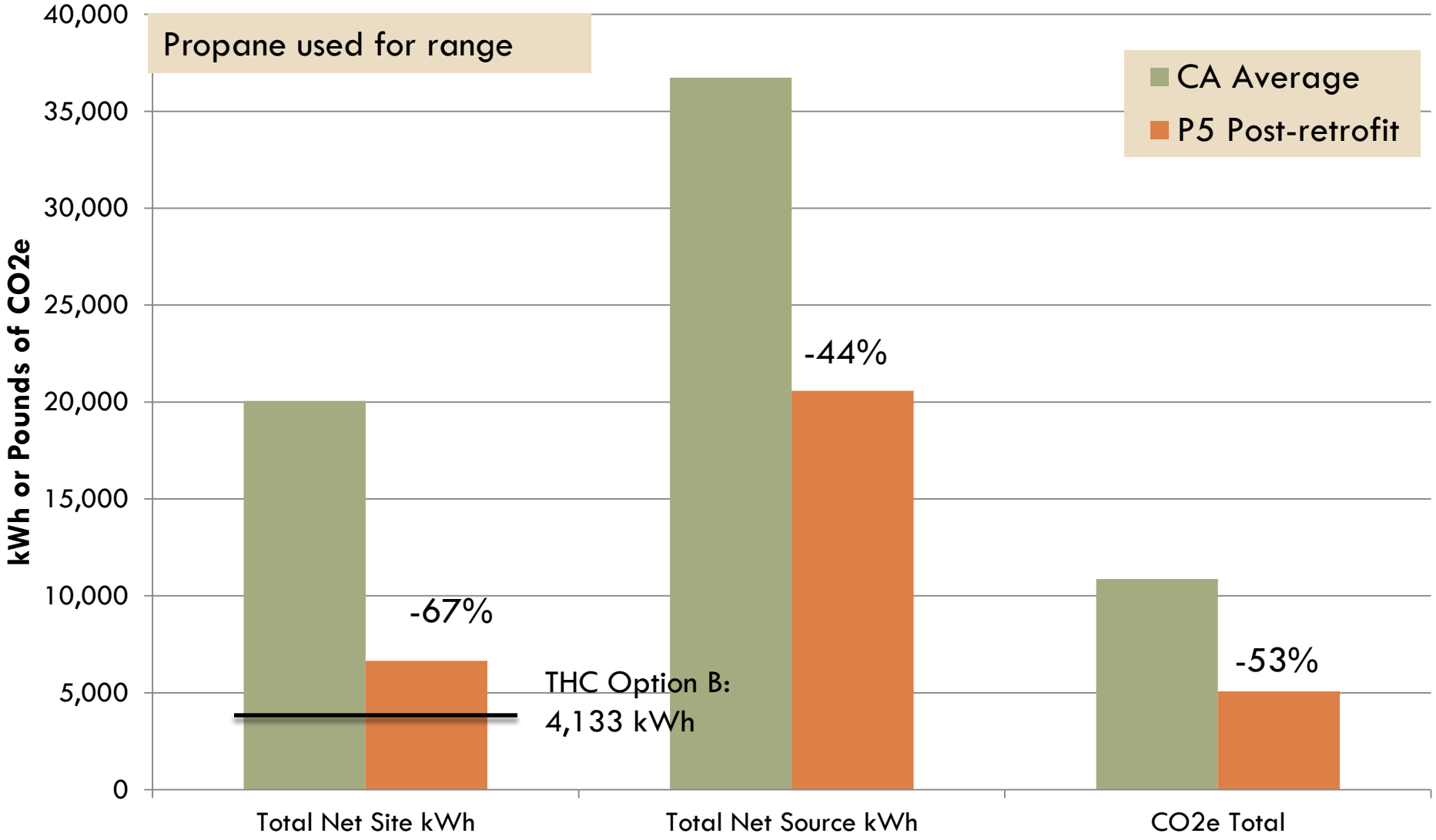
P5	Pre-retrofit	Post-retrofit
ENVELOPE		
Wall Insulation	3.5” fiberglass batts	3.5” cellulose, 1” ext XPS - R18
Attic/Roof Insulation	Some fiberglass batts	16” loose fill cellulose - R57
Foundation Insulation	R19 fiberglass batts	Sealed crawl space, 11.5” blown cellulose in floor framing - R41
Windows	Single pane aluminum frame	2-pane, Low E, argon filled, fiberglass frame. Unknown values
Air Leakage		292 CFM_{50}, 0.097 CFM_{50}/SA, 2.4 ACH_{50}
MECHANICAL		
Heating	Wood fireplace	Electric wall radiators
DHW		40-gal. electric tank; EF 0.88
Ventilation		Bath & kitchen exhaust, point source ERV
LIGHTS/APPLIANCES/MEL		Mostly CFL, very low MELs

P5 Retrofit Description

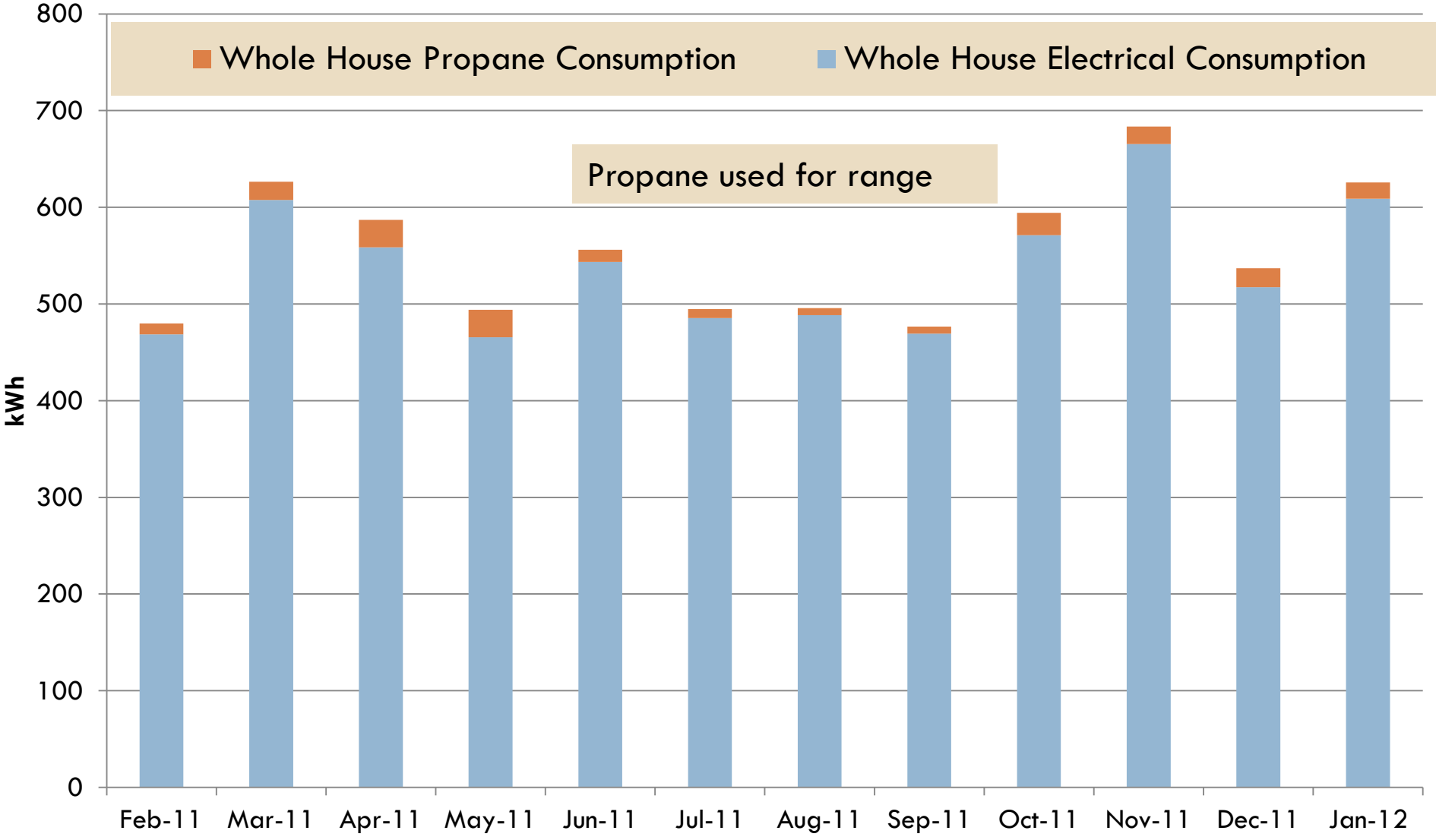
Crawl space
R41 insulation in floor

P5 Retrofit Description

P5 Annual Net Energy Performance

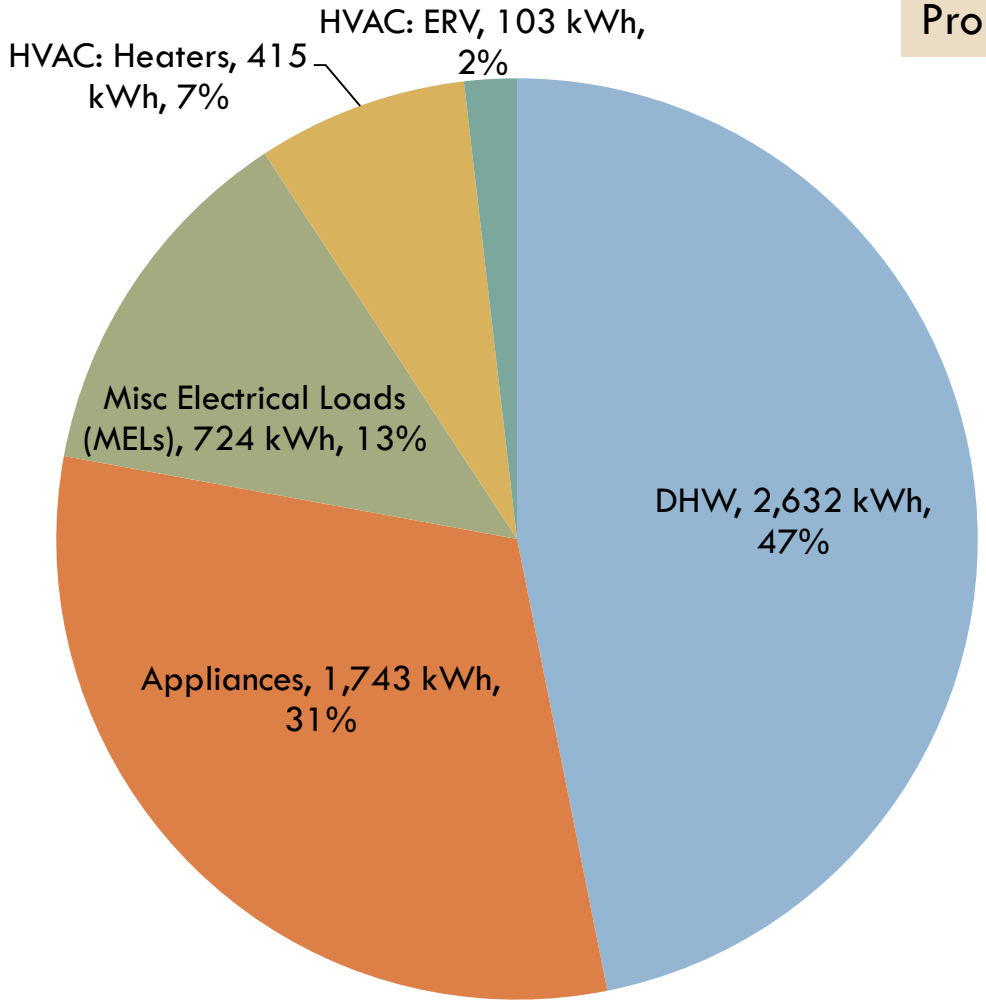


P5 Total Monthly Energy Use

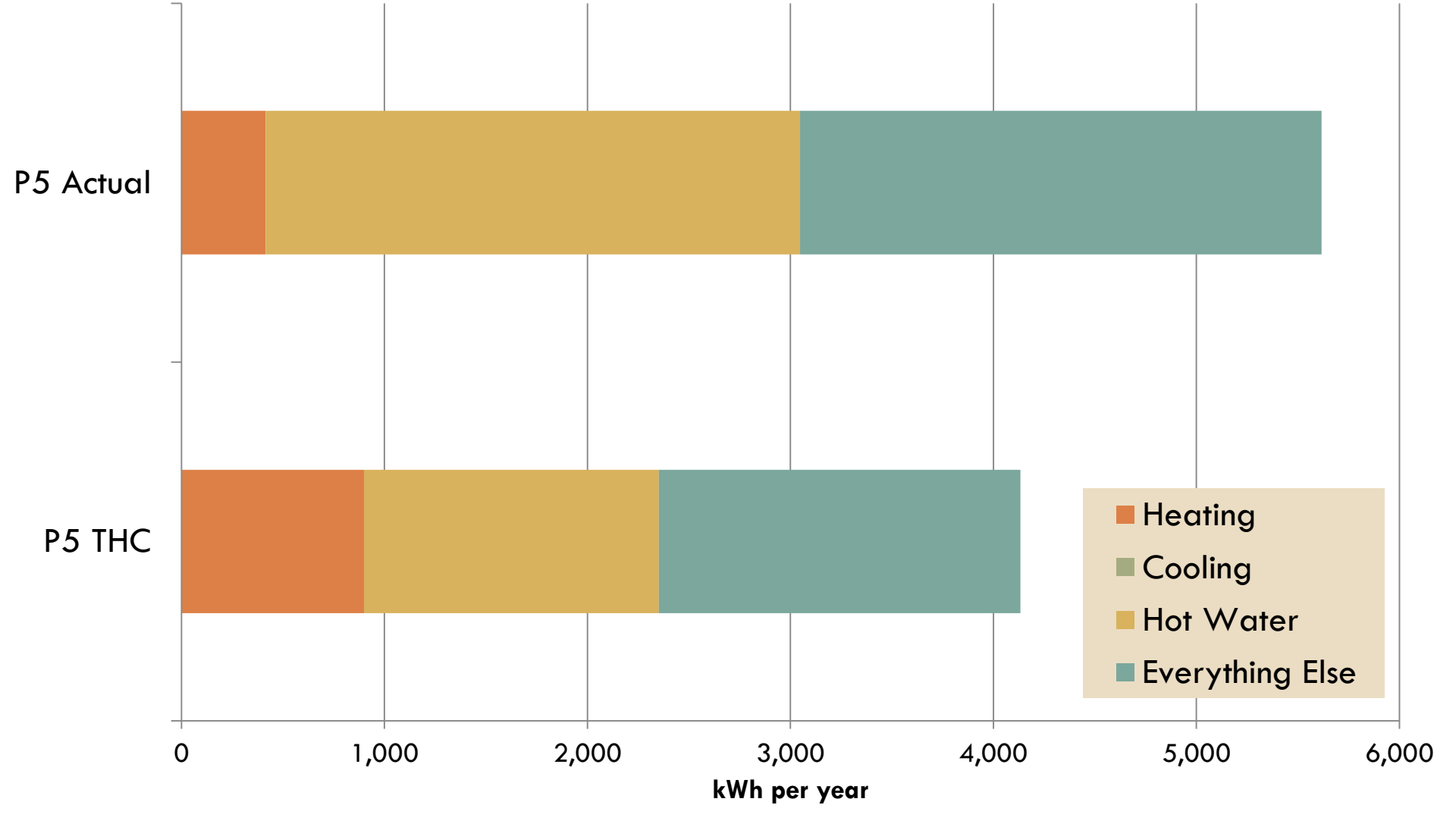


P5 Annual Energy End Use

Propane used for range



P5 THC Option B End Use Vs. Actual (kWh/year)



