GTI ENERGY

solutions that transform

Affordable Zero Net Energy Homes

Final Training Webinar Part 2: Project Outcomes & Lessons Learned

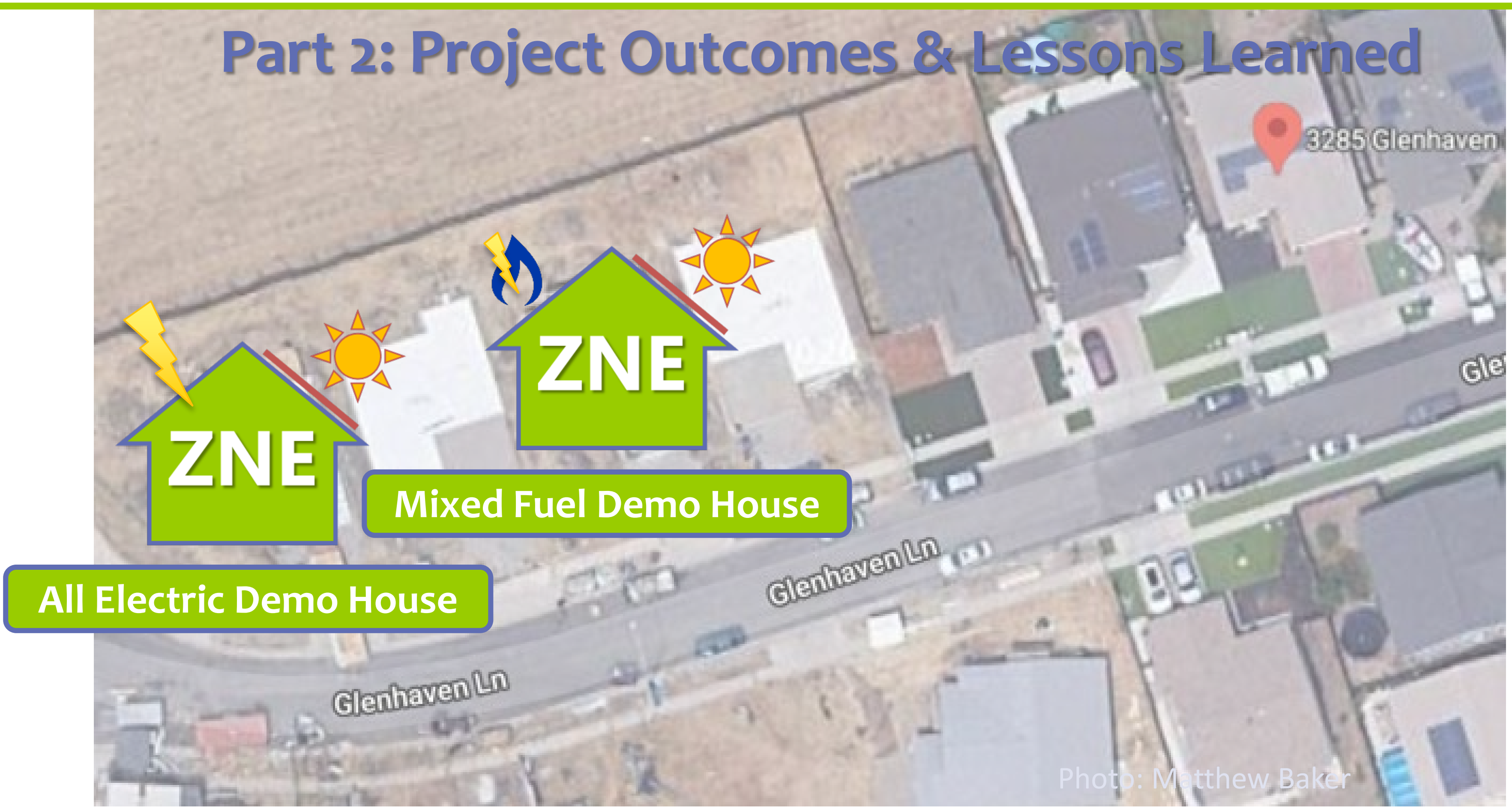
Prime Funding:
California Energy Commission's Electric Program Investment Charge Program

Co-funding:
Southern California Gas Company's RD&D and Energy Efficiency Programs

March 24, 2022

Zero Energy/Electricity/Emissions Homes

Part 2: Project Outcomes & Lessons Learned



ANN V EDMINSTER
DESIGN AVEnues LLC

With major contributions from
Mike MacFarland, Energy Docs
Home Performance Contractor

POLL

Which best describes YOU?

A. **General contractor**

B. **Trade contractor** (select B + specify in chat box)

C. **Architect or engineer**

D. **Other** (select D + explain in chat box!)

Resuming Our Story …

Zero Energy/Electricity/Emissions Homes

Part 1: Project Description

- ZNE background—context and value
- History of ZNE homes
- Defining ZNE
- Our starting point: the prior project ★
- **Current project & what we hoped to learn** ★

Tuesday’s cliffhanger

Zero Energy/Electricity/Emissions Homes

Part 2: Project Outcomes & Lessons Learned

Energy performance

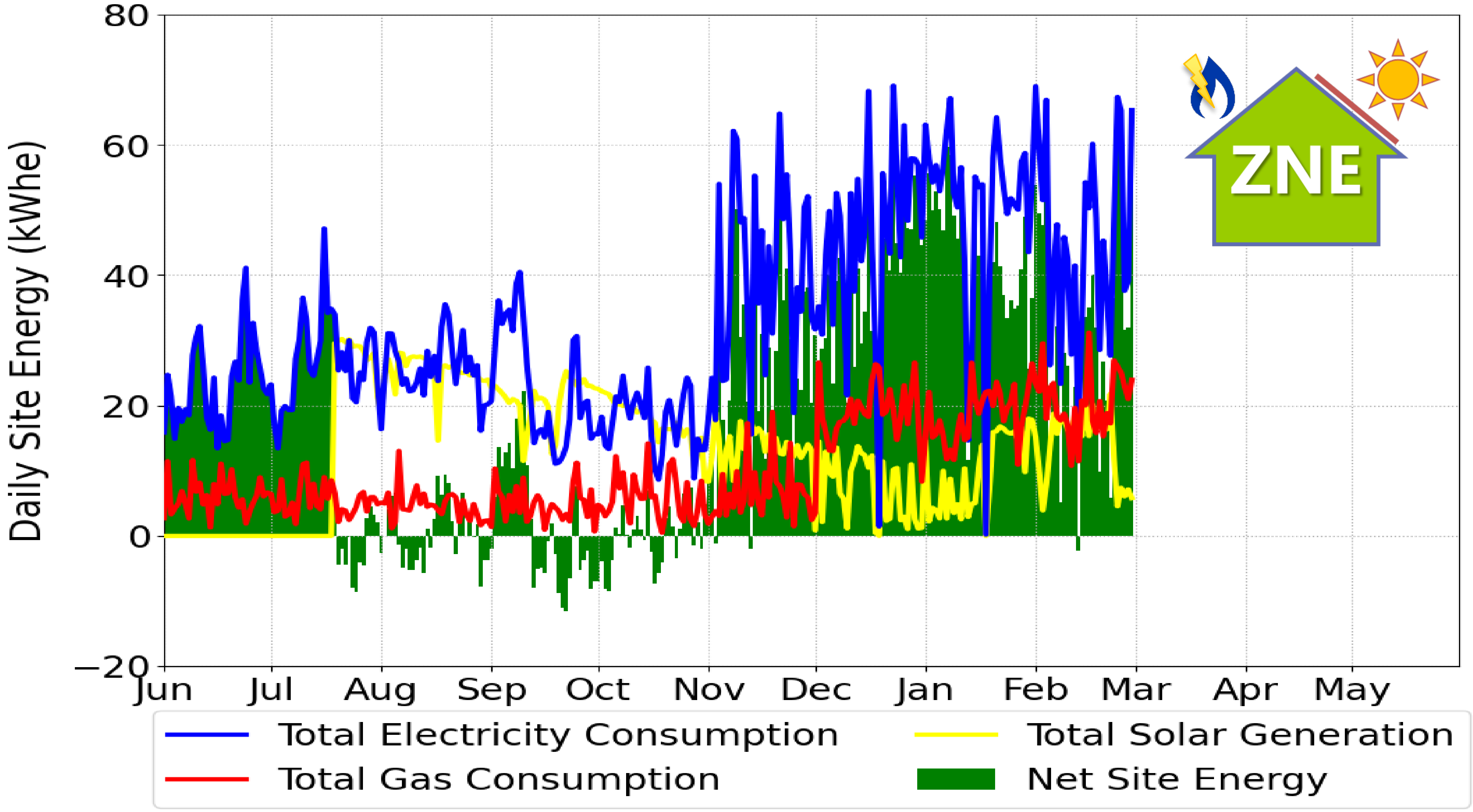
- What’s different about ZNE homes
- Process takeaways
- High-level lessons learned
- Resources

How did the two homes perform? (and compare?)