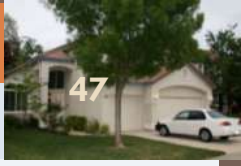
P9 Project Description

1998 Tract Home

Folsom, CA

Pre: 2,850 ft^2 ⟹ Post: 2,850 ft^2

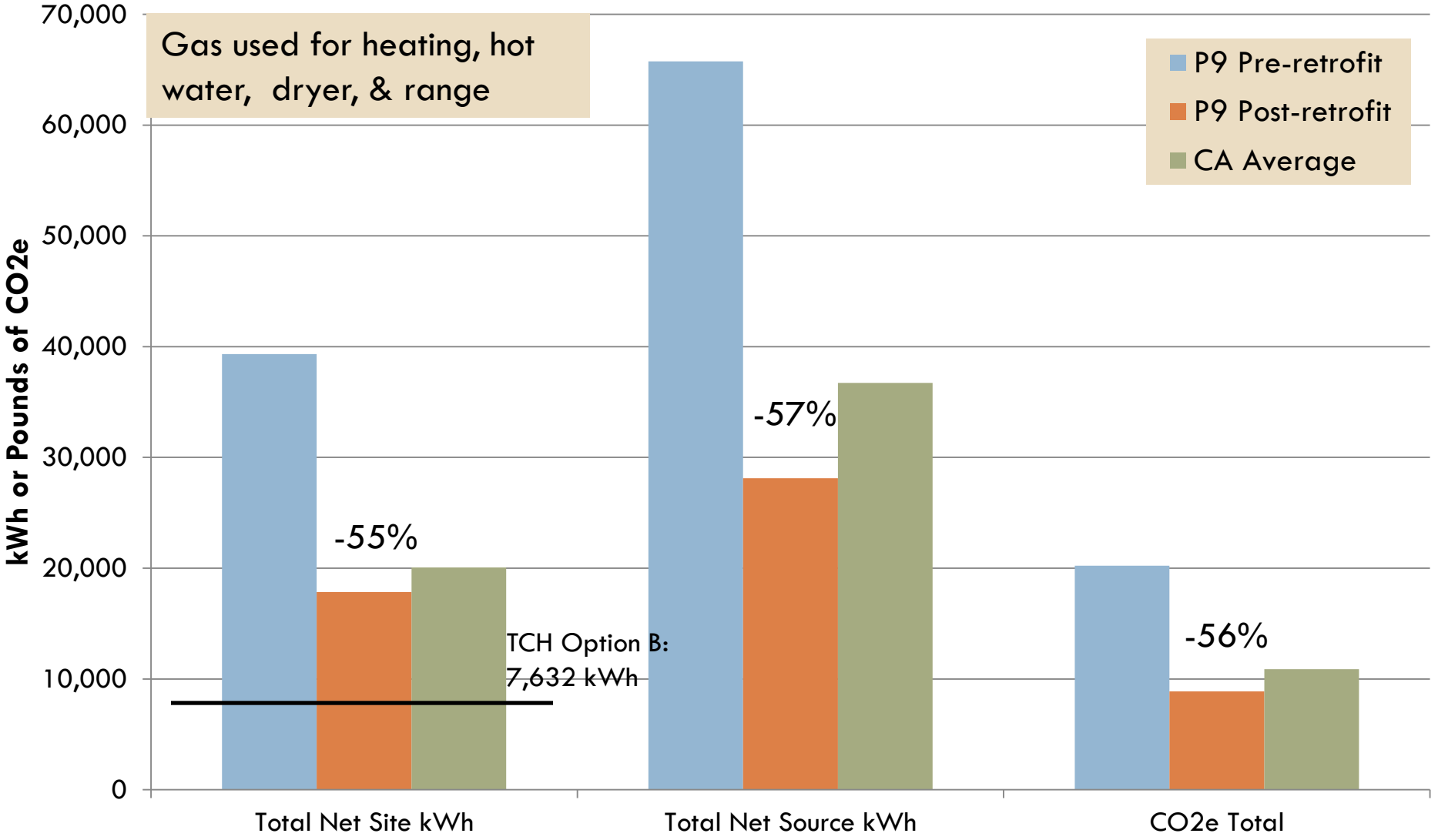
- SMUD Advantage home with a significant energy upgrade & a kitchen remodel
- Increased insulation, air sealed, lighting retrofit & an extensive HVAC overhaul
- 3 bedrooms, 2.5 baths, 4 occupants



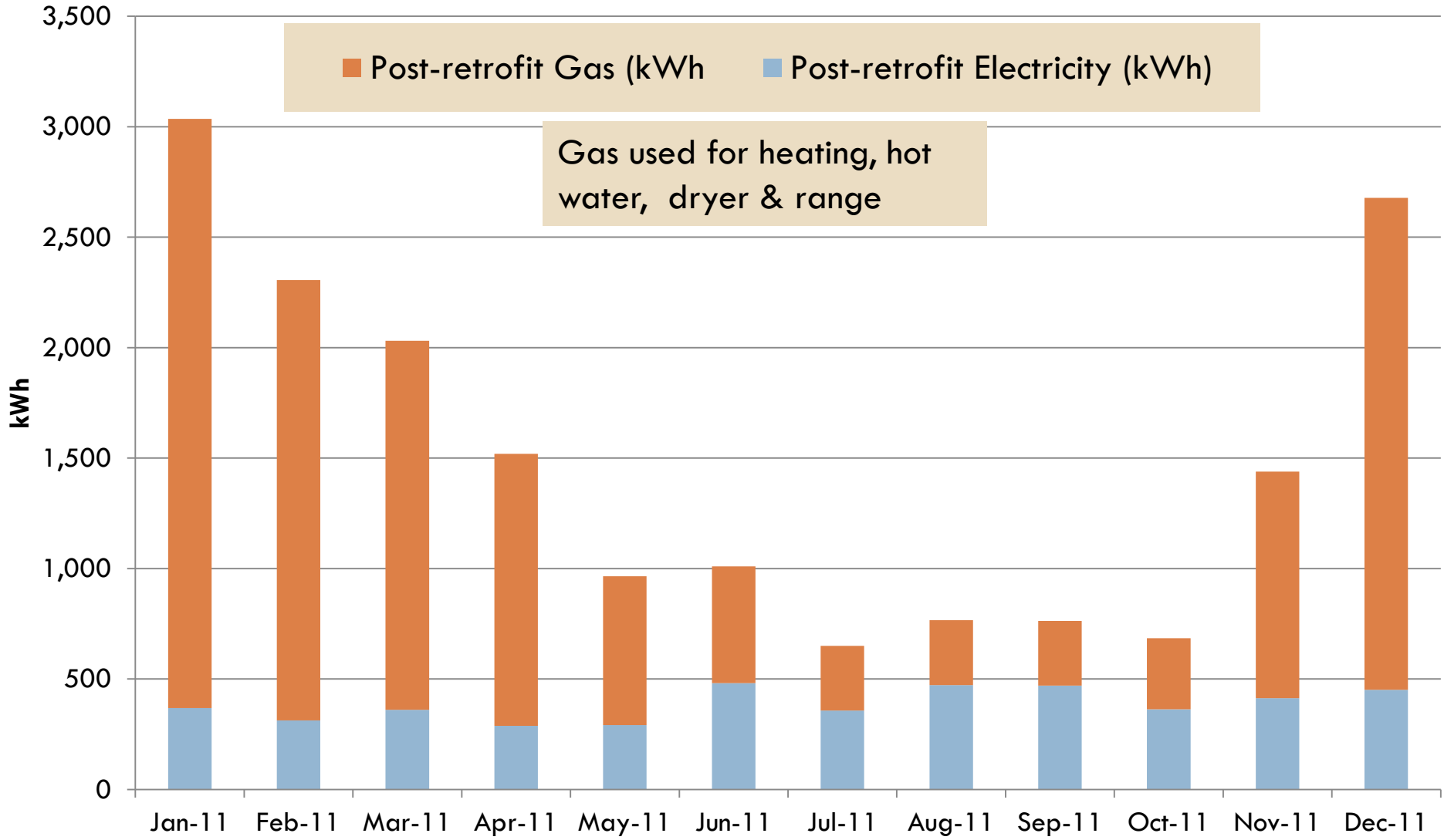
P9	Pre-retrofit	Post-retrofit
ENVELOPE		
Wall Insulation	Poorly installed Fiberglass batts -R13	Fiberglass batts - R13, improved installation & air sealed in Kitchen & stairs, insulated attic knee wall
Roof Insulation	Blown fiberglass	Increased to R40
Foundation Insulation	Uninsulated slab on grade	Garage ceiling R19 batts did not fill joist space, filled with cellulose
Windows	Double pane vinyl frame, Low E	Added interior foam filled plantation shutters
Air Leakage	1,879 CFM_{50}	1,227 CFM_{50}, 0.183 CFM_{50}/SA, 2.44 ACH_{50}
MECHANICAL		
Heating	78 AFUE forced air furnace, 100 kBtu/hr	96 AFUE two-stage condensing furnace, disabled 2nd stage to limit capacity to 35 kBtu/hr
Cooling	Old 3.5 ton, 8 or 10 SEER	2-ton, 17 EER with evaporatively cooled condenser coil, charged refrigerant, replaced txv
DHW	40-gal. gas tank	40-gal. gas tank, insulated, recirc pump
Ventilation	Bath & kitchen exhaust	Night ventilation cooling integrated into 350W air handler. Bath exhaust, range hood
Distribution	R6 foil faced flex duct, unbalanced	Balancing dampers, repositioned ducts, buried in insulation, new return from master bed, jumper ducts, 2” MERV 8 filter, adjustable registers w/curved grills
LIGHTS/APPLIANCES/ MELs	Incandescent	11 watt LED recessed can fixtures, mix of CFL & LED everywhere else, new appliances exceed Energy Star by 10-15%, smart strips on all A/V & computers

P9 Retrofit Description

P9 Net Energy Performance



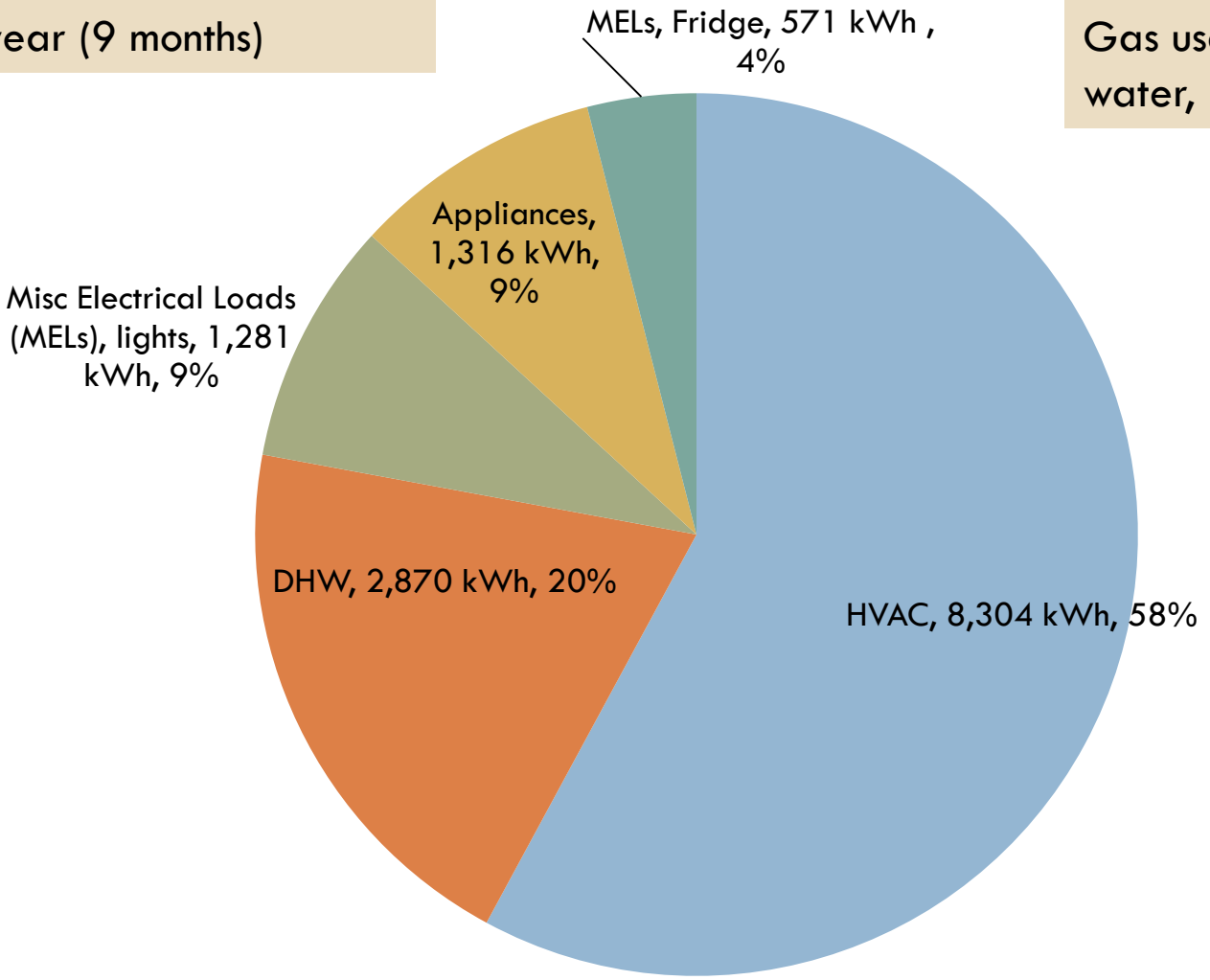
P9 Total Monthly Energy Usage



P9 Part-year Energy End Use

Not a full year (9 months)

Gas used for heating, hot water, dryer, & range



P10 Project Description

1000 Home Challenge

1938 Cottage

Pacifica, CA

Pre: 1,440 ft^2 ⟶ Post: 1,745 ft^2

- Family-built "Shamrock Shack" remodeled for retirement with goals of resource & energy efficiency, while maintaining original charm with modern comforts
- 2 bedrooms, 1.5 baths, 2 occupants