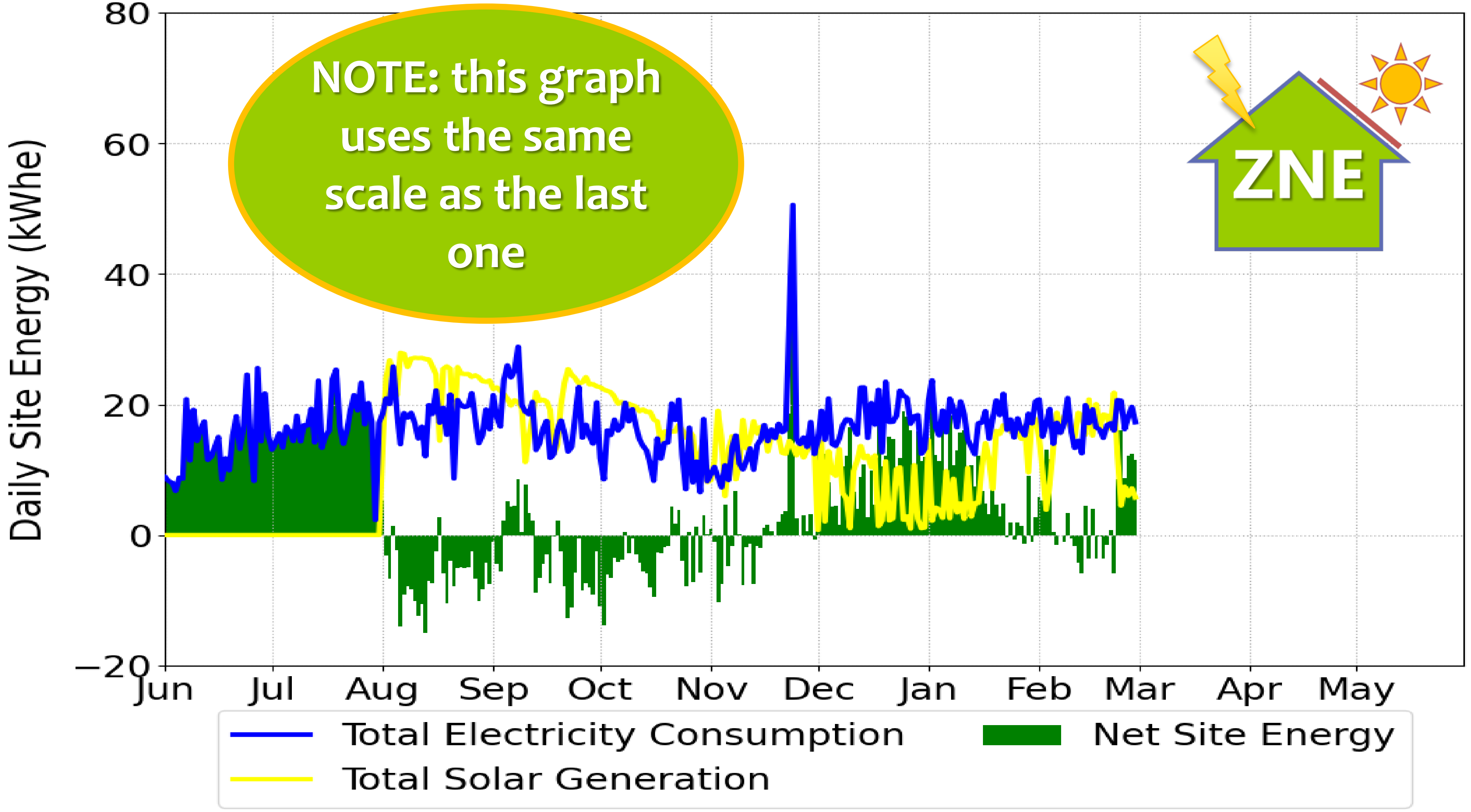
We monitored to find out.

Performance Category	Monitored Items	Monitoring Instruments
Electrical consumption	HVAC, DHW, appliances, plug load circuits, lighting circuits	SiteSage with current transducers
Gas consumption	HVAC, DHW, appliances	SiteSage
DHW	Temperatures, flows	Onicon BTU meters, temperature sensors
HVAC	Temperatures	Onicon BTU meters
Indoor conditions and operation	Temperature and RH in various rooms, setpoints, modes	Ecobee
Weather	Dry bulb, solar radiation	Onsite weather station
Heat flux	Heat flow through exterior walls	Heat flux sensors
Solar generation	Electrical generation	SiteSage with current transducers