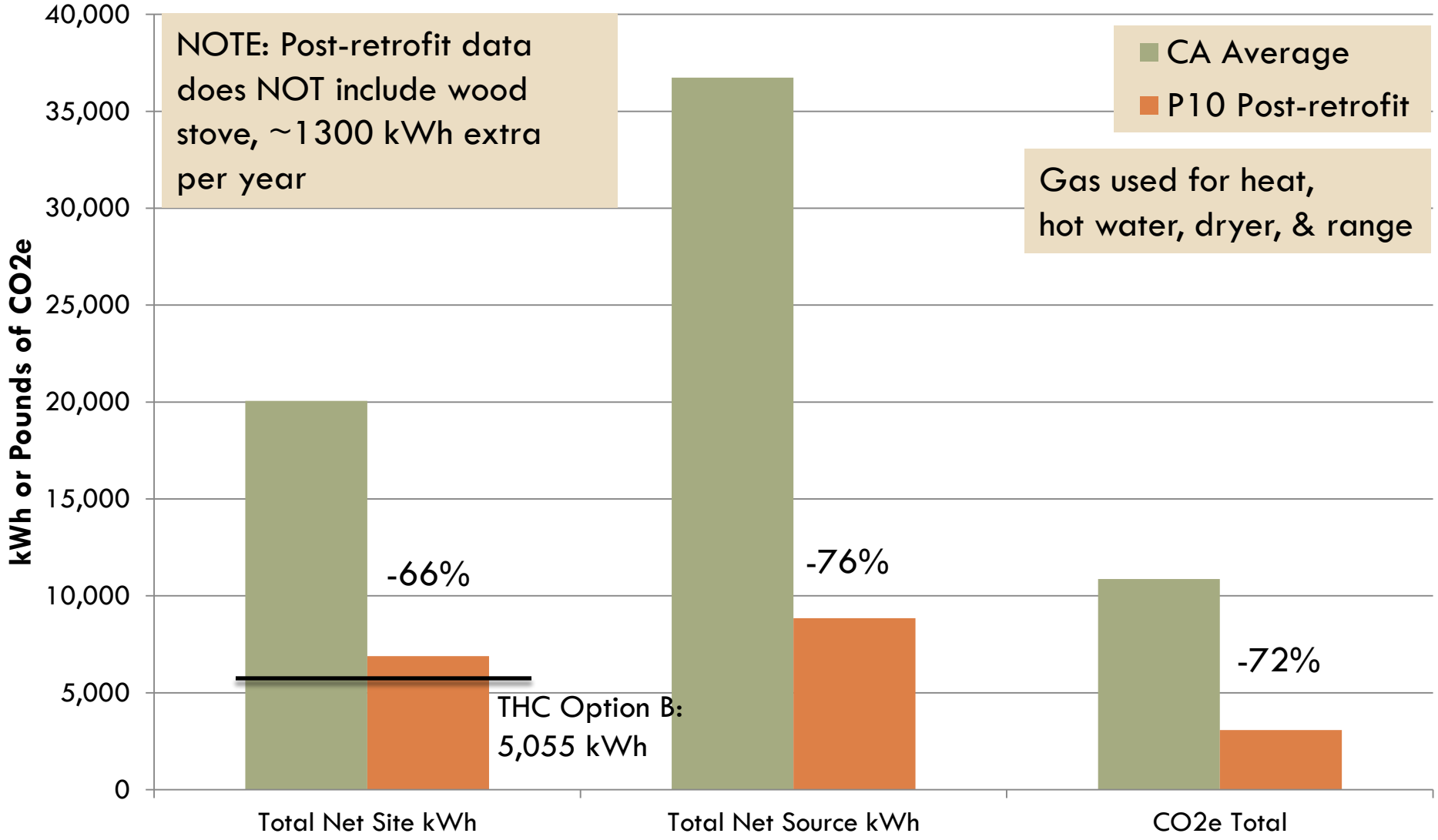
P10	Pre-retrofit	Post-retrofit
ENVELOPE		
Wall Insulation	None	3.5” LD spray foam - R13 5.5” LD spray foam in garden room - R19
Roof Insulation	None	7.5”- 9.5” LD spray foam - R25-R32
Foundation Insulation	None	4.5”- 6” LD spray foam - R16-R22
Windows	Single pane wood frame	Most windows replaced with 2-pane, Low E, argon, alum. clad; U: 0.29-0.34 SHGC: 0.23-0.32
Air Leakage		1,455 CFM_{50}, 0.288 CFM_{50}/SA, 6.1 ACH_{50}
MECHANICAL		
Heating & DHW	Wood fireplace	Woodstove, 75% thermally efficient; 2-panel solar thermal combi system with 96% efficient condensing gas boiler, 120-gal storage tank, zone controlled underfloor hydronic
Ventilation	None	Bath & kitchen exhaust
Distribution	None	Insulated PEX
LIGHTS/APPLIANCES/ MEL	Old, dark, inefficient	Energy Star appliances, CFL, LED & halogen lighting, skylights, & solar light tubes
RENEWABLES	None	3.3 kW PV