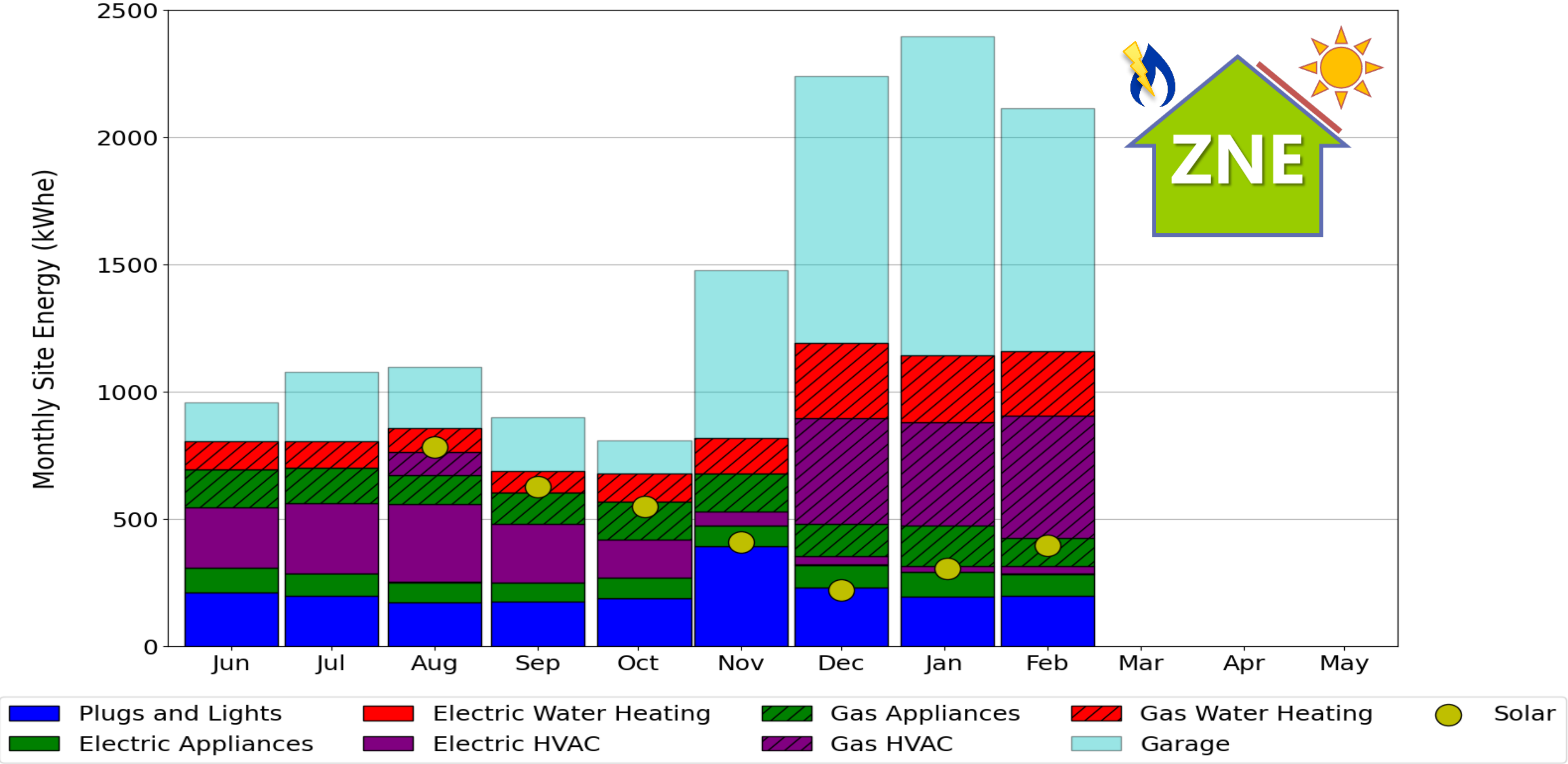
Mixed-fuel home: consumption



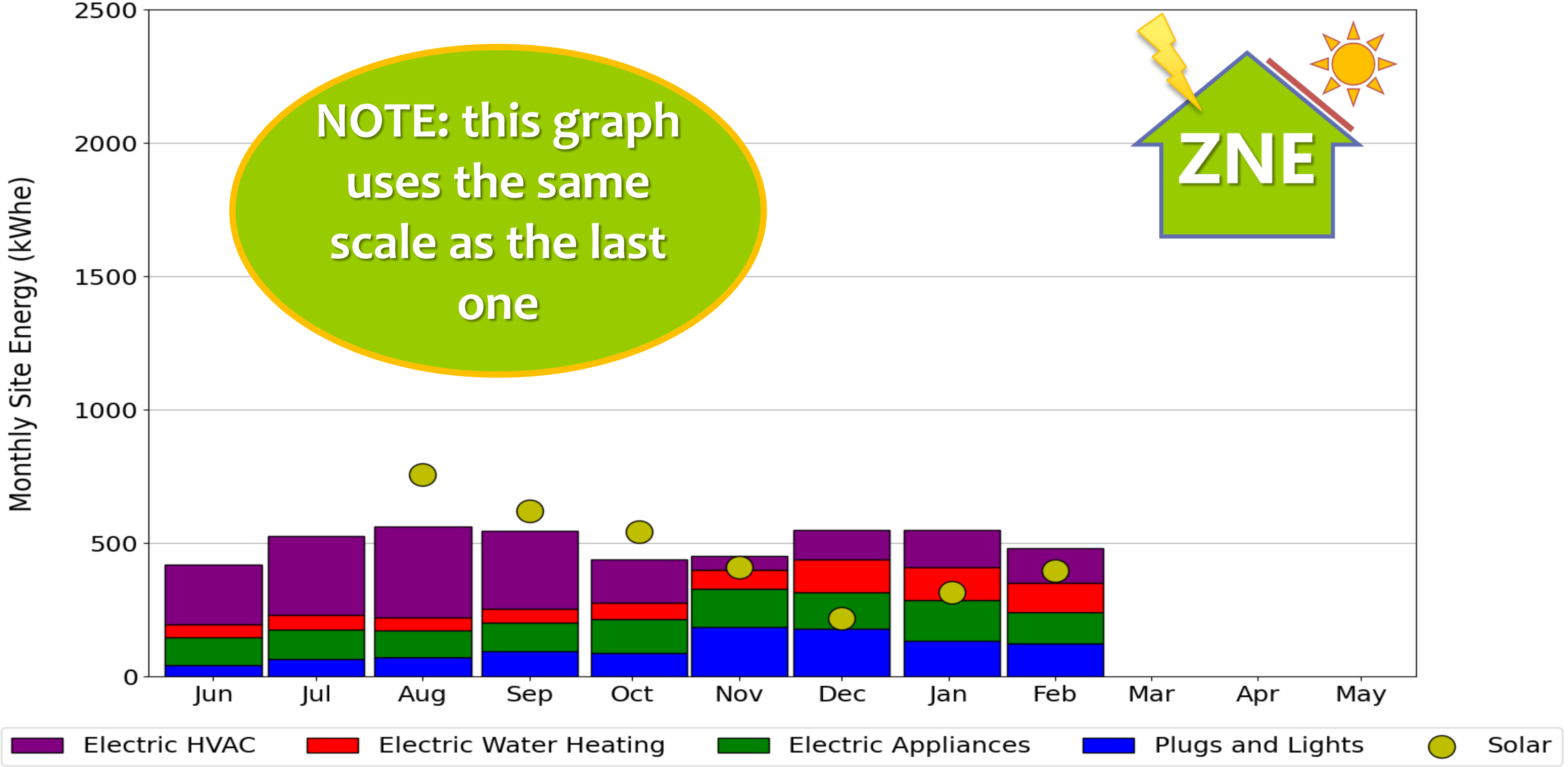
All-electric home: consumption



Mixed-fuel home: consumption by end use

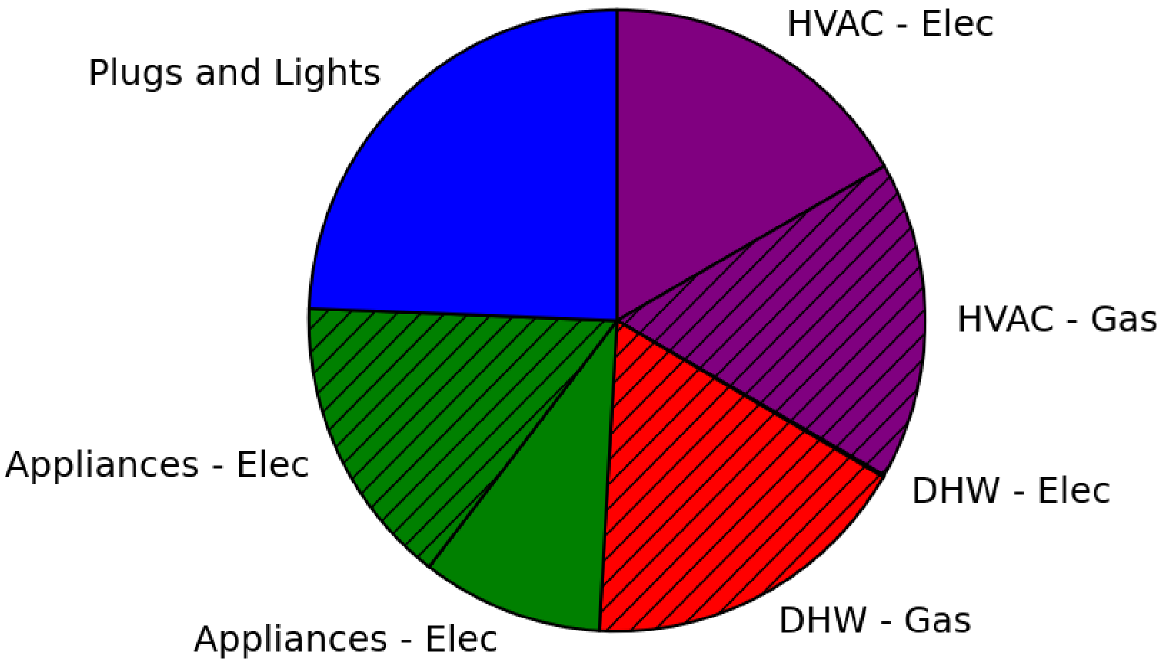


All-electric home: consumption by end use

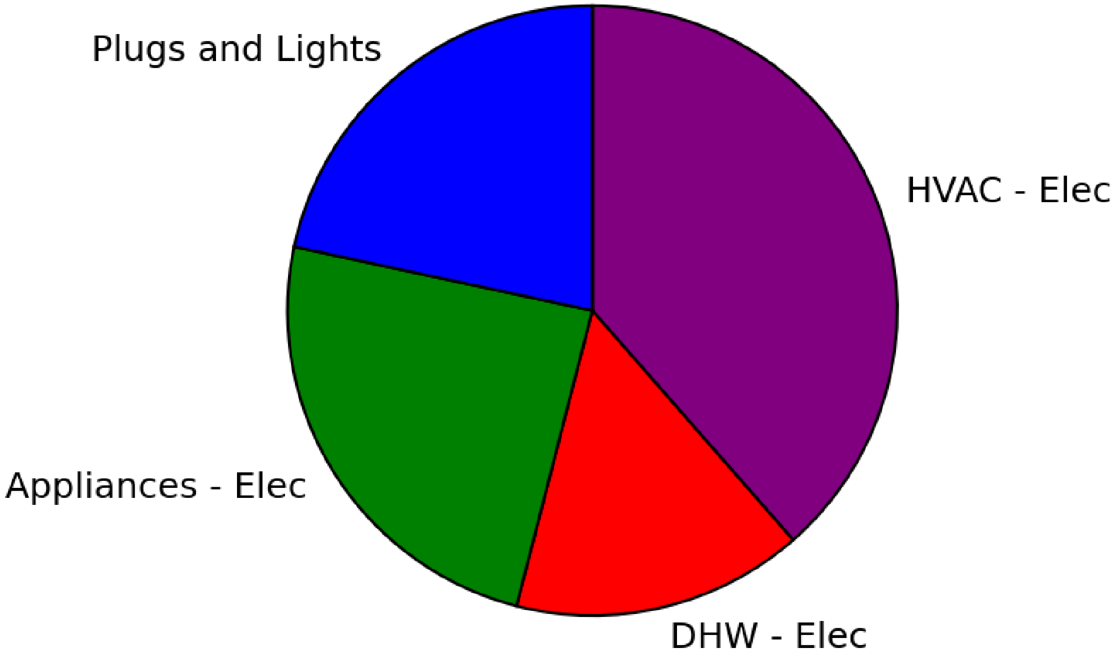


End use comparison

Mixed-fuel home

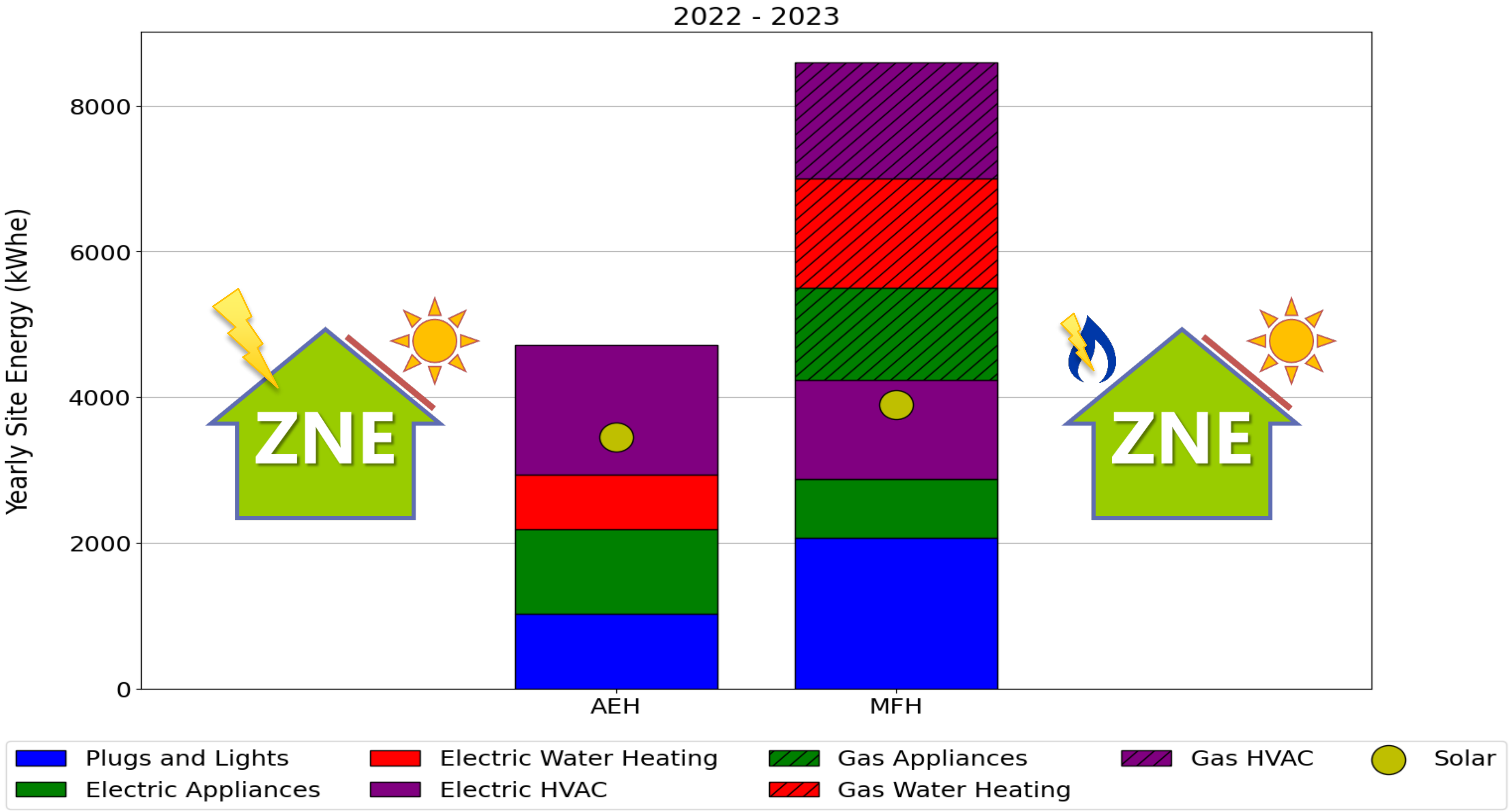


All-electric home

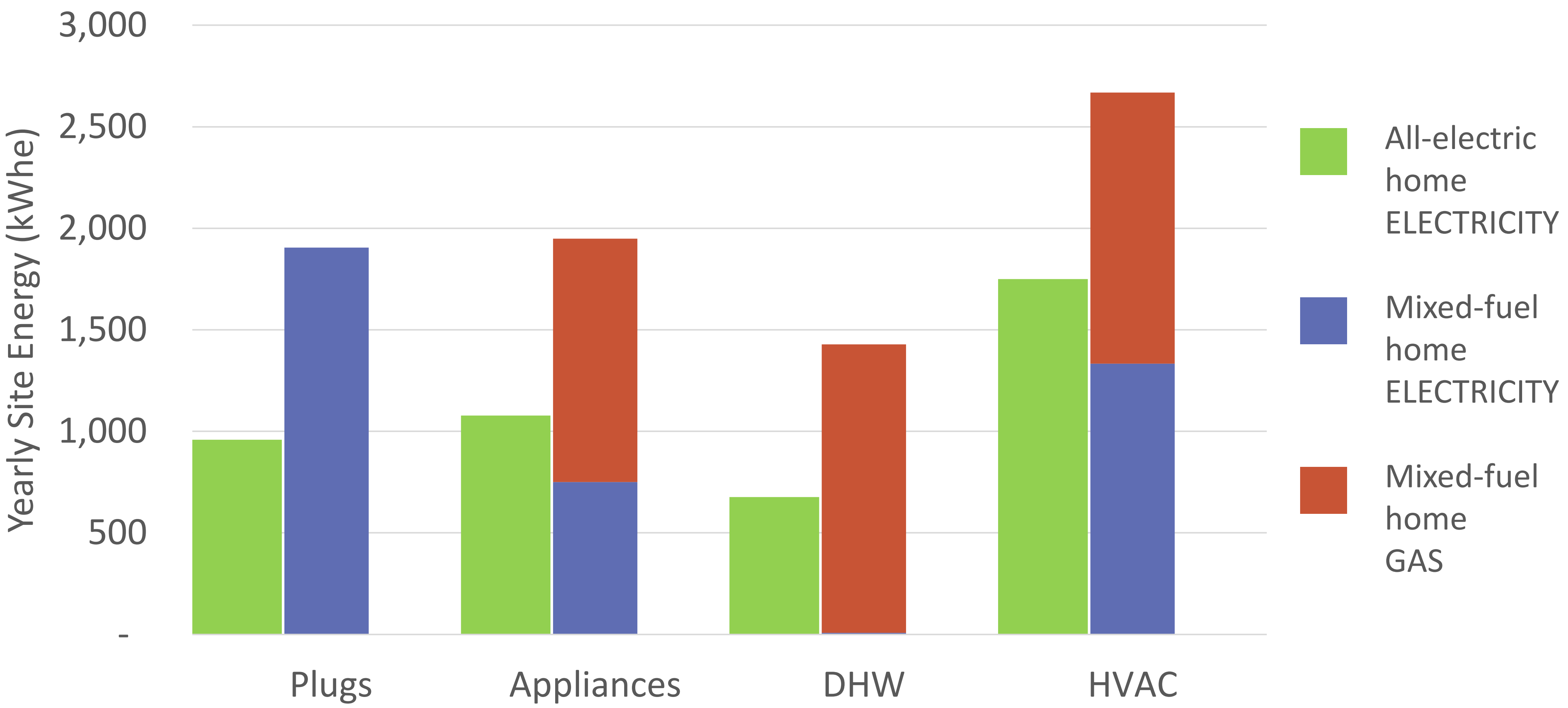


Consumption to date by end use

with solar generation

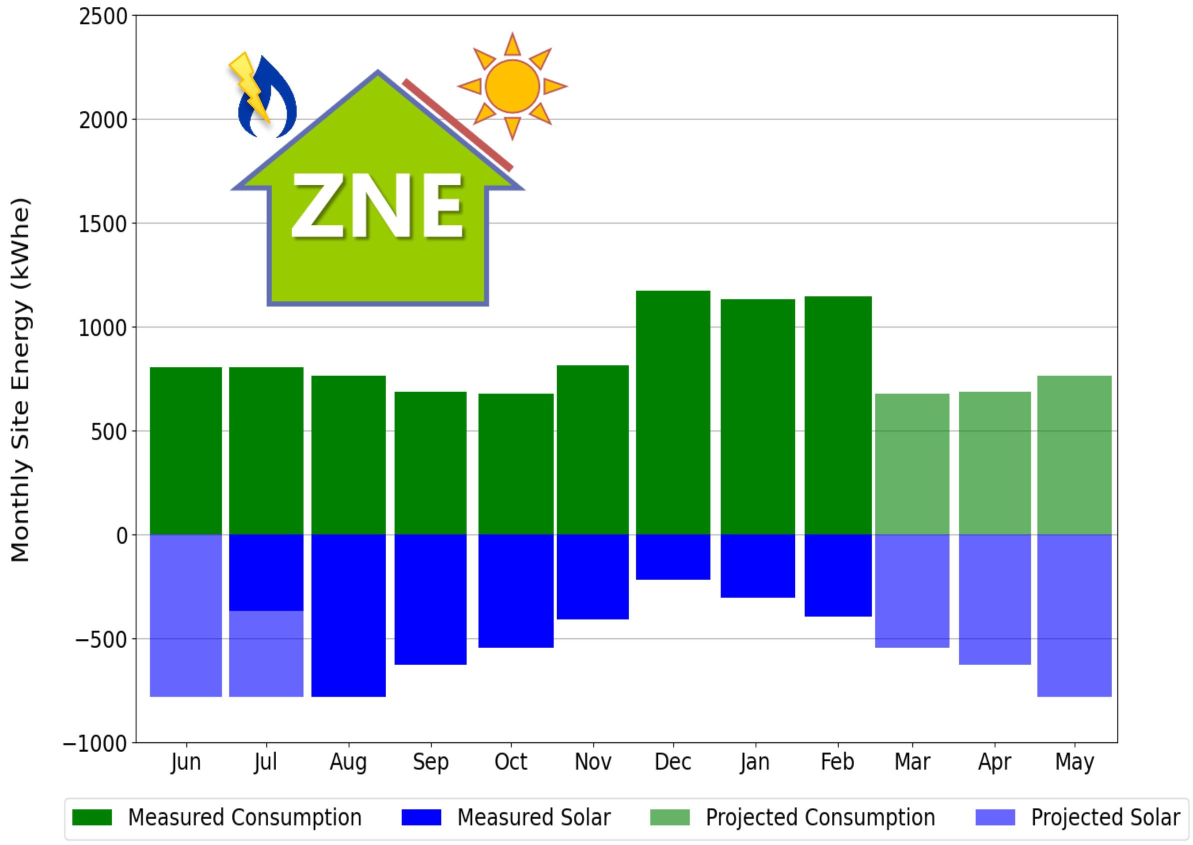


Consumption to date by end use *and fuel*

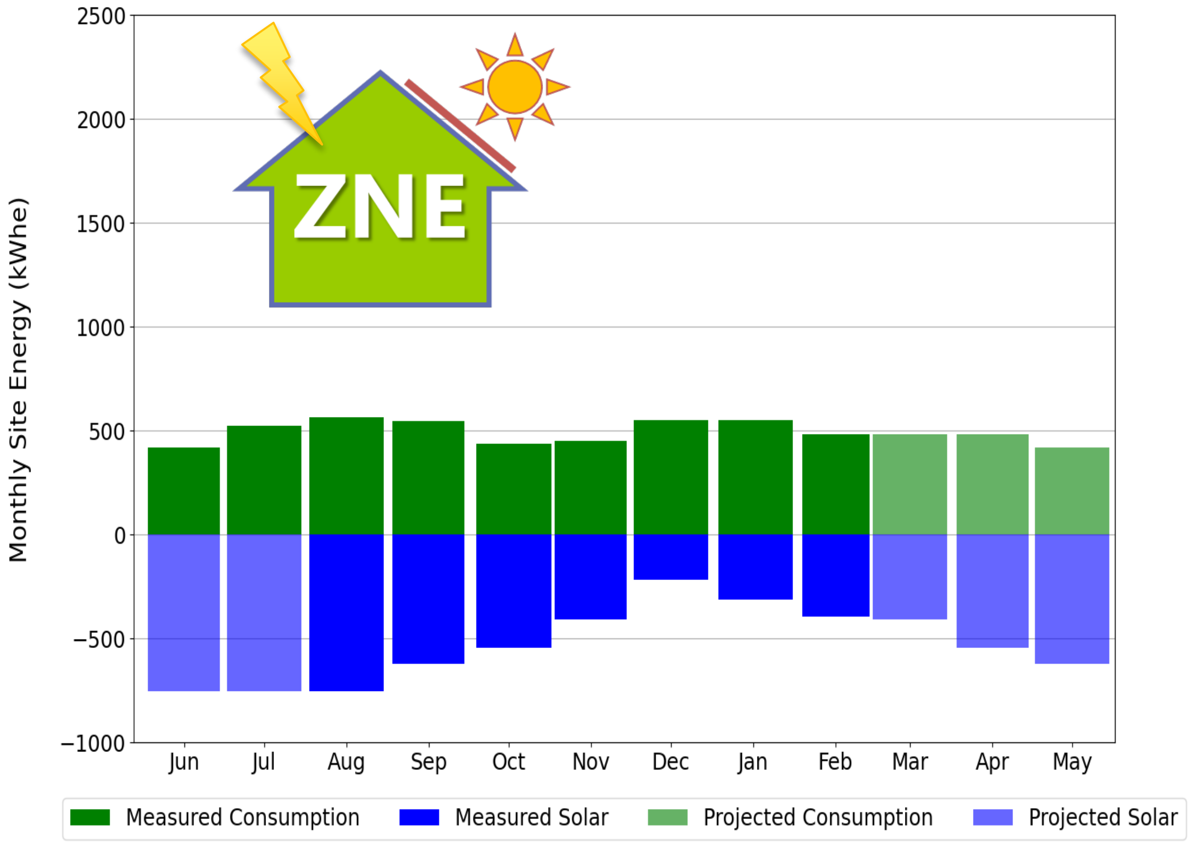


Estimated 1-year performance

Mixed-fuel home

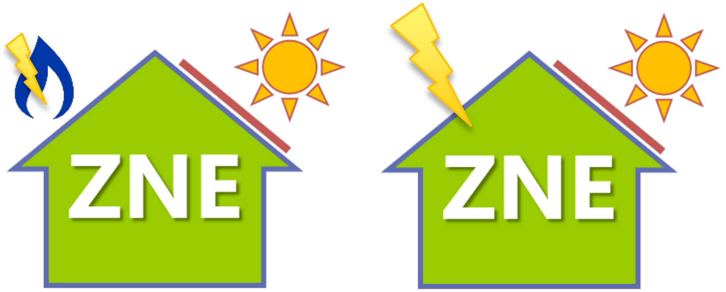


All-electric home



Energy use intensity (EUI) – 1,200-sf homes

NOTE: In Climate Zone 12, a good target EUI for ZNE is **16.6***



SITE EUI (kBtu/sq-ft-year)		MIXED-FUEL	ALL-ELECTRIC
Measured (9 months)	Load	22.7	12.8
	Solar	(10.4)	(9.3)
	Net	**12.4**	**3.6**