P10 Retrofit Description

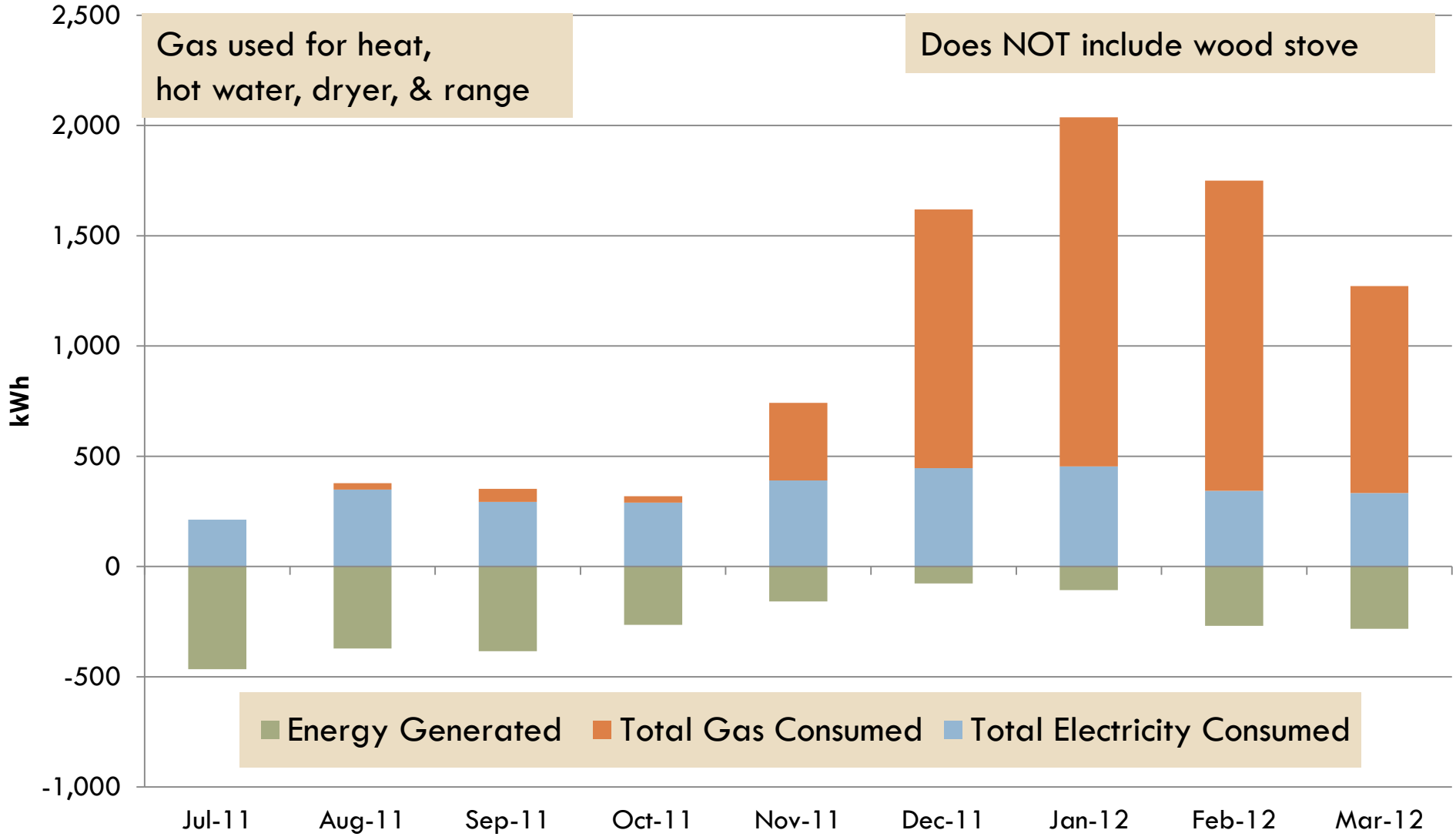
Solar combi system tank, in garage

Spray foam insulation in small addition

P10 Net Energy Annual Performar



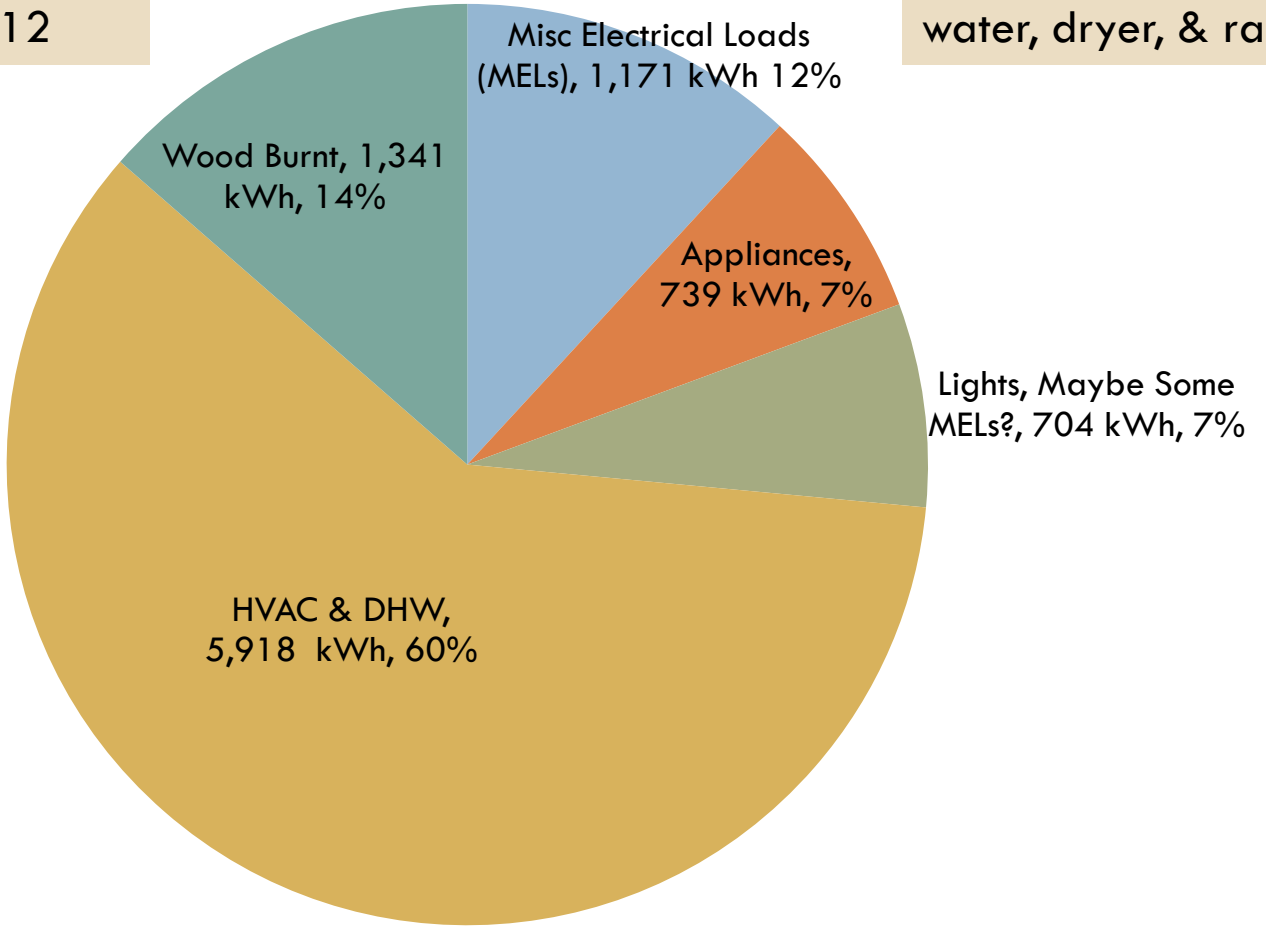
P10 Monthly Site Energy End Use



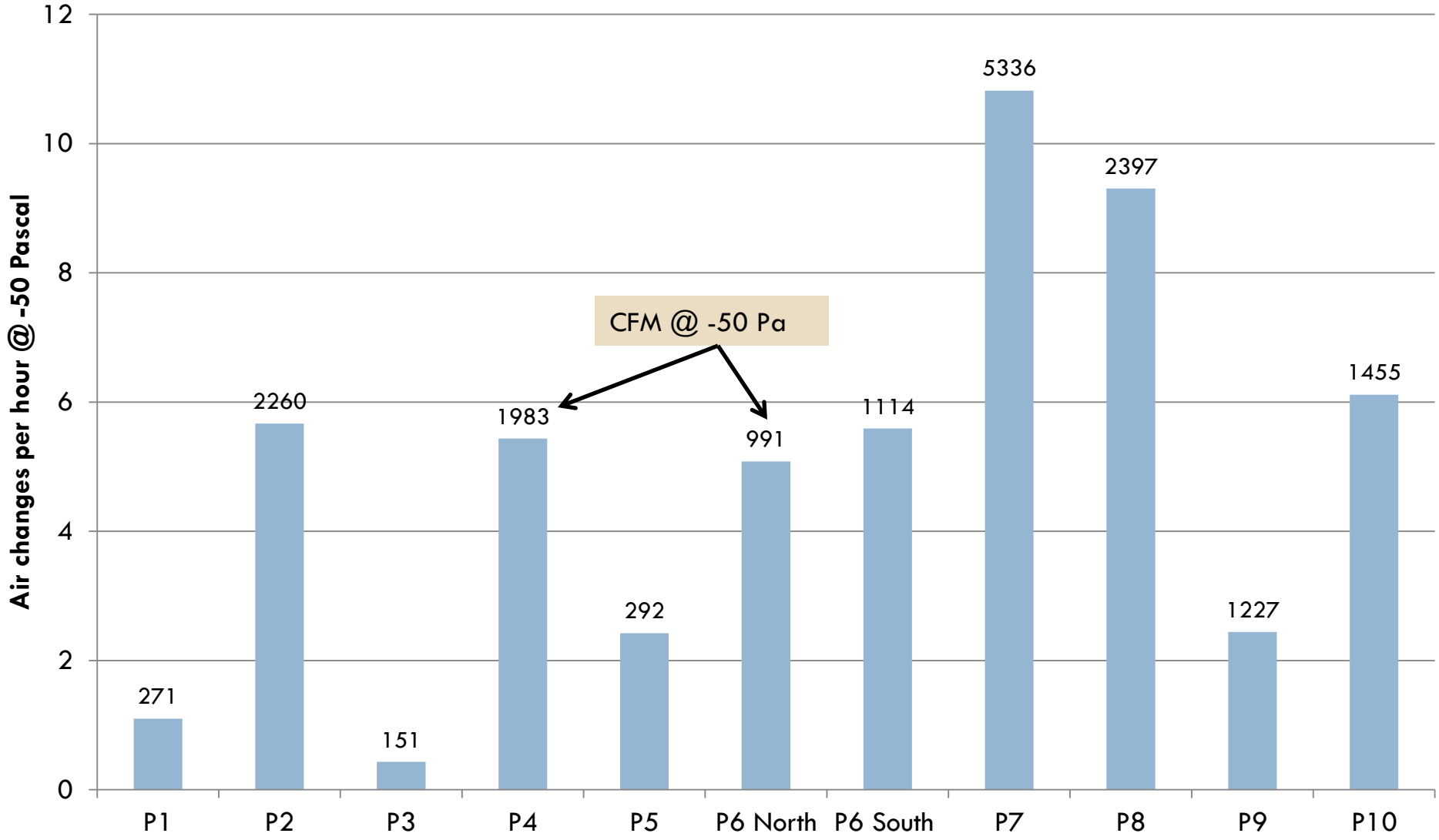
P10 Energy End Uses

NOTE: End uses not for full year, July ' 11 – March '12

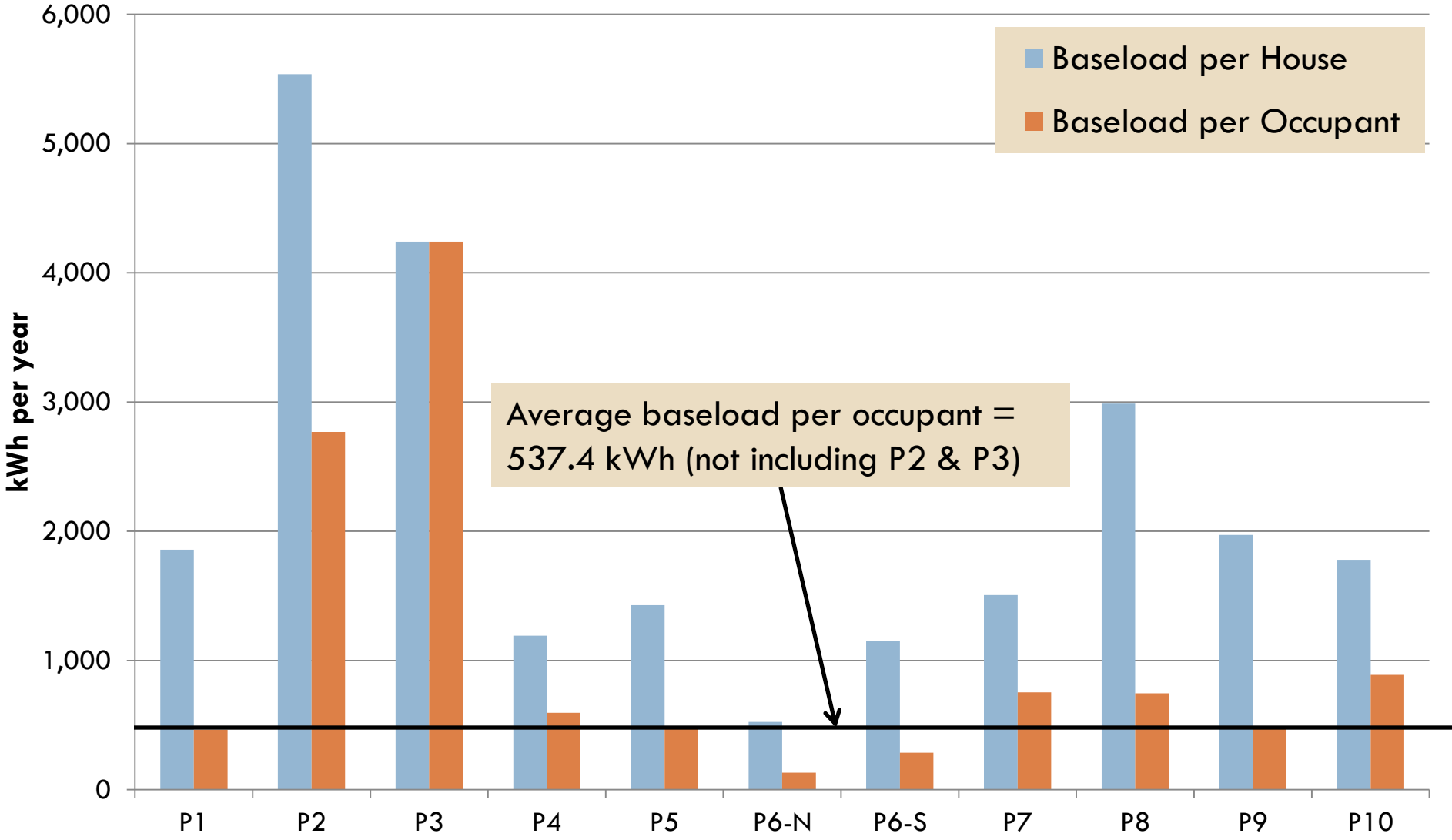
Gas used for heat, hot water, dryer, & range



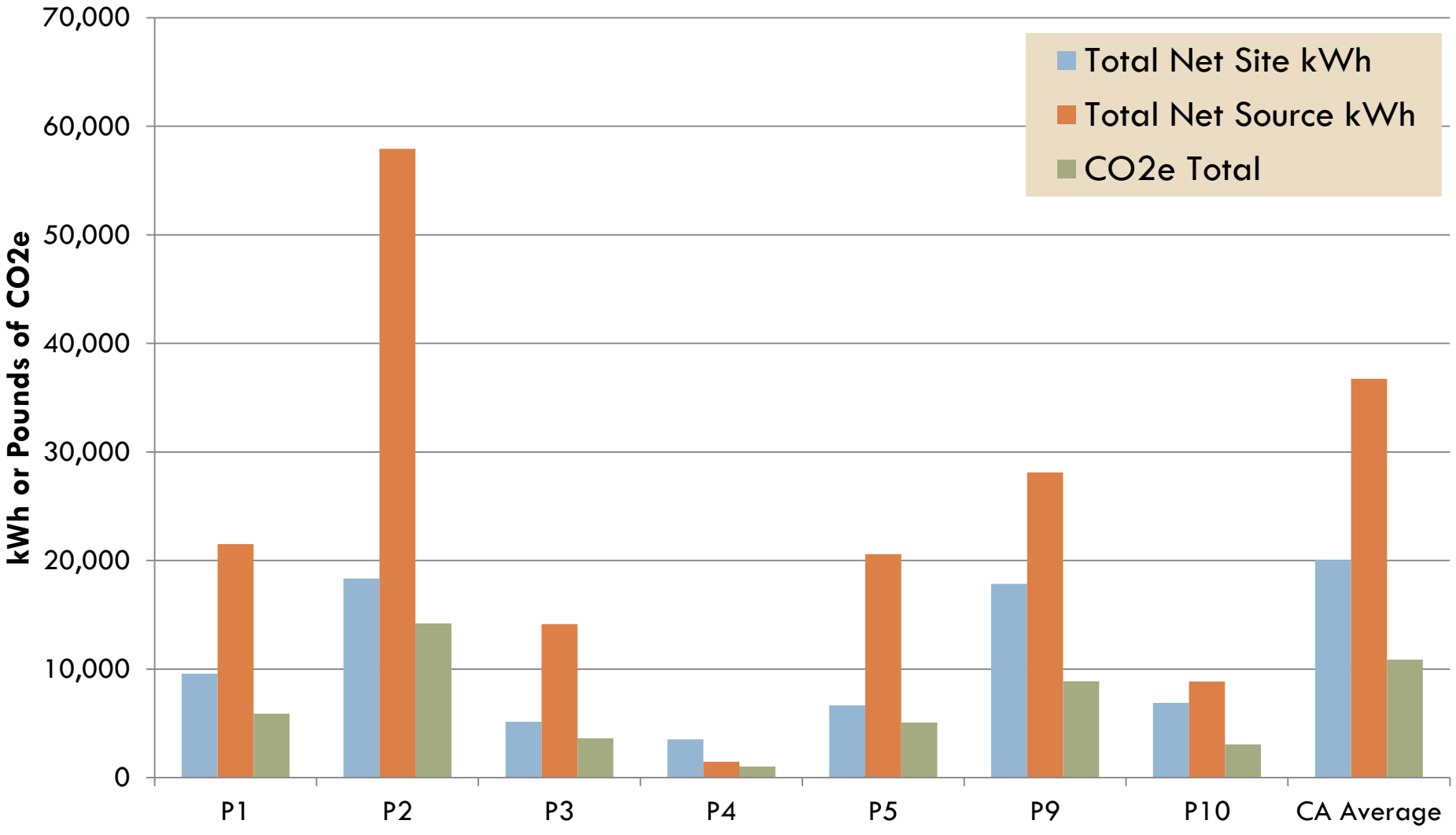
Airtightness of 10 Projects



Average Baseload Comparison Per House & Per Person

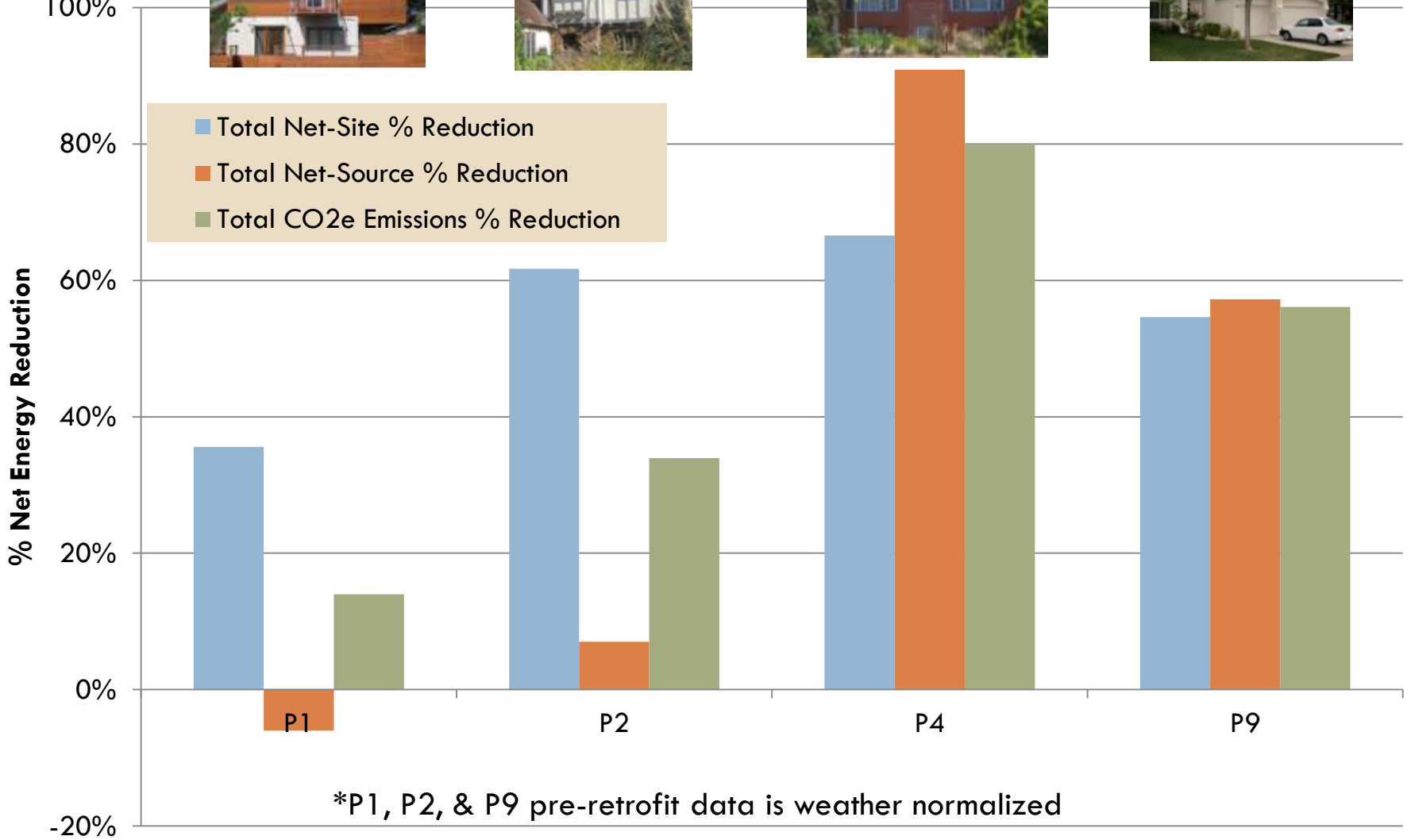


Post Retrofit Net Energy Usage

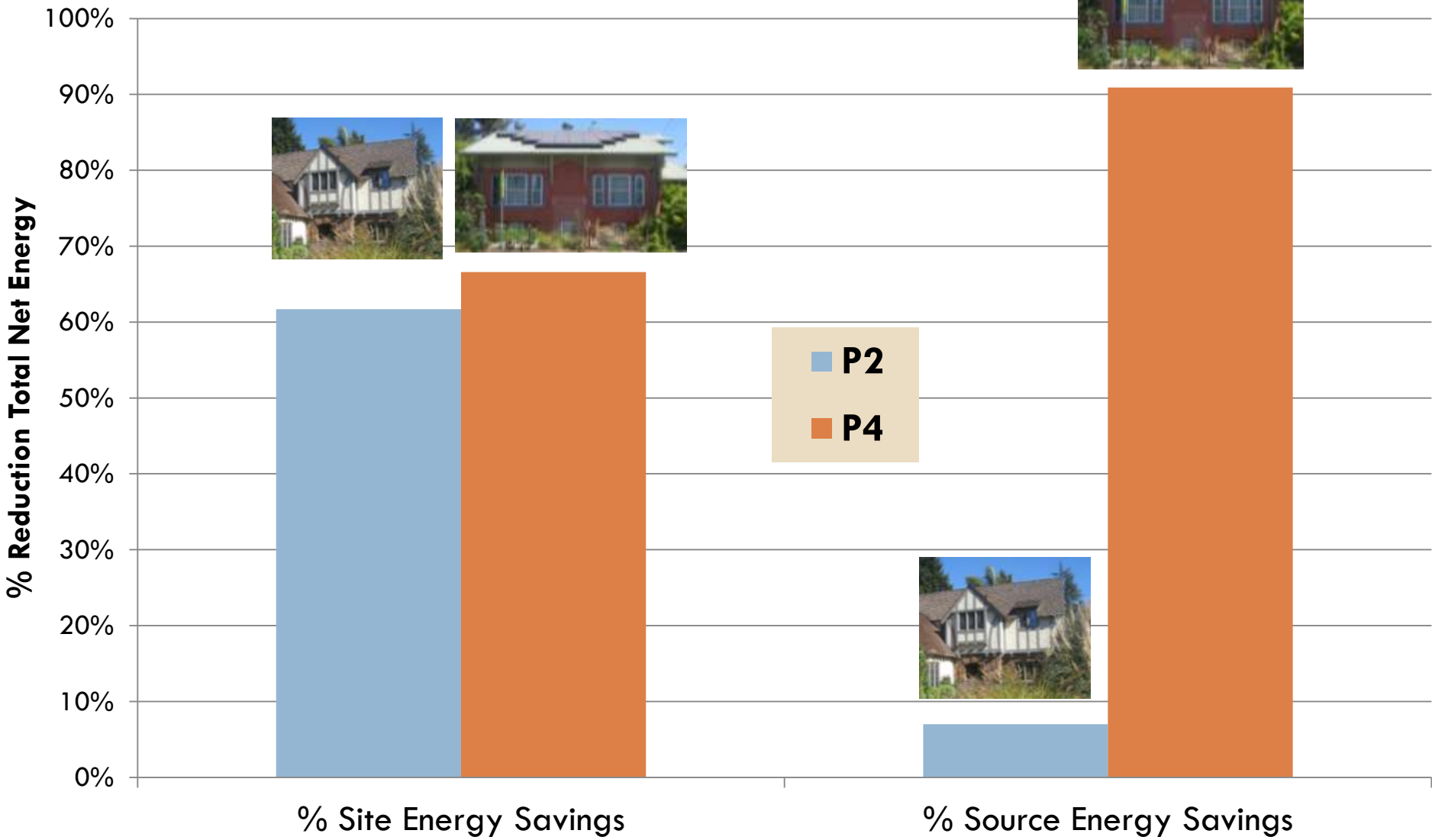


% Reduction in Net Energy Usage Across Metrics



Percent Savings Site & Source Energy P2 & P4



Lessons Learned

- There are a variety of paths to achieve deep energy savings; the most successful projects embrace multiple paths
  - Occupant behavior
  - Building enclosure
  - Building technologies
  - Design strategies
- Switching from gas to electric for heating can negatively affect source energy savings. Possible exceptions:
  - Ductless heat pump with COP >3
  - Heat pump water heater with COP>2.6
  - Major MEL reductions
- Heating & DHW still make up the majority (>50%) of annual energy use in most projects
- Misc electrical loads & baseload electricity are important (DVRs, servers, etc.)
- Complex systems seem prone to failure/high energy use, & may be less cost effective
- A DER should be thoroughly planned from the beginning to avoid mistakes & last-minute decisions that negatively affect deep energy reductions

Cost of Deep Energy Retrofit

- Benefits
  - Energy reductions, cost savings, tax incentives
  - Possibly more important for homeowners are increased thermal & acoustic comfort, IAQ, aesthetics, utility, & ecological impacts
- Remodeling Trends
  - 20 million remodels each year (AHS 2009)
  - Kitchen remodel costs $64K-$120K (Remodeling Magazine Cost vs. Value Report 2011-12)
- DER costs
  - Costs of DER are often quoted as $100K (total remodel cost) (NYSERDA, greenbuildingadvisor.com)
  - We assessed incremental costs from a baseline code compliant remodel, not total project costs
  - Incremental costs of these DERs ranged from $10K -$57K, average of $26K

Summary

- Deep energy reductions are possible with existing technologies & strategies
- The metric chosen to assess performance & drive design decisions is very important
- NorCal mild climate means moderate (not super-insulated or super-airtight) approaches can work
- With low envelope loads, occupant behavior & MELs can matter a lot
  - Successful projects either leverage occupant behavior/energy conservation, or aggressive technology solutions, both would be ideal
- Costs: $26K average increment for DER over standard whole-house remodel

Contact Information & Further Information

- Brennan Less
  - GSRA, LBNL Residential Building Systems, EETD
  - bdless@lbl.gov
  - 510-486-6895
- Jeremy Fisher
  - RA, LBNL Residential Building Systems, EETD
  - jfisher@lbl.gov
  - 510-486-7119

- Other Presentations & Sources of Information about California Deep Retrofit Monitoring Study
  - Fisher Thesis http://thousandhomechallenge.com/spring-2012-webinar1
  - ACI National Home Performance Conference, March 2011 http://2011.acinational.org/sites/default/files/session/81105/aci11pro6lessbrennan.pdf
  - LBNL Presentation, August, 2011 http://homes.lbl.gov/projects/deep-energy-retrofits
  - Passive House US National Conference, October 2011 http://bit.ly/HlrMWe
  - Passive House Northwest, Spring Conference, March, 2012 http://www.phnw.org/637/conference-presentations.html
- Watch the Residential Building Systems Website for Publications on this project and others related to residential energy at LBNL
  - http://homes.lbl.gov/projects/deep-energy-retrofits

Notes about Assumptions, Calculations, Etc.