Projected (full year)	Load	28.5	15.8
	Solar	(18.1)	(17.9)
	Net	**10.3**	**(2.1)**

Very good value!

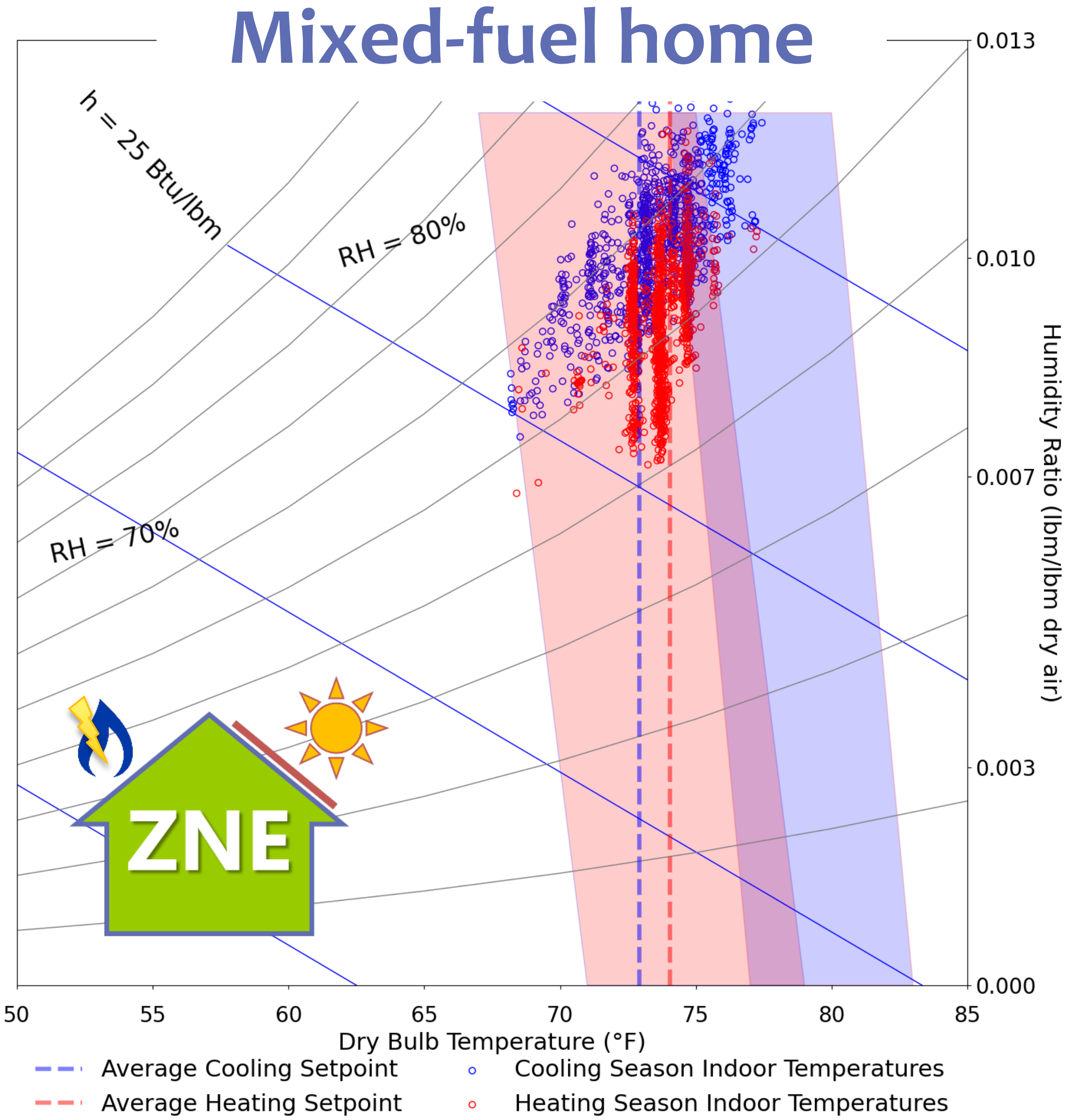
Negative → net energy producer!

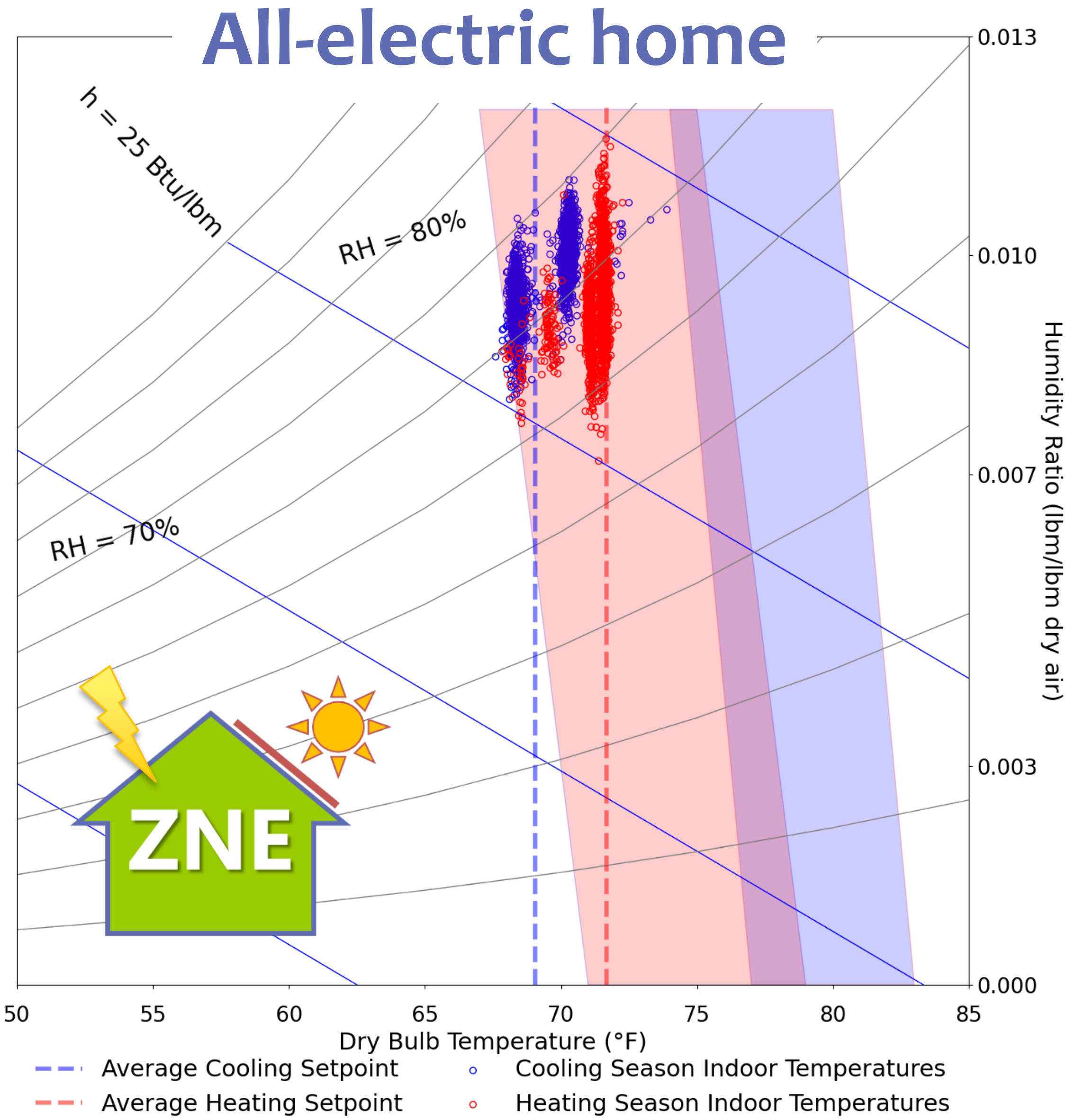
Much higher than expected

High, but lower than typical non-solar home

* See slide 23

Comfort


Mixed-fuel home
h = 25 Btu/lbm
RH = 80%
RH = 70%
0.013
0.010
0.007
0.003
0.000
Humidity Ratio (lbm/lbm dry air)
50
55
60
65
70
75
80
85
Dry Bulb Temperature (°F)
ZNE
Average Cooling Setpoint
Average Heating Setpoint
Cooling Season Indoor Temperatures
Heating Season Indoor Temperatures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Dry Bulb Temperature (°F)
ZNE
Average Cooling Setpoint
Average Heating Setpoint
Cooling Season Indoor Temperatures
Heating Season Indoor Temperatures

Surveys: occupant behaviors

BOTH households:
- 3 regular occupants
- 1 home with young child, 1 working at home

MIXED-FUEL

ALL-ELECTRIC

Laundry	10 loads/week, warmer water	6 loads/week, cooler water
Showers	same overall length, but fewer/longer	same overall length, but more/shorter
Garage fridge/freezer	No	Yes
Passive cooling	Used windows	Did not use windows
Supplemental heat	Space heater used in master bedroom, day and night	None

Surveys: occupant goals & comfort

BOTH households:
- 3 regular occupants
- 1 home with young child, 1 working at home

MIXED-FUEL

ALL-ELECTRIC

	MIXED-FUEL	ALL-ELECTRIC
Winter setpoint	Monitoring: 73-75	Monitoring: 70-72
Summer setpoint	Survey: 74 | Monitoring: 73	Survey: 71 | Monitoring: 68-70
Goal for use of thermostat setpoints	"Entirely to be comfortable"	"A compromise between comfort and controlling energy bills"
Goal for use of heating & cooling equipment	"We use the heater and AC as much as we need it to be comfortable"	"We try to be frugal, but we want to be comfortable, too"
Comfort comments	Really liked the system Reported discomfort, but not rising to the level of a problem	Really liked the system

Conclusions: what do the data tell us?

Were ZNE goals met?

- All-electric home is projected to meet ZNE goal:
  - Good EUI: 15.8 kBtu/sf-yr
  - Plenty of solar production: 17.9 kBtu/sf-yr
  - Net negative consumption (net generation): 2 kBtu/sf-yr
- Mixed-fuel home is not projected to meet ZNE goal:
  - Poor EUI: 28.5 kBtu/sq ft
  - Same amount of solar production: 18.1 kBtu/sf-yr
  - Net positive consumption of about: 10 kBtu/sf-yr
  - Not including garage: add an additional 17 kBtu/sf-yr (home)

Zero Energy/Electricity/Emissions Homes

Part 2: Project Outcomes & Lessons Learned

- Energy performance
- **What's different about ZNE homes**
- Process takeaways
- High-level lessons learned
- Resources

What's different about ZNE homes?

Key characteristics	Which means you need to make it easy to:
More energy-efficient than most	▪ Air seal & insulate effectively (and meet QII) ▪ Have nature help (not hinder) performance
Enough solar PV to meet annual loads	▪ Find enough contiguous roof space for a rational solar array
High-performance HVAC system ▪ Mixed-fuel ▪ All-electric	▪ Pre-design entire system, including distribution system layout ▪ Understand the different space requirements based on fuel choice ▪ Accommodate all parts in conditioned space
High-performance DHW system	▪ Pre-design entire system, including piping sizes and routing

The devil's in the details

Image: Openclipart via publicdomainvectors.org

Critical factors for achieving ZNE affordably:

- Roof
- Basic building form
- Floor plan & system design
- Windows and shading
- Documentation
- Commissioning

Roof—why start here?

- Achieving ZNE dictates a solar production goal
  - Just code (zero net electricity)? *or*
  - Zero net energy? *or*
  - Zero net emissions?
- Metrics that matter
  - Energy use intensity (EUI)
  - Total load (KW DC energy)
  - PV square footage
  - Roof area

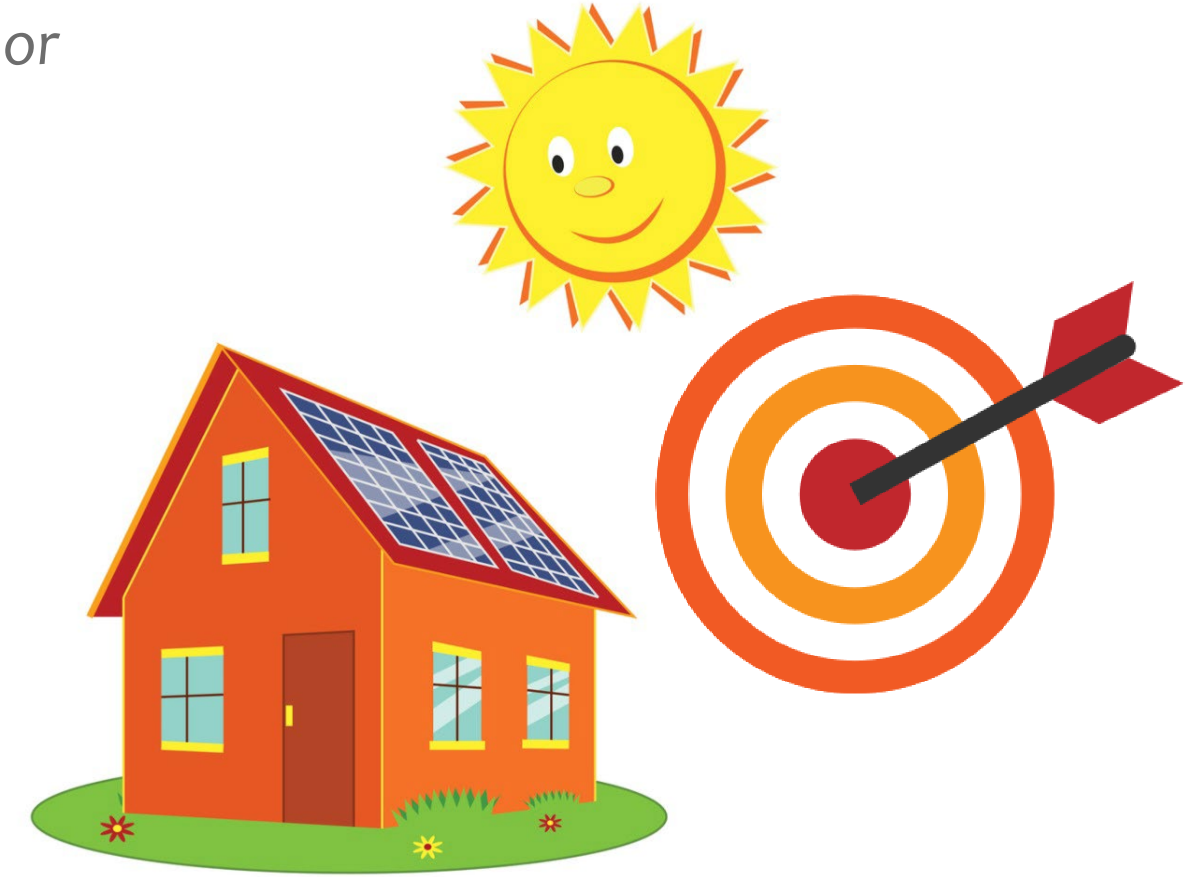


Image Xana_UKR via iStock

Choose a target energy use intensity (EUI)

- **What's a "good" EUI in KBtu/sf/yr?**

Single Family Residential

Size:	**2,116**	ft^2
Number of Floors:	**1**	floor

Climate Zones

Site-kBtu /ft^2	**15**	**13**	**12**	**10**	**7**	**3**	**16**
Load:	12.9	16.4	16.6	12.9	11.5	12.7	17.3
Solar:	-12.9	-16.4	-16.6	-12.9	-11.5	-12.7	-17.3
Net:	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Source: *The Technical Feasibility of Zero Net Energy Buildings in California*, Arup, December 2012

Use EUI to estimate annual energy load

- **What's the total load in kilowatt-hours (kWh)?**

EUI (kBtu/sf/yr) x House Size (sf)

EXAMPLE: 1,800 sf house in Oakland (Zone 3)

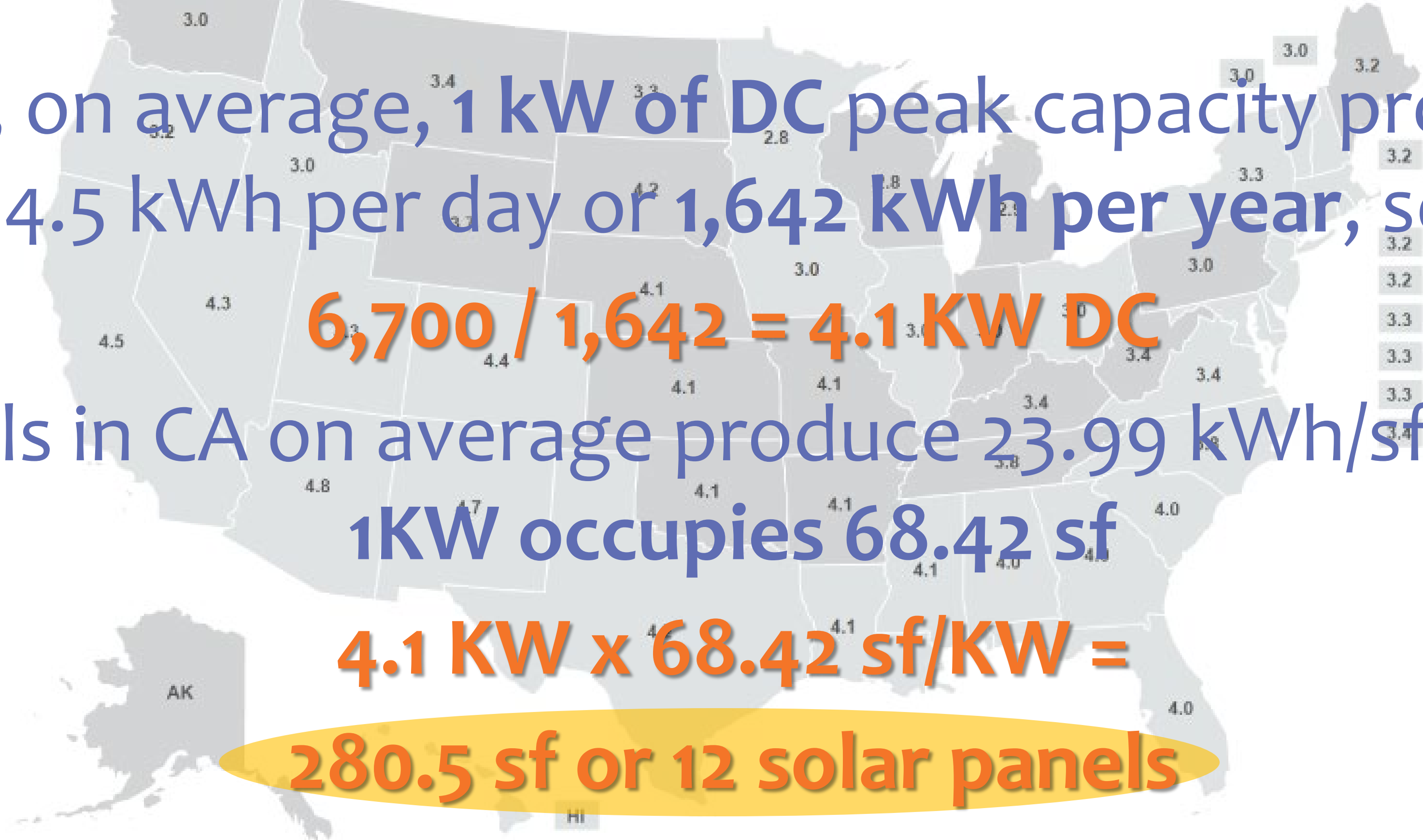
12.7 kBtu/sf/yr x 1,800 sf = 22,860 kBtu/yr