- Site to source conversion (Building America Performance Analysis Procedures, 2004)
  - Net Source Electricity = Net Site Elec. kWh x 3.16
  - Net Source Gas=Net Site Gas kWh x 1.02
- CO_2e conversion (US EPA)
  - Net CO2e lbs. = (Net Site Elec. kWh x 0.775)+(Net Site Gas kWh x 0.4)
- CO_2e conversion (CA, http://www.pge.com/mybusiness/environment/calculator/assumptions.shtml)
  - Net CO2e lbs. = (Net Site Elec. kWh x 0.575)+)Net Site Gas kWh x 0.4)
- Btu/kWh
  - 3,412 Btu per kWh
  - 1,026 Btu per cubic foot of natural gas
- California average energy usage is from the 2009 Residential Appliance Saturation Survey (http://www.energy.ca.gov/appliances/rass/)
  - Statewide, single family average
  - Electricity = 7,605 kWh
  - Gas = 12,456 kWh = 425 therms
  - Average floor area = 1,579
  - Average occupancy = 2.93

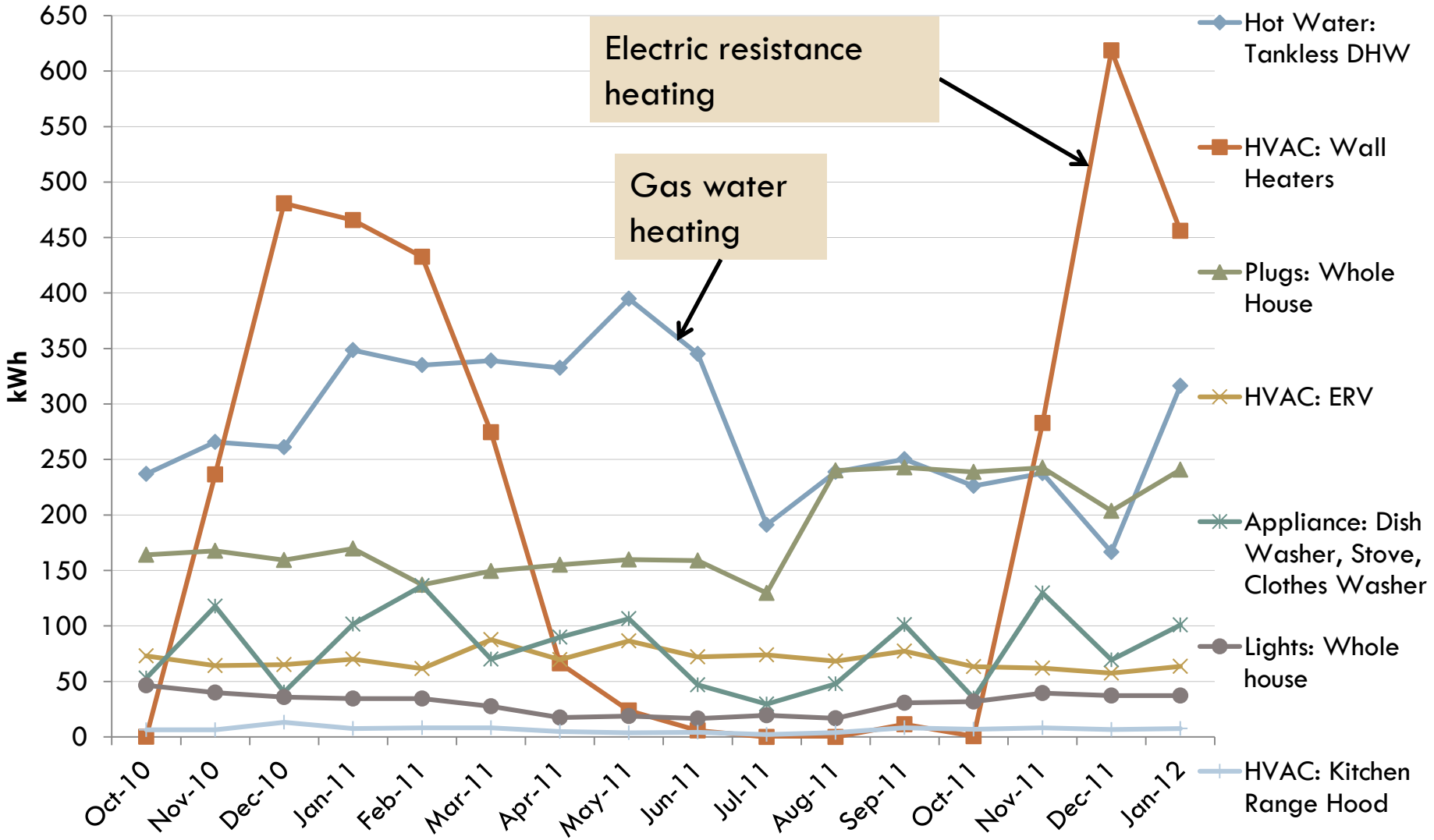
Weblinks to DER Initiatives/References

- ACI Thousand Home Challenge
  - http://thousandhomechallenge.com/
- DOE Building America
  - http://www1.eere.energy.gov/buildings/building_america/
- NYSERDA
  - http://www.nyserda.ny.gov/en/Page-Sections/Research-and-Development/Advanced-Residential-Buildings/Deep-Retrofit.aspx
- National Grid
  - https://www.powerofaction.com/der/
- IEA Task 37 - Advanced Housing Renovation with Solar & Conservation
  - http://www.iea-shc.org/task37/
- Retrofit for the Future - England's Technology Strategy Board
  - http://retrofitforthefuture.org/
- EnerPHIT - Passive House retrofit standard
  - http://www.passiv.de/01_dph/Bestand/EnerPHit/EnerPHit_Criteria_Residential_EN.pdf

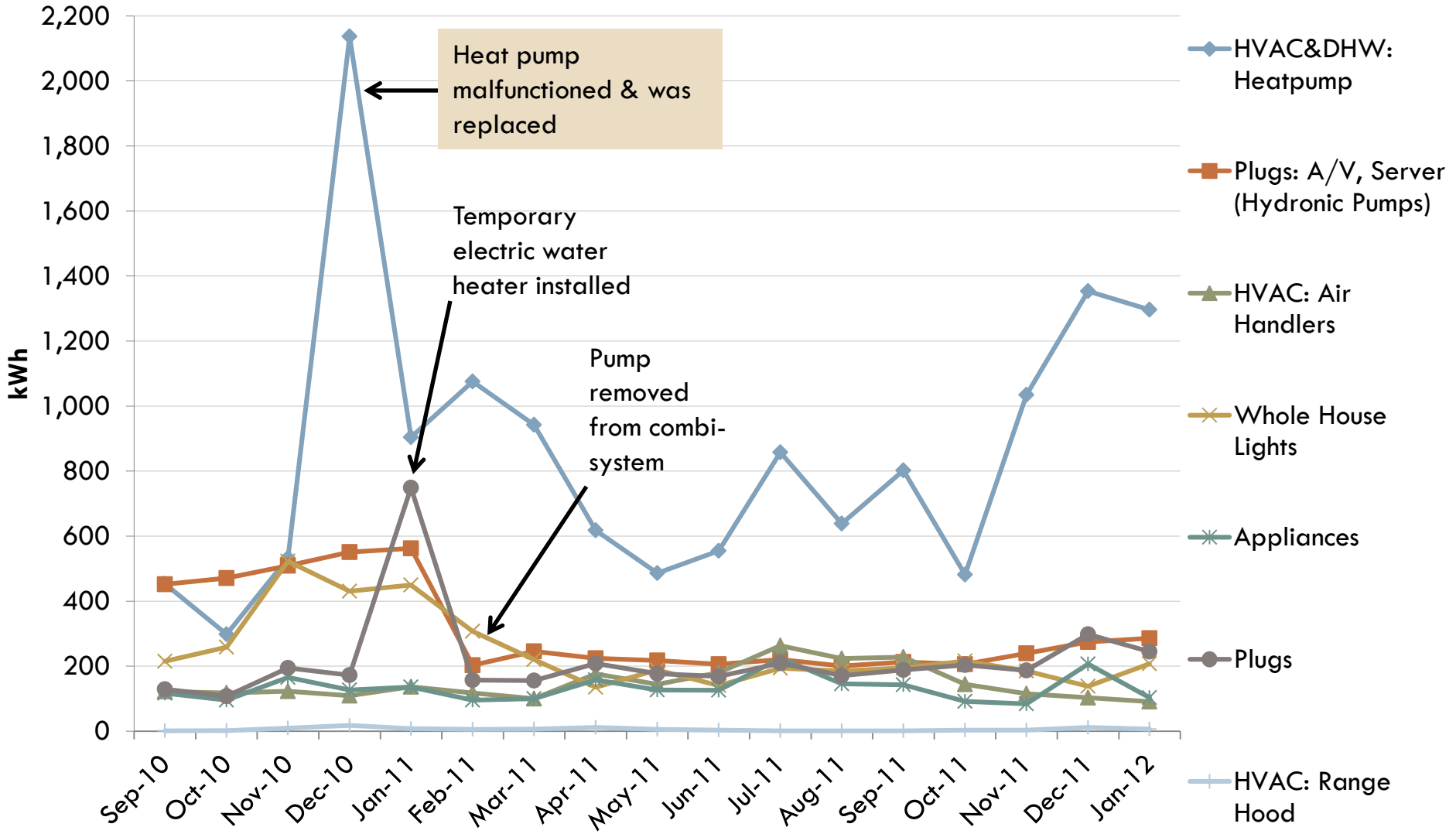
Appendices

- Monthly energy end use line graphs
- P6-P8 descriptions & limited data

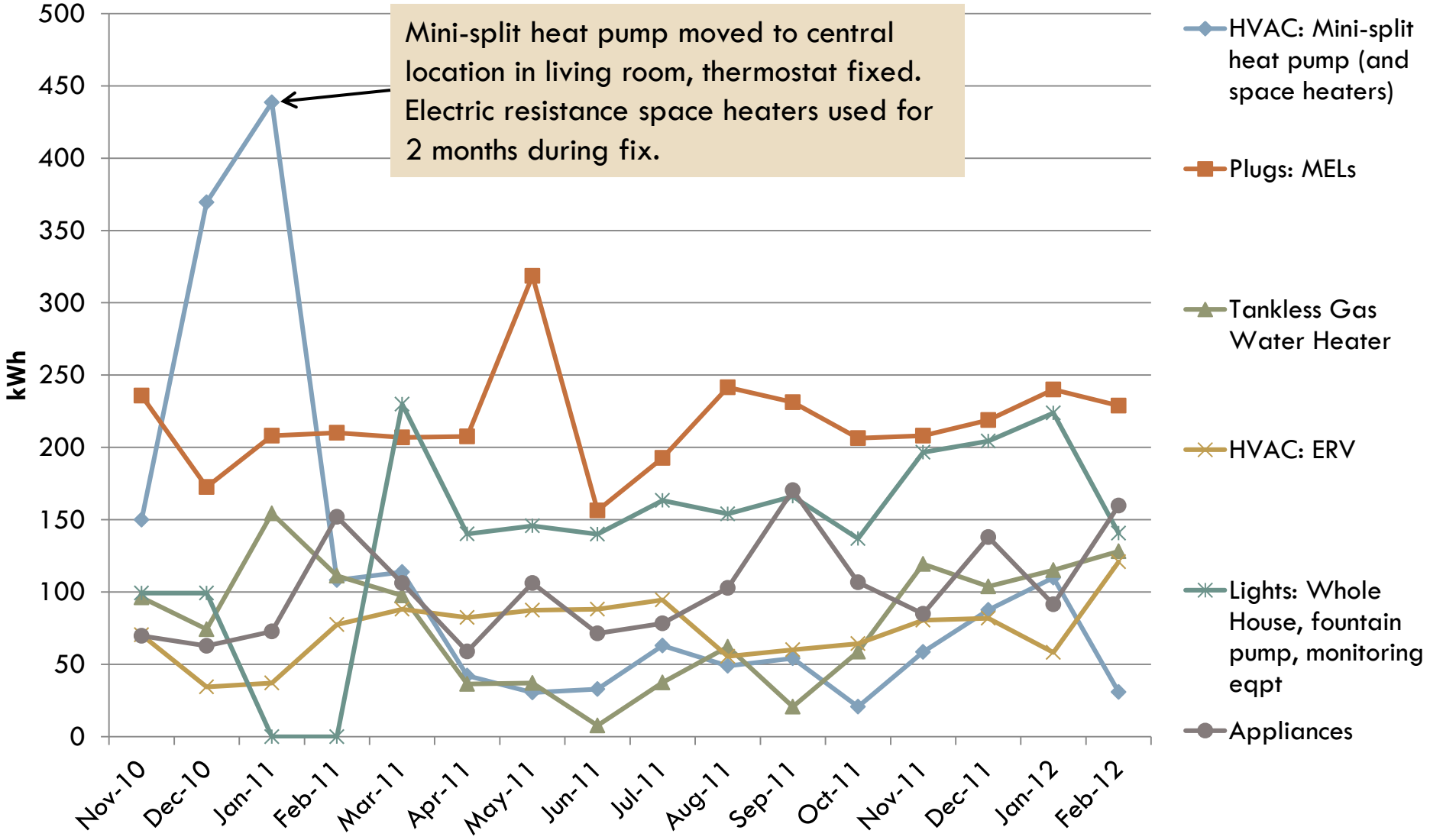
P1 Monthly Energy End Use



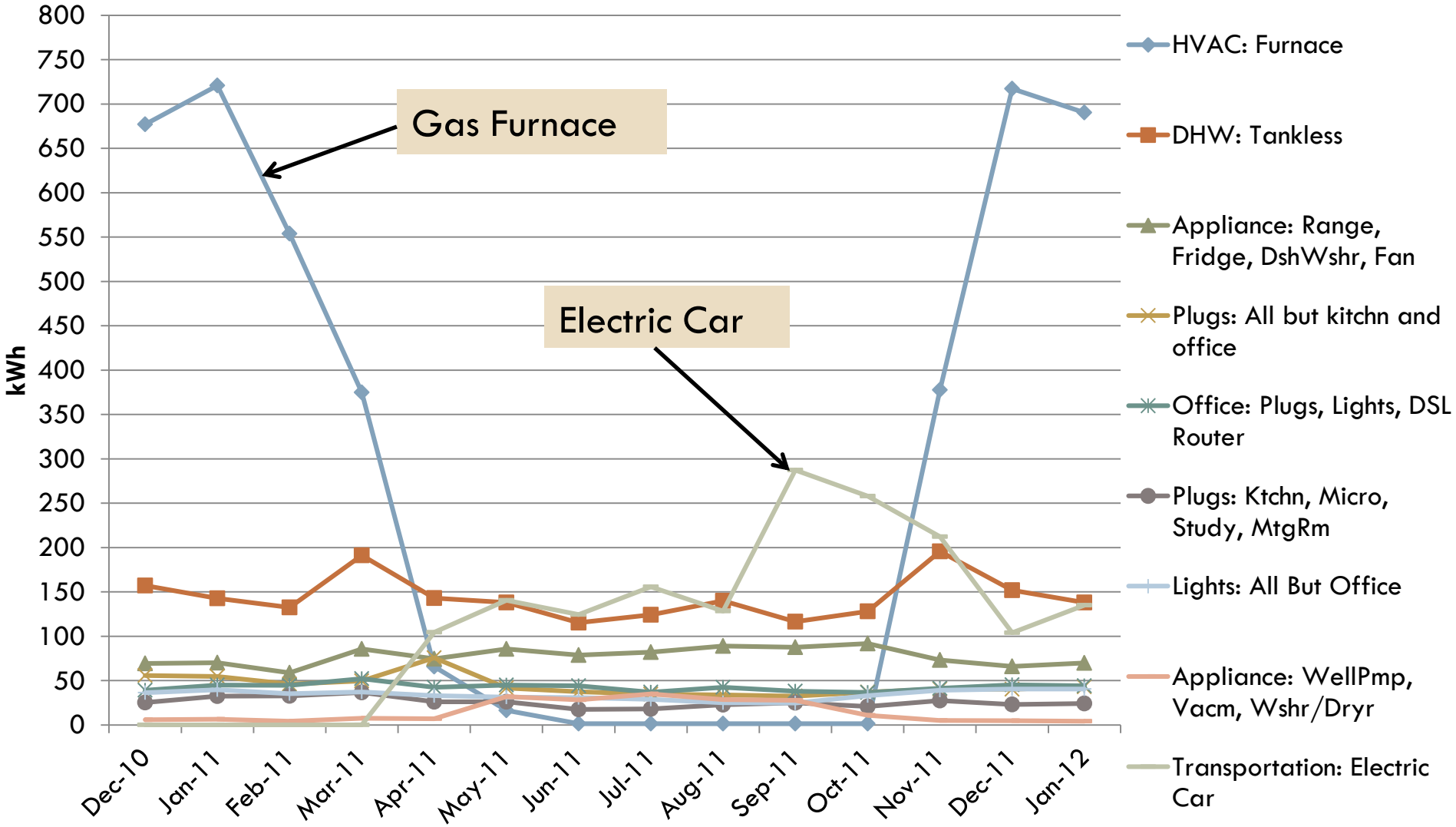
P2 Monthly Energy End Use



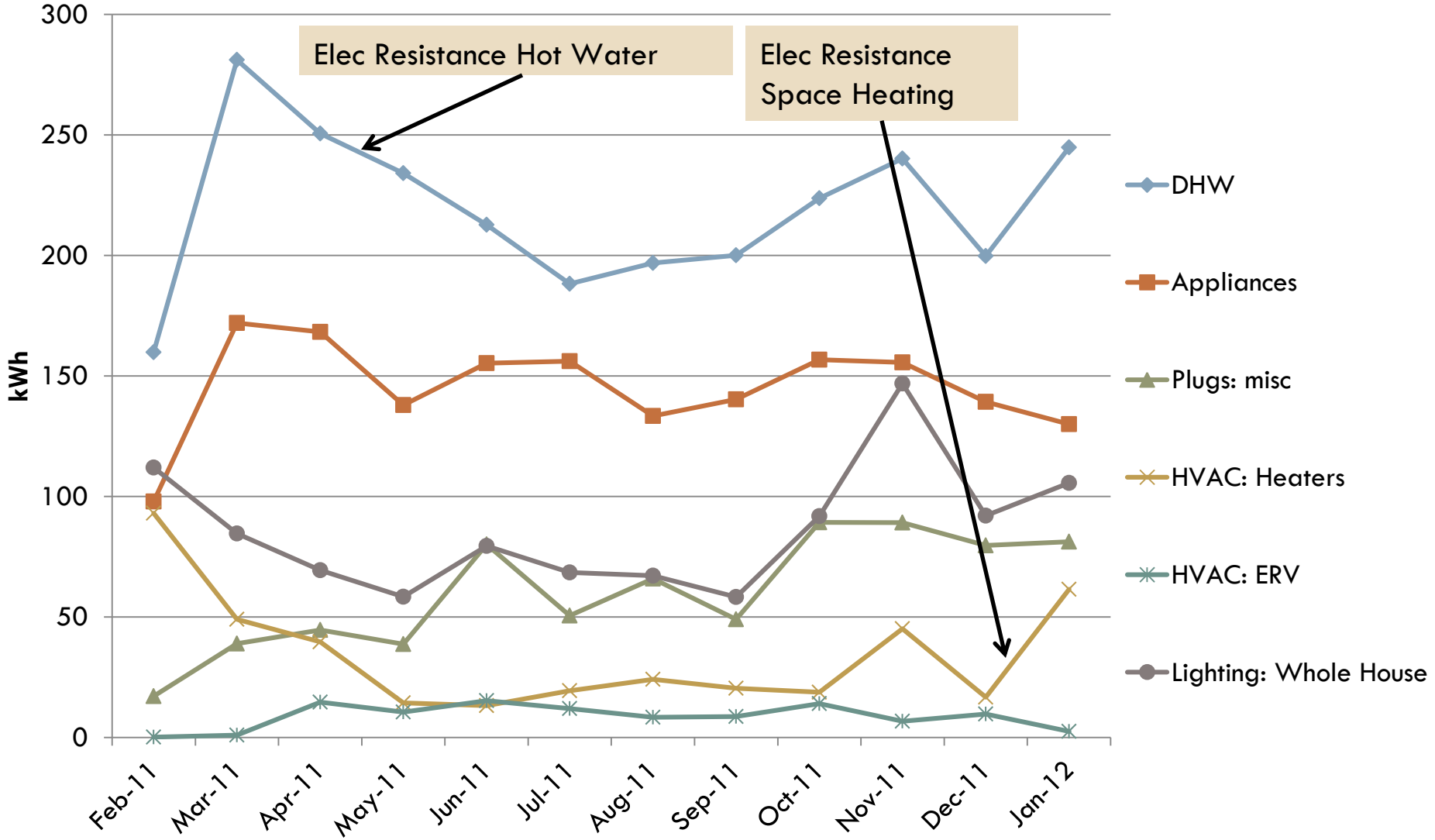
P3 Monthly Energy End Use



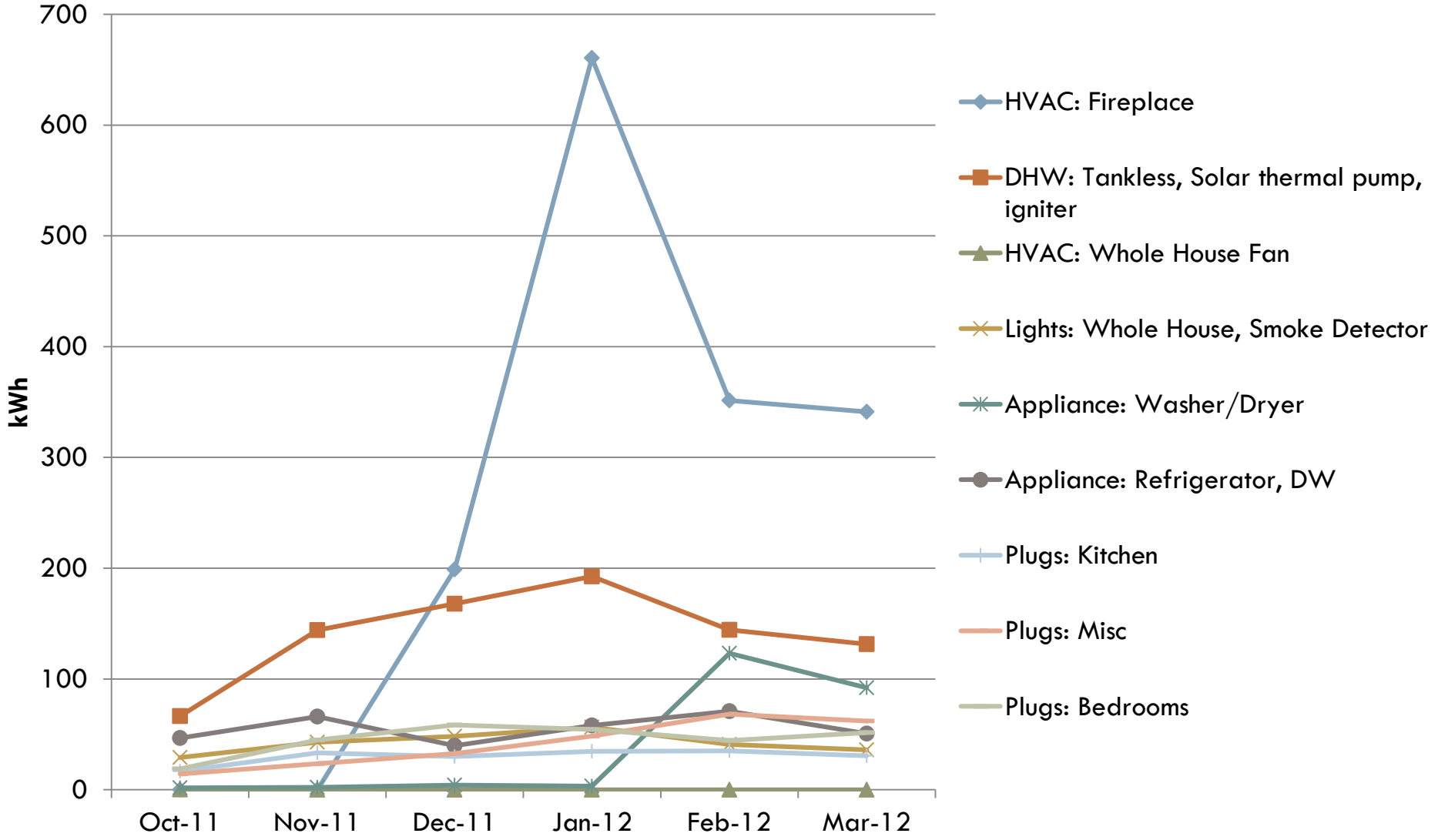
P4 Monthly Energy End Use



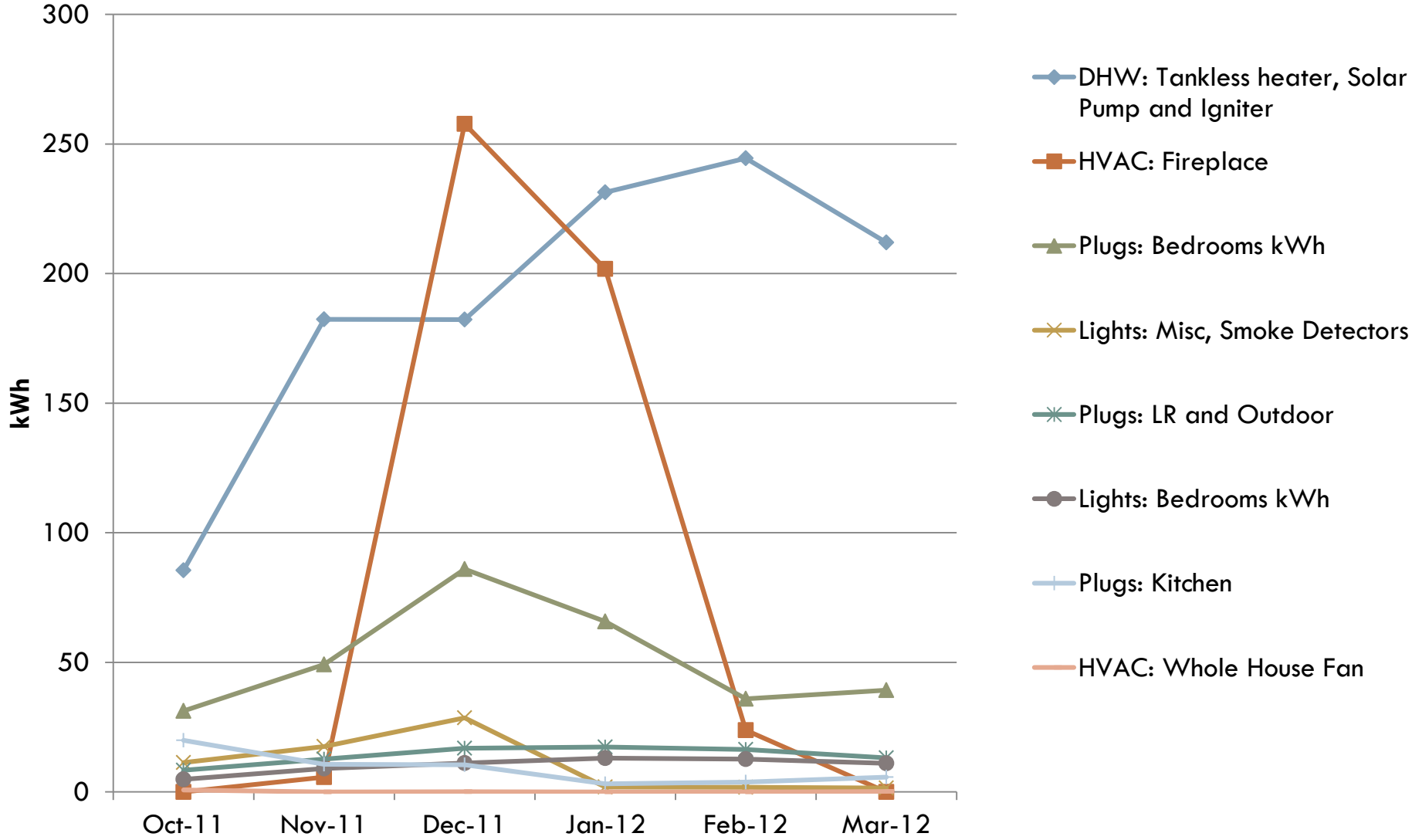
P5 Monthly Energy End Use



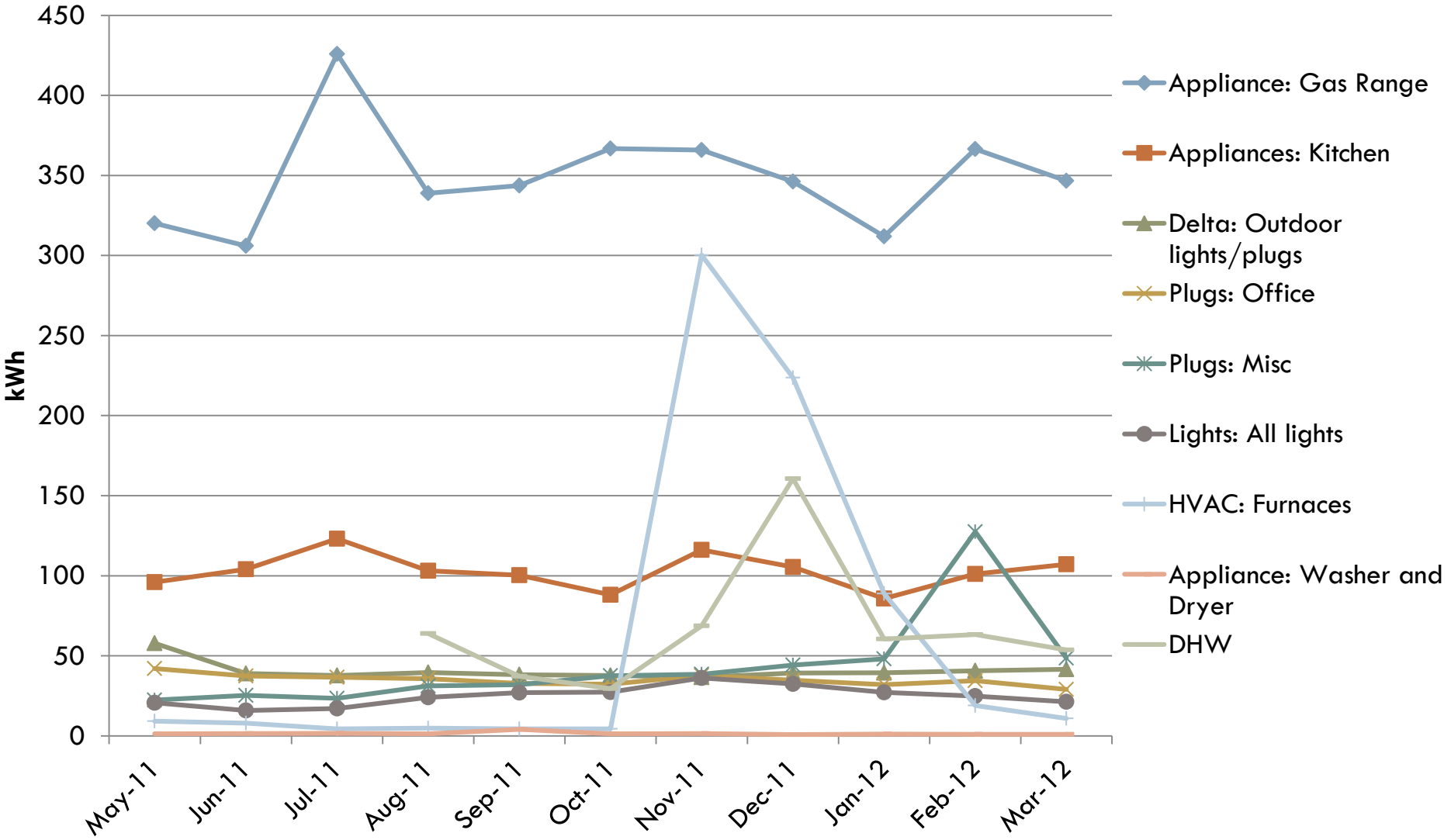
P6 South Monthly Energy End Use



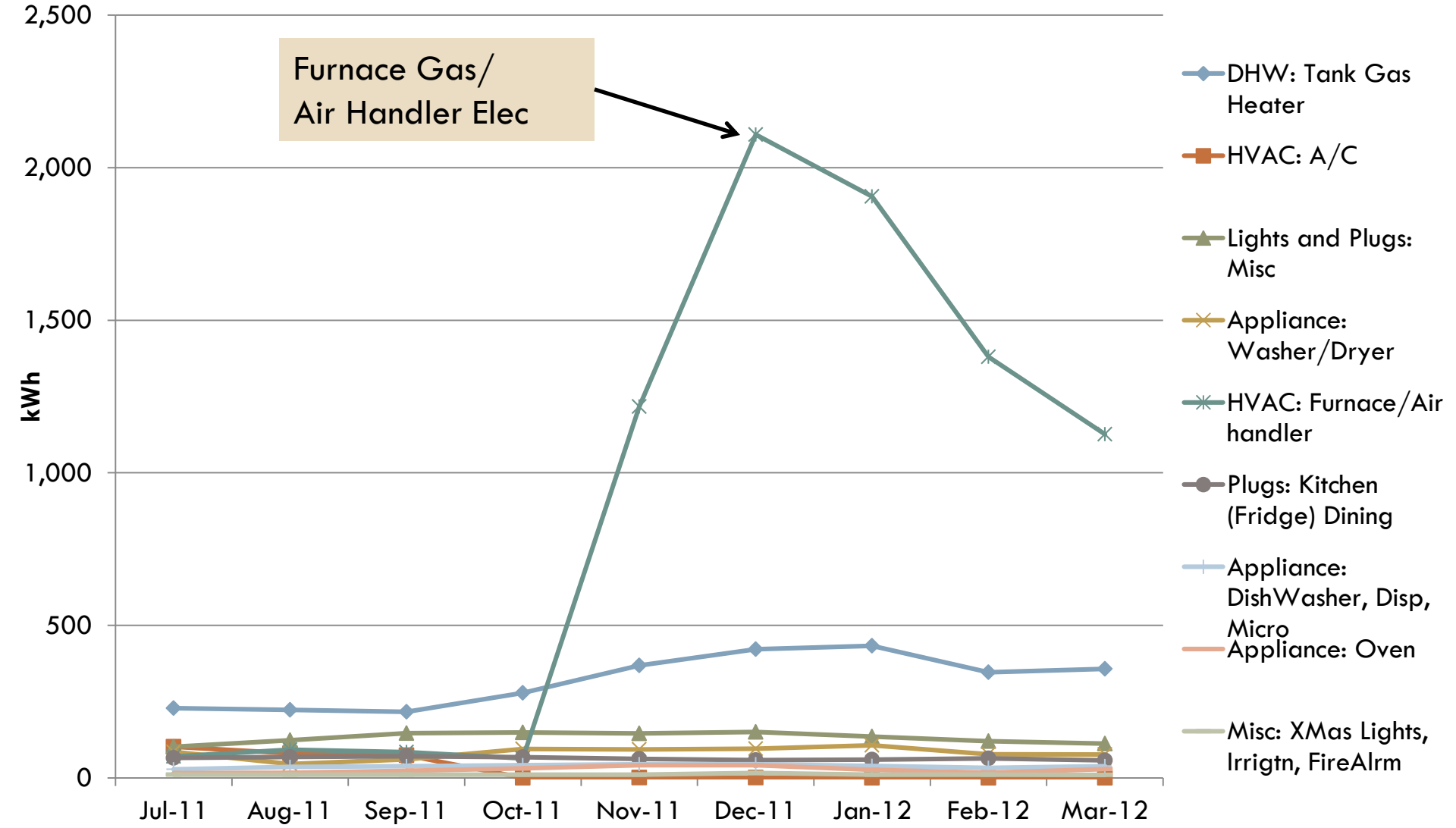
P6 North Monthly Energy End Use



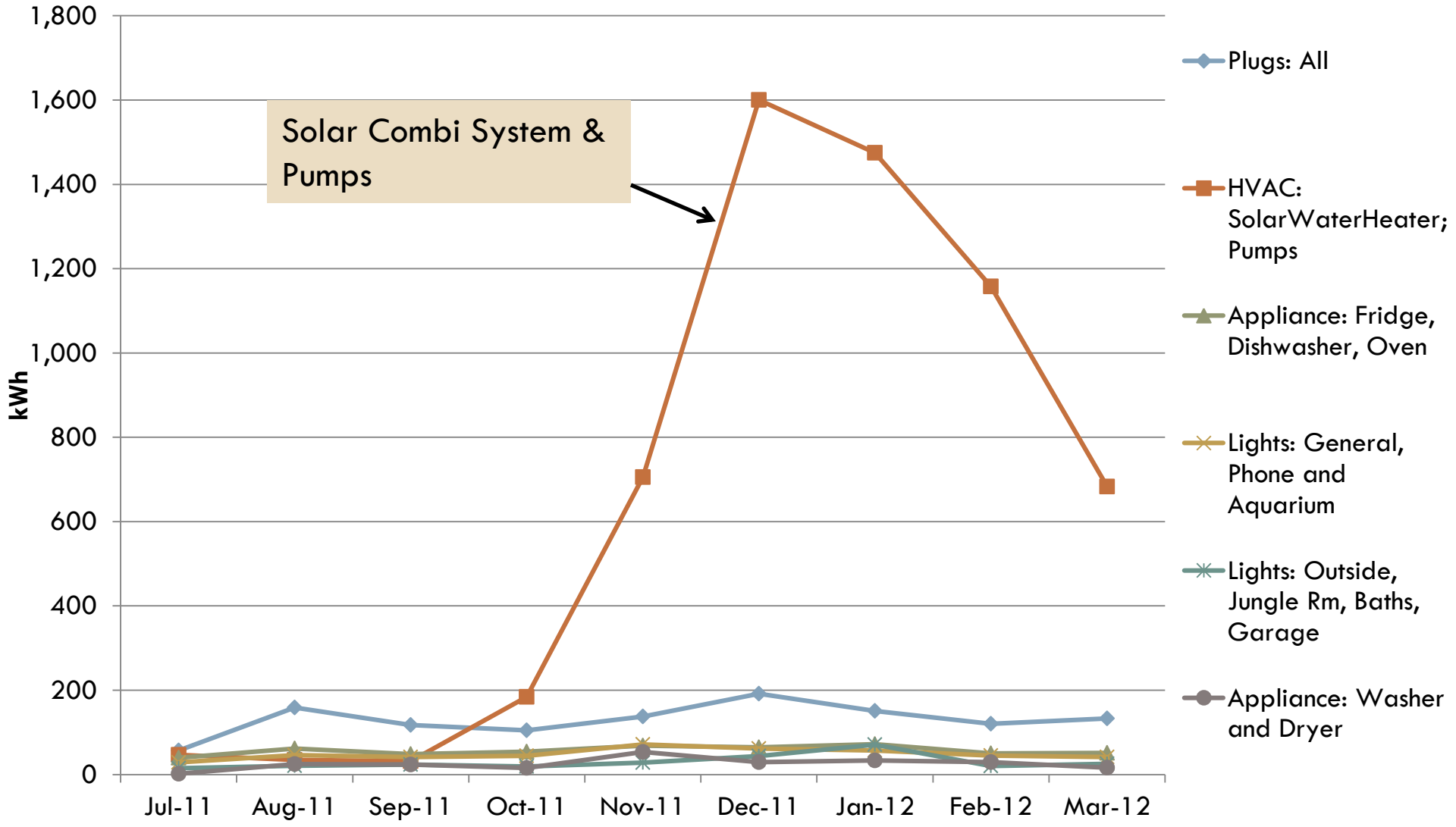
P7 Monthly Site Energy Use



P9 Monthly Energy End Use



P10 Monthly Energy End Uses



P6 Retrofit Description

1932/1934 Ranch Style

Davis, CA

North – 1,462 ft^2

South – 1,496 ft^2

- Two existing homes were moved to a nearby site
- Double stud wall homes with solar thermal are occupied by members of local co-housing association
- North: 5 bedrooms, 1 bathroom, 5 occupants
- South: 3 bedrooms, 1 bathroom, 3 occupants

P6	Pre-retrofit	Post-retrofit
ENVELOPE		
Wall Insulation	None	7” cellulose - R25
Roof Insulation	Some fiberglass batts	13” loose fill cellulose - R 44
Foundation Insulation	None	Sealed crawl spaces, 2” rigid XPS interior stem wall, 6” low density spray foam at rim joist
Windows	Single pane aluminum frame	North: 2-pane, Low E, argon filled, fiberglass frame; U: 0.33 SHGC: 0.18 South: Refabbed existing windows with 2nd pane
Air Leakage		North: 991 CFM_{50}, 0.222 CFM_{50}/SA, 5.1 ACH_{50} South: 1,114 CFM_{50}, 0.247 CFM_{50}/SA, 5.6 ACH_{50}
MECHANICAL		
Heating & cooling		Both: direct vent, gas fireplace
DHW		North: Solar thermal preheat, condensing gas tankless South: Integrated storage solar thermal preheat, condensing gas tankless