Convert kBtu/yr to kWh/yr: divide by 3.412

22,860 / 3.412 = 6,700 kWh/yr

Set preliminary solar energy production goal

- **How much PV is needed?**



In CA, on average, **1 kW of DC** peak capacity produces 4.5 kWh per day or **1,642 kWh per year**, so

6,700 / 1,642 = 4.1 KW DC

Panels in CA on average produce 23.99 kWh/sf/yr, so **1KW occupies 68.42 sf**

4.1 KW x 68.42 sf/KW =

280.5 sf or 12 solar panels

Source: https://www.solarreviews.com/blog/how-much-electricity-does-a-solar-panel-produce

Estimate uninterrupted roof area

- **How much roof space is that, *really*?**

Typical residential panels are about **65" x 39"** so an array

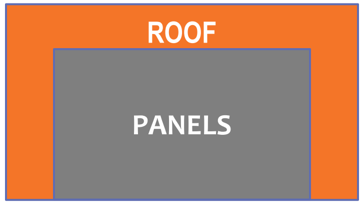
2 panels high by 6 panels wide is

about 11 ft. high x 20 ft. wide

plus 3' on 3 sides for fire clearance

gives a **total roof area** of

14 x 26 ft = 364 sq.ft.



With NO obstructions!

Source: http://news.energysage.com/average-solar-panel-size-weight/

Basic building form: simplifying AVE

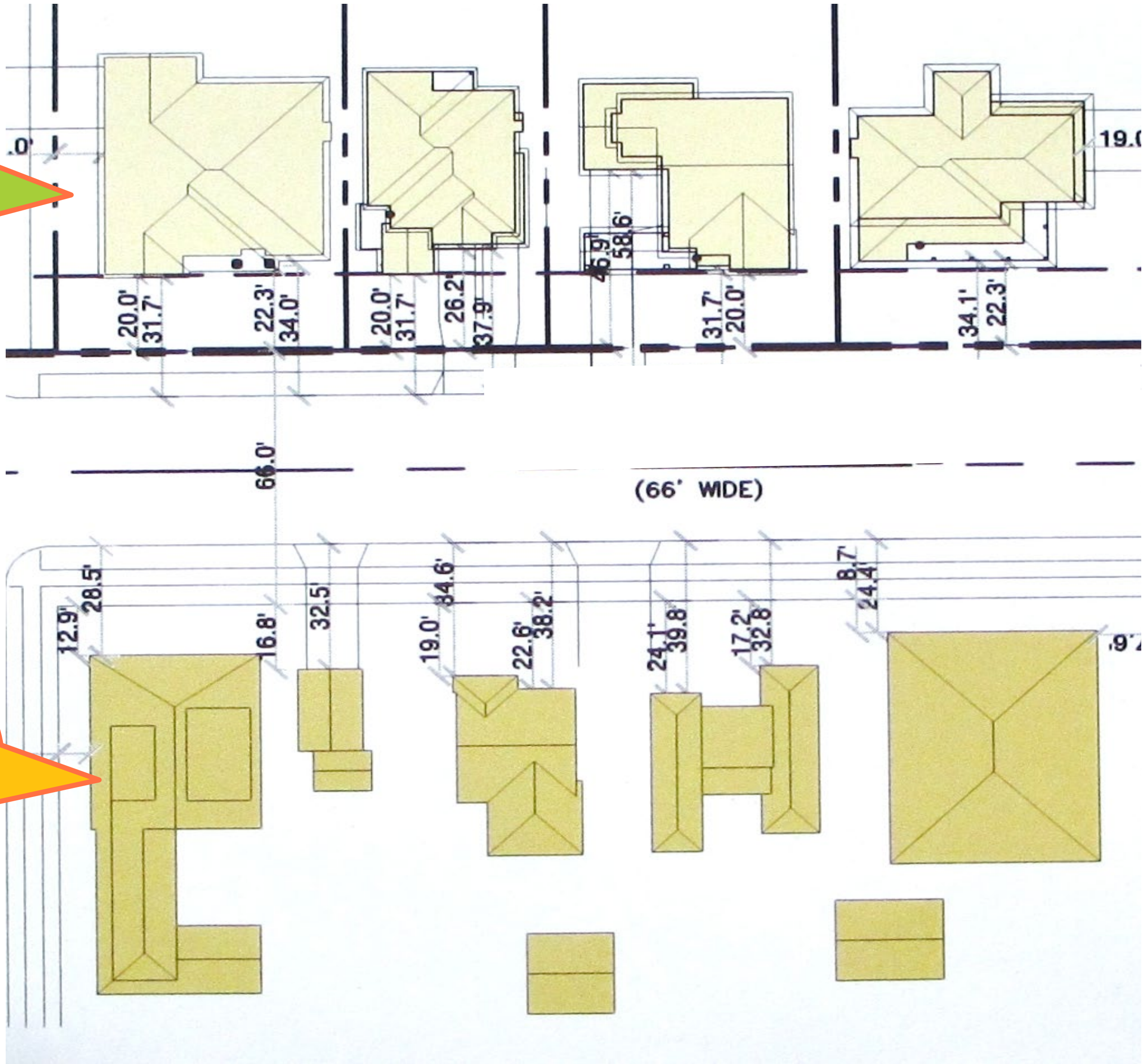
REALLY HARD to heat, insulate, & air seal COMPLEX forms!

MUCH EASIER to heat, cool, insulate, & air seal SIMPLE forms

Basic building form: the *value* of simplifying

NEW
(more
complex)

EXISTING
(simpler)

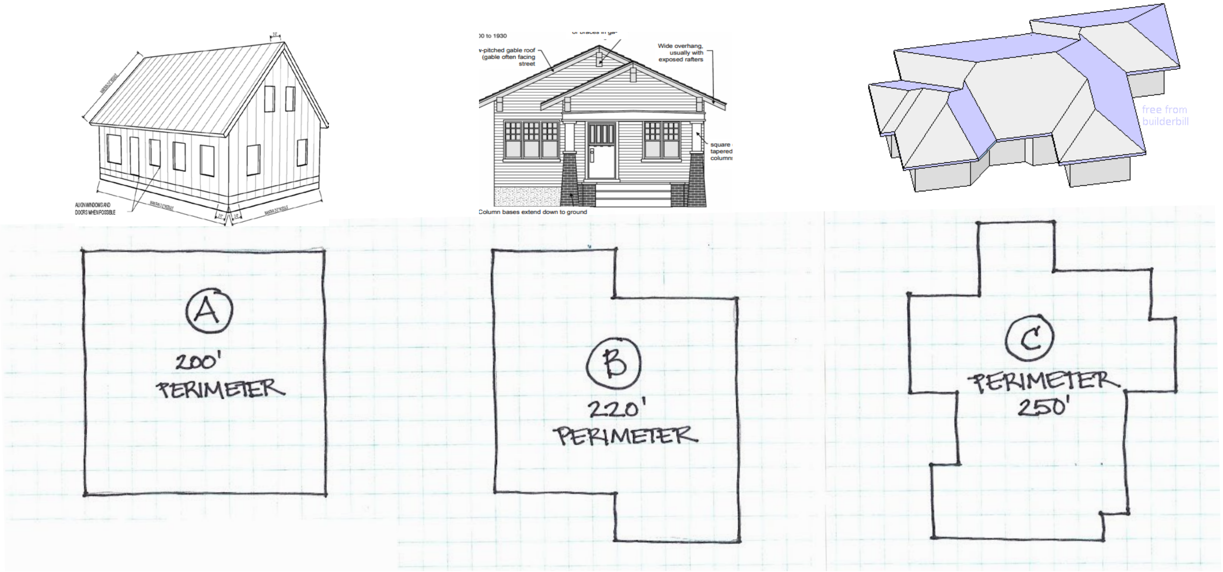


What are the costs of complexity here?