Ventilation		Bath & kitchen exhaust, whole house fan
Distribution		None
LIGHTS/APPL/MELs		Mostly CFL
RENEWABLES		PV to be installed 2012

P6 Retrofit Description

P7 Project Description

1000 Home Challenge

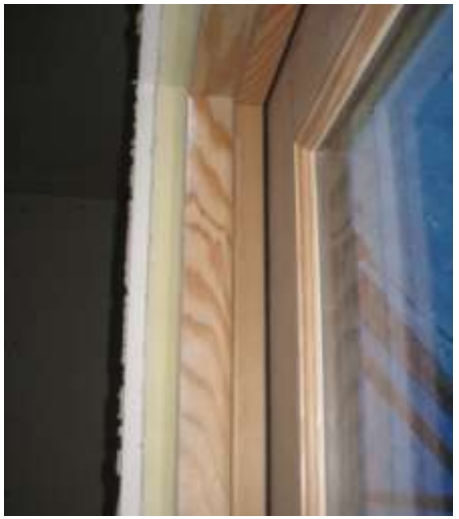
1910 Craftsman Bungalow
San Mateo, CA

Pre: 3,136 ft^2 ⟹ Post: 3,288 ft^2

- House within a house concept, using kitchen & rear zone as primary living space in winter
- Insulated portions of home, maintaining architecturally significant interiors, increased comfort
- Hope to achieve 1,000 Home Challenge with future PV installation
- 3 bedrooms, 2.5 baths, 2 occupants

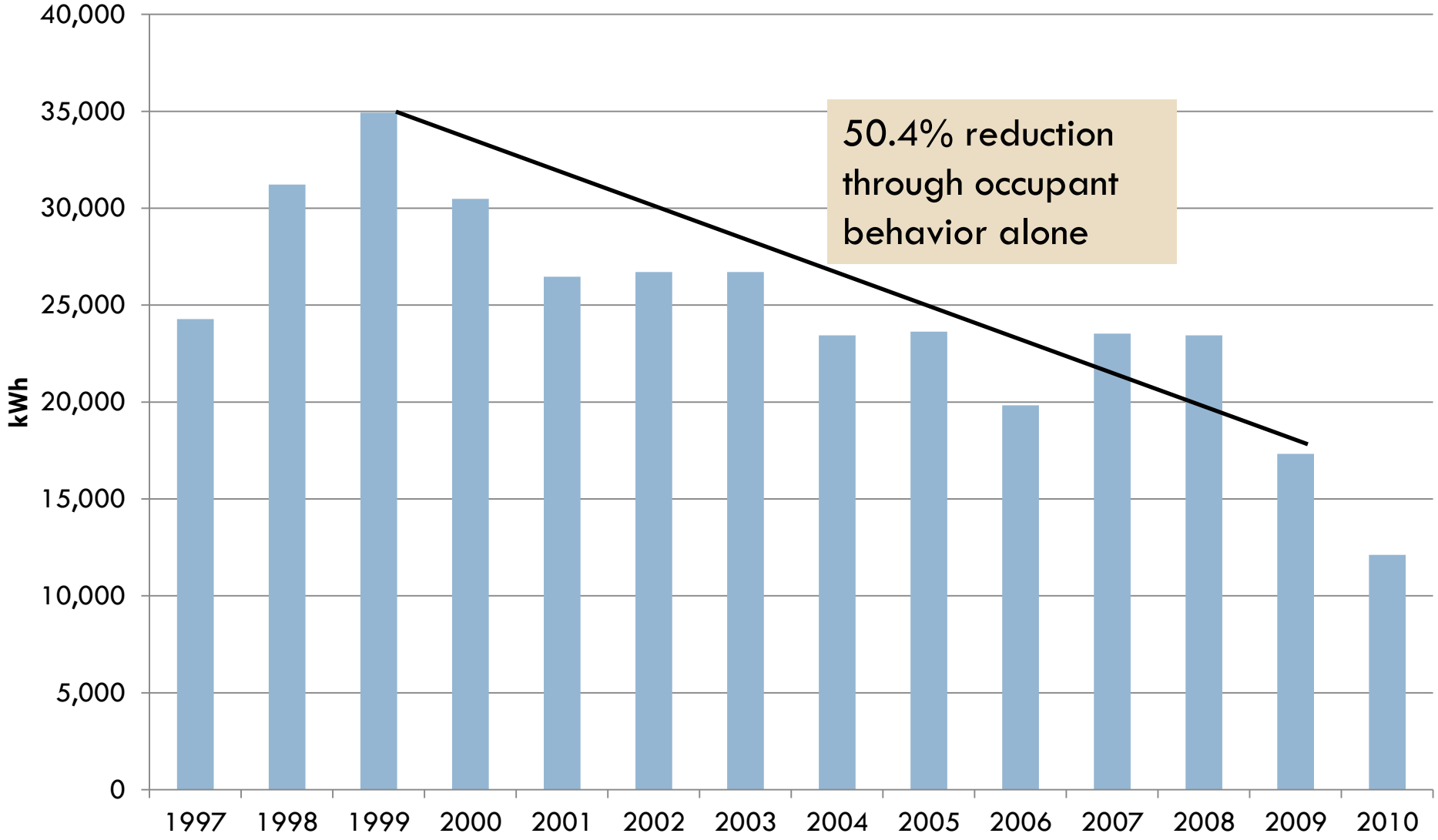
P7	Pre-retrofit	Post-retrofit
ENVELOPE		
Wall Insulation	None	Rear zone: 5.5” BIB, 1” polyiso - R23 Upstairs: 3.5” blown fiberglass - R13 Downstairs: none
Roof Insulation	Some fiberglass batts	5.5” BIB, 2” polyiso - R36 Rear zone ceiling: 7.5” BIB - R30
Foundation Insulation	None	2” polyiso under floor joists - R12.9
Windows	Rear zone: 1-pane aluminum frame Rest of house: old, leaky DH wood frame, 1- pane	Rear zone: 2-pane, Low E, argon filled, fiberglass frame – U: 0.28 SHGC: 0.27 Rest of house: no change
Air Leakage	8,432 CFM_{50}	5,336 CFM_{50}, 0.79 CFM_{50}/SA, 10.8 ACH_{50}
MECHANICAL		
Heating & Cooling	119 kBtu/hr gas furnace AFUE 75-80%	(2) 26-40 kBtu/hr gas furnaces, 3-stage variable speed blower, 95% AFUE
DHW	Tankless gas heater & 40-gal gas tank heater	Condensing gas tankless with 2-gal. integrated storage tank
Ventilation	Bath exhaust	Bath & 1,400 CFM kitchen exhaust
Distribution	Sheet metal, supply leakage 115 CFM, return 123 CFM	R6 foil faced flex duct
LIGHTS/ APPLIANCES/MELs	6-burner commercial gas range, 6 pilots	Disabled all but 1 pilot

P7 Retrofit Description

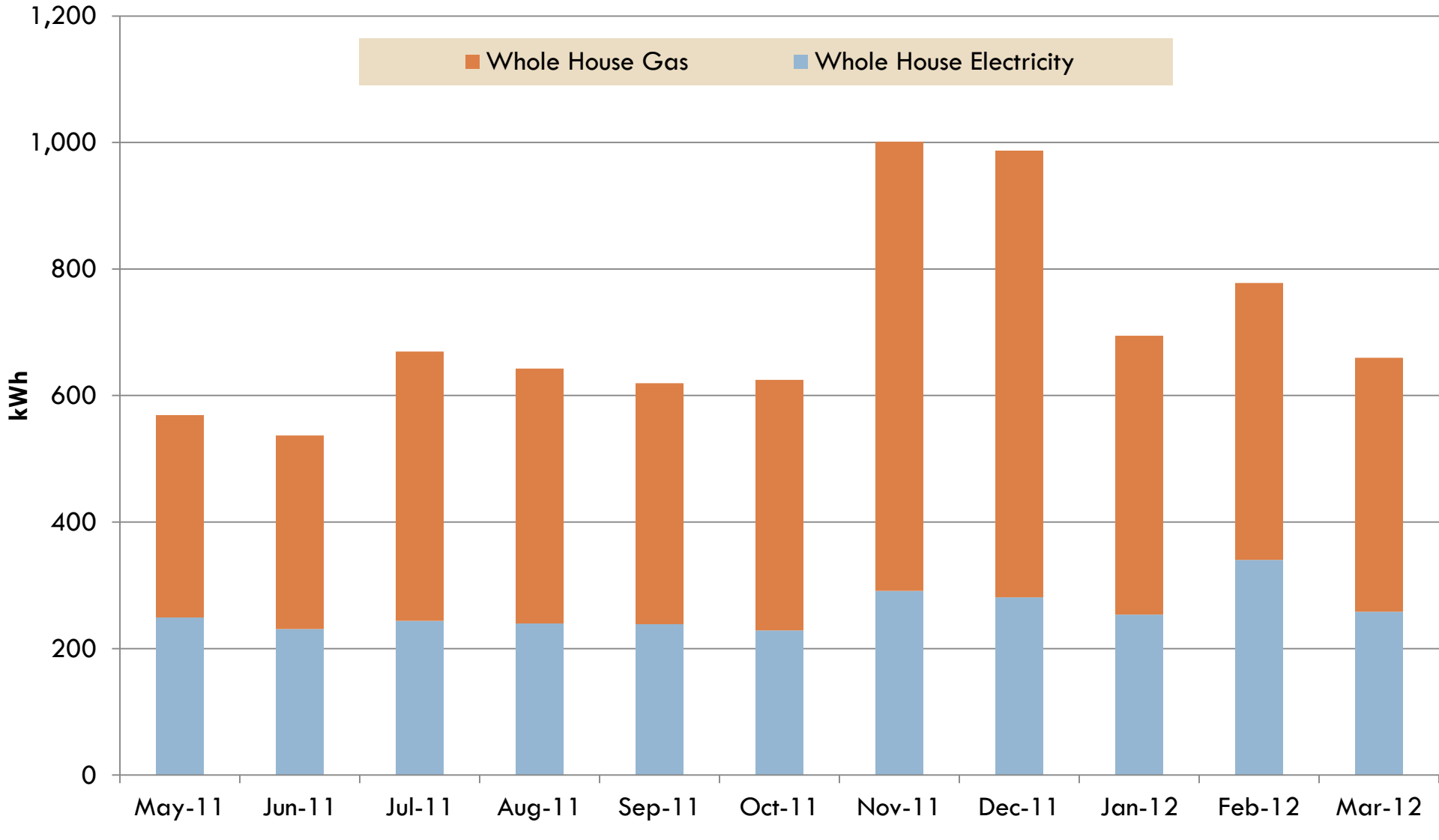


P7 Retrofit Description

P7 Historical Annual Utility Bills

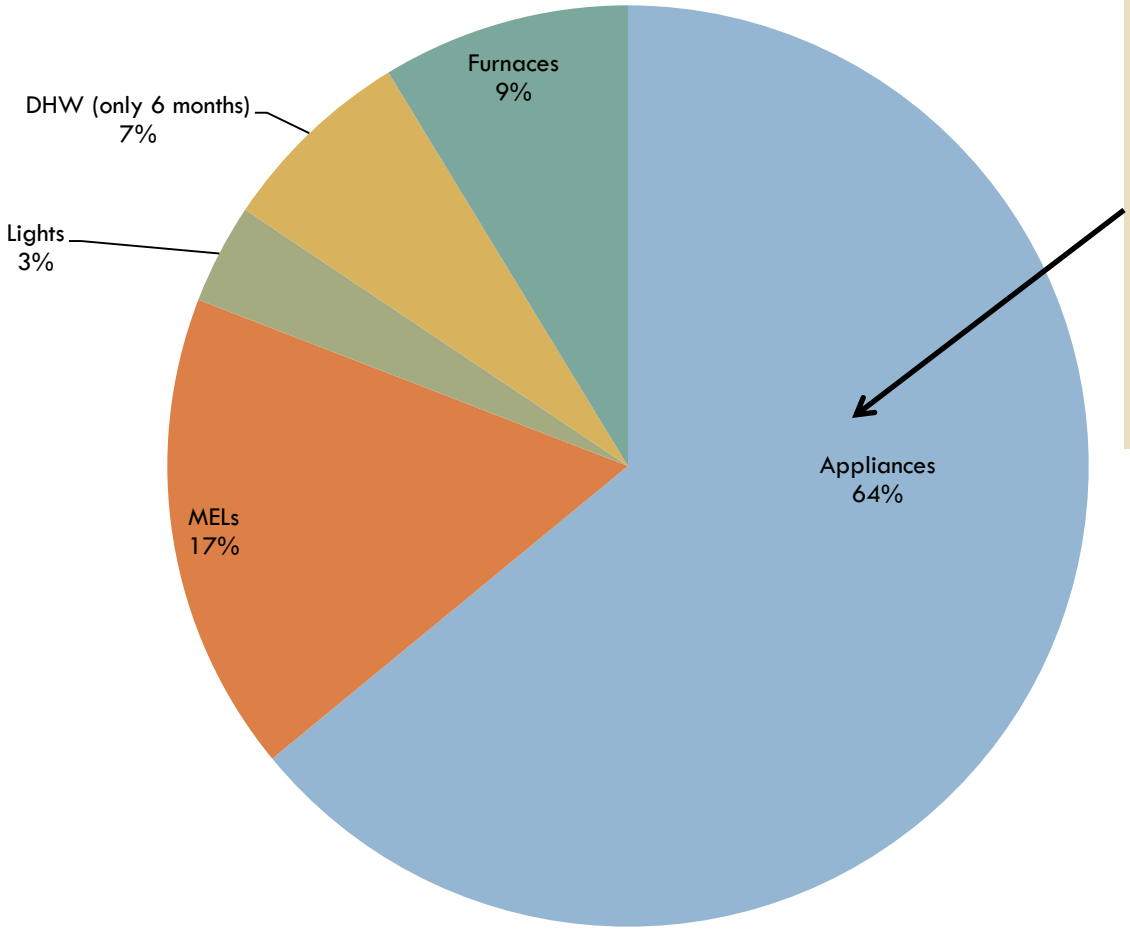


P7 Total Monthly Energy Use



P7 May 2011-Mar 2012 Energy End Use

Not a full year (11 months)



Gas range is the major consumer, 4 cooktop pilots were extinguished shortly after monitoring began. Occupants are experimenting with means of reducing cooking energy

P8 Project Description

1915 Craftsman Bungalow
Oakland, CA

Pre: 1,440 ft^2 ⟶ Post: 1,440 ft^2

- Super Green Retrofit– LEED Platinum rated, greywater, rainwater, sustainable materials & landscaping, low flow fixtures + energy efficiency
- 3 bedrooms, 1.5 baths, 4 occupants

P8	Pre-retrofit	Post-retrofit
ENVELOPE		
Wall Insulation	None	3.5” blown cellulose - R13
Roof Insulation	Some fiberglass batts	4” closed cell spray foam - R28
Foundation Insulation	None	Fiberglass batts -R19
Windows	Single pane wood frame	Most windows replaced with 2-pane, Low E, argon, fiberglass frame ; U: 0.33 SHGC: 0.3
Air Leakage		2,397 CFM_{50}, 0.476 CFM_{50}/SA, 9.3 ACH_{50}
MECHANICAL		
Heating & DHW	Old gas furnace with 2 floor grills, gas tank DHW	3-panel solar thermal combi system with 96% efficient condensing gas boiler, 120-gal. storage tank, hydronic baseboard radiators, zone controlled
Ventilation	None	Bath & kitchen exhaust
Distribution	Sheet metal	Insulated PEX
LIGHTS/APPLIANCES/ MELs	Old, inefficient	New, highest efficiency, CFL & LED lighting, 2nd refrigerator in garage
RENEWABLES	None	2.7 kW PV

P8 Retrofit Description

Source: http://www.elledecor.com/home-remodeling/articles/greenest-little-house-america

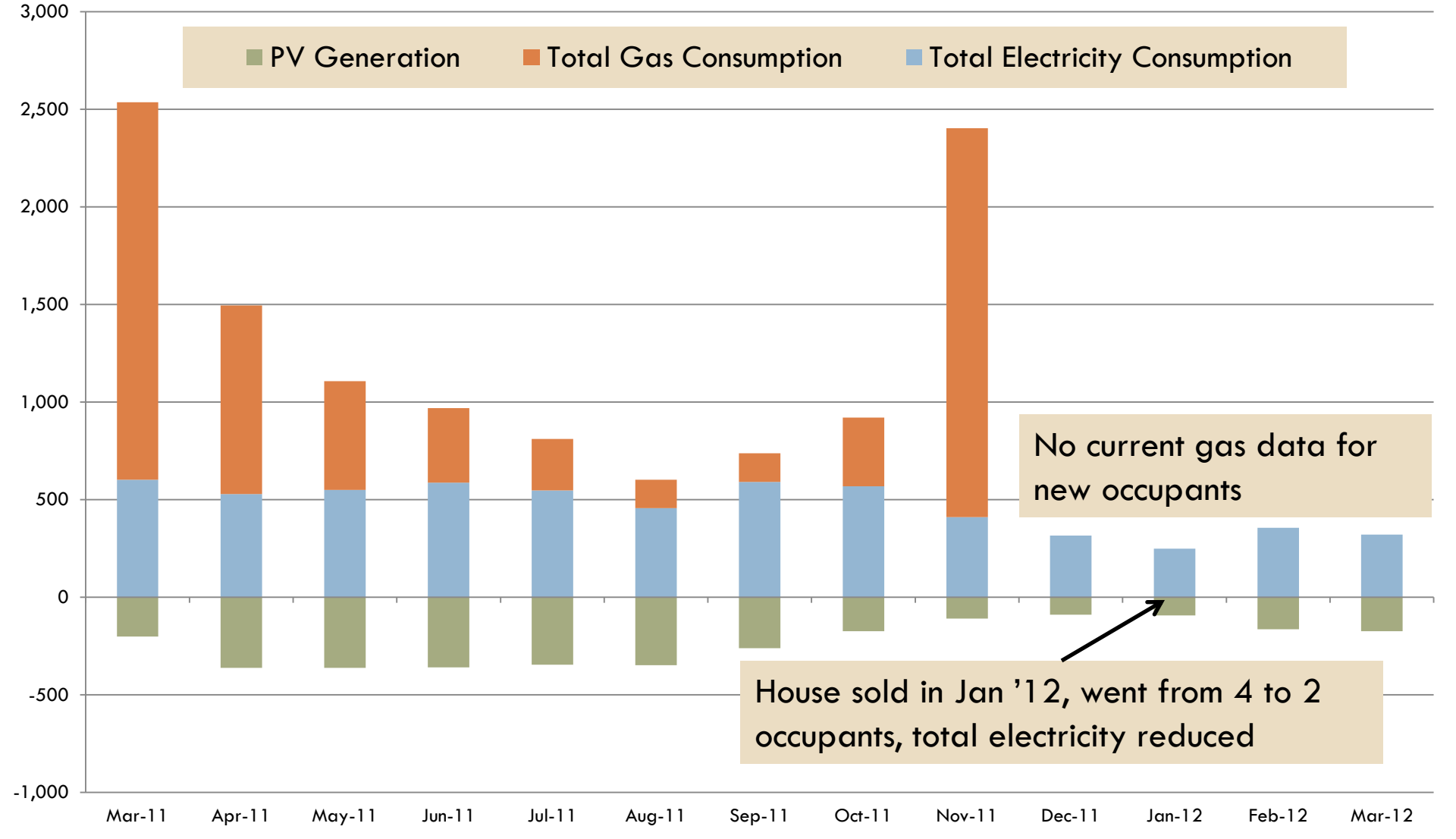
Office "Pod"

Rainwater Catchment

Hot Water Radiator Manifold in Crawl Space

P8 Retrofit Description

P8 Monthly Site Energy Usage



Contact Information & Further Information

- Brennan Less
  - GSRA, LBNL Residential Building Systems, EETD
  - bdless@lbl.gov
  - 510-486-6895
- Jeremy Fisher
  - RA, LBNL Residential Building Systems, EETD
  - jfisher@lbl.gov
  - 510-486-7119
- Other Presentations & Sources of Information about California Deep Retrofit Monitoring Study
  - Fisher Thesis http://thousandhomechallenge.com/spring-2012-webinar1
  - ACI National Home Performance Conference, March 2011 http://2011.acinational.org/sites/default/files/session/81105/aci11pro6lessbrennan.pdf
  - LBNL Presentation, August, 2011 http://homes.lbl.gov/projects/deep-energy-retrofits
  - Passive House US National Conference, October 2011 http://bit.ly/HlrMWe
  - Passive House Northwest, Spring Conference, March, 2012 http://www.phnw.org/637/conference-presentations.html
- Watch the Residential Building Systems Website for Publications on this project and others related to residential energy at LBNL
  - http://homes.lbl.gov/projects/deep-energy-retrofits