- Design $$$
- Construction $$$
- Liability risks
- Lost solar opportunity
- Higher utility costs
- Potential moisture intrusion

Example calculation: the cost of complexity

2,500 square foot floor plans



Construction cost assumptions (labor + materials):

- $300 / foot of perimeter
- $500 / corner

Not included:

- Interior impacts
- Roofing impacts
- Design costs
- Occupant utilities

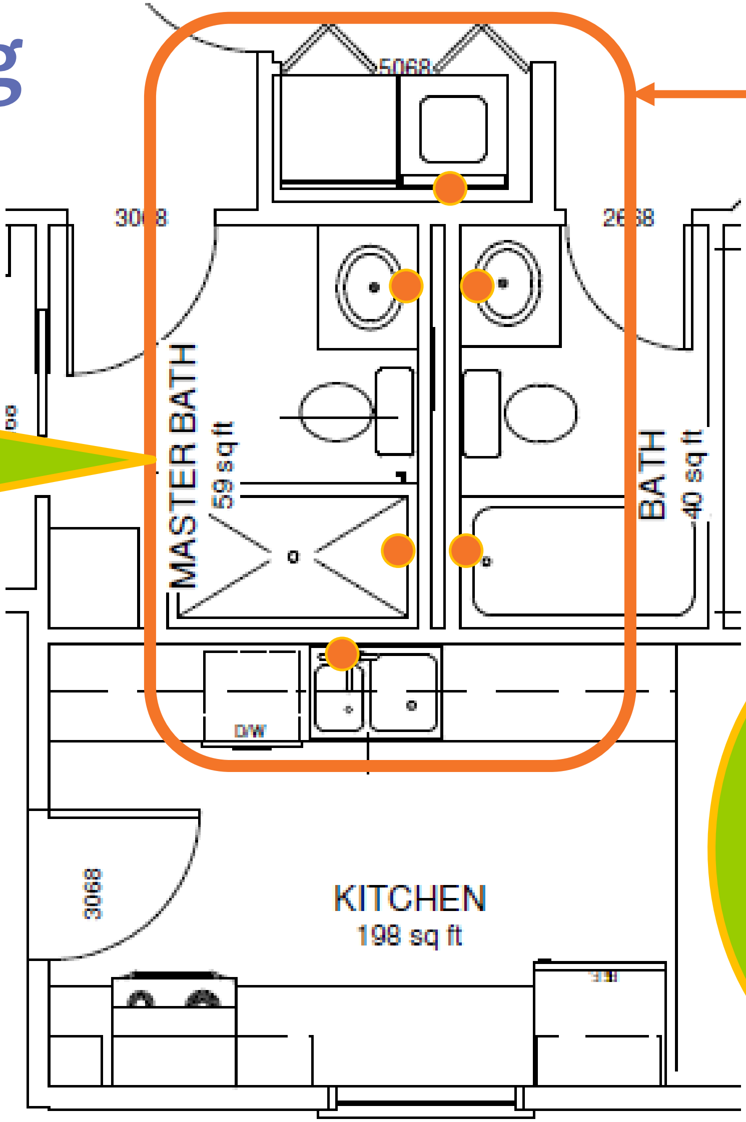
Compare:	Plan A	Plan B	Plan C
Perimeter	200 ft	220 ft	250 ft
Corners	4	8	18
$ increase		**$9,000**	**$15,000**

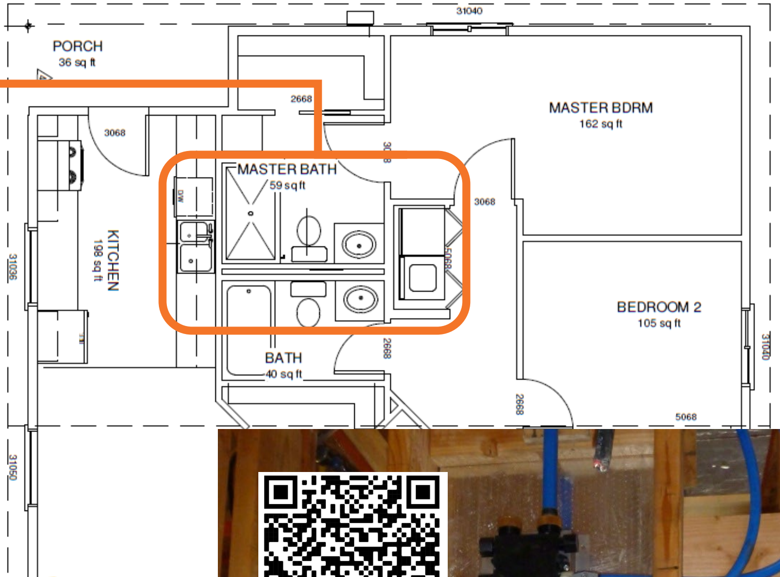
Image A greenbuildingadvisor.com | Image B greenvillesc.gov | Image C www.builderbill-diy-help.com

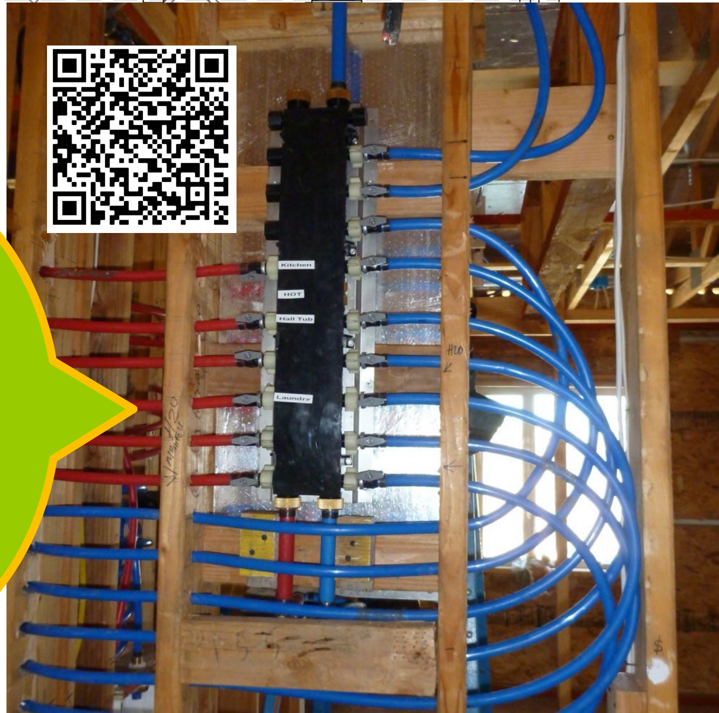
Floor plan & system design: hot water distribution

Compact plumbing

LONGEST HOT WATER PIPE
12 ft.







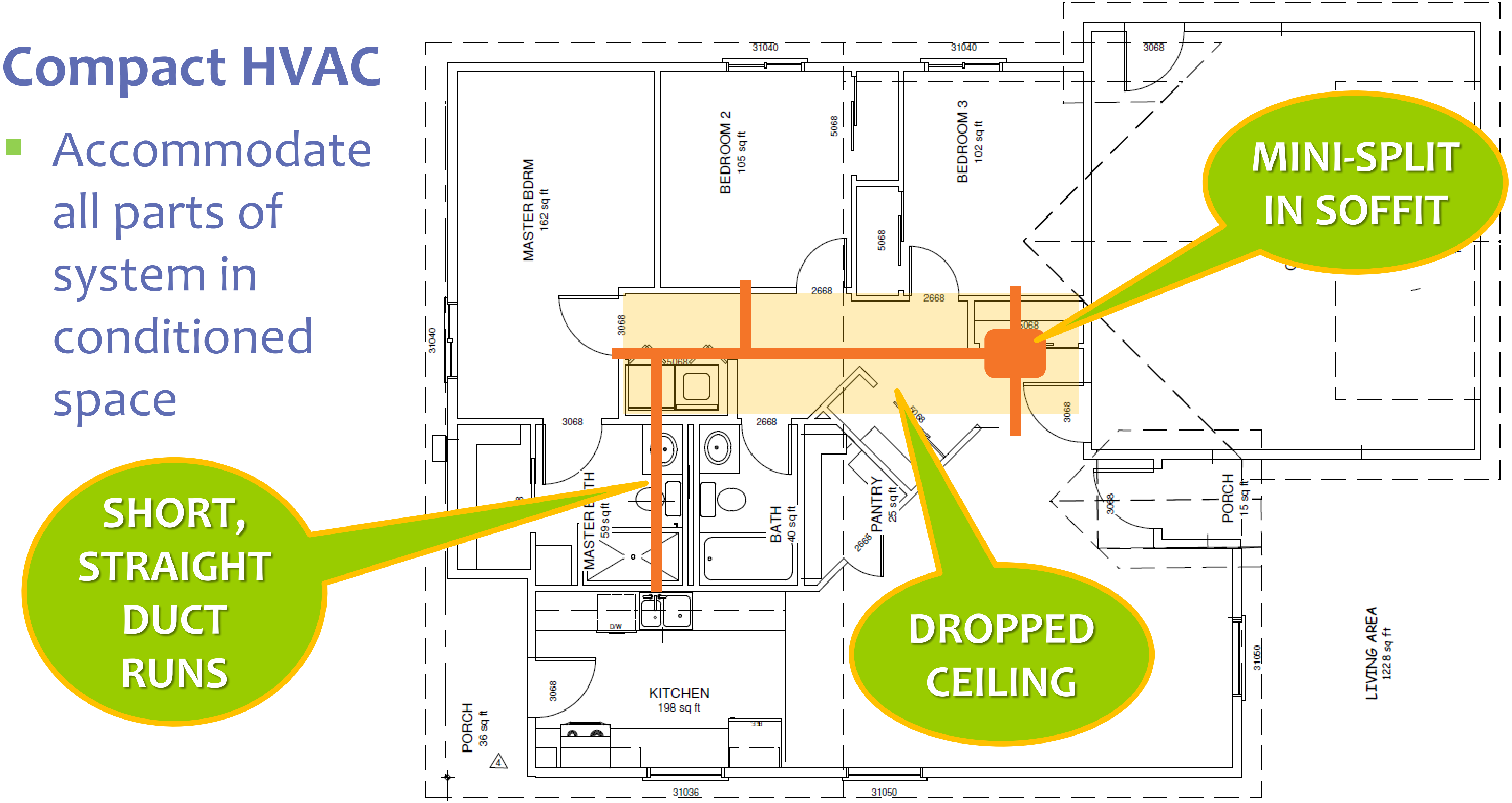
1/2" PIPING TO MINIMIZE WATER WASTE

- Labor savings
- Material savings

Floor plan & system design: mechanical layout

Compact HVAC

- Accommodate all parts of system in conditioned space



Windows and shading: fundamentals

- Hold glass **area** in check (minimize heat loss and heat gain)
- Specify high-performance **U-factor & SHGC** (solar heat gain coefficient)
  - **U ≤ 0.27, SHGC ≤ 0.24**
- Include **shading & glare protection**
- **Avoid** double/single-hung and **sliders**
- Size windows to **fit within framing**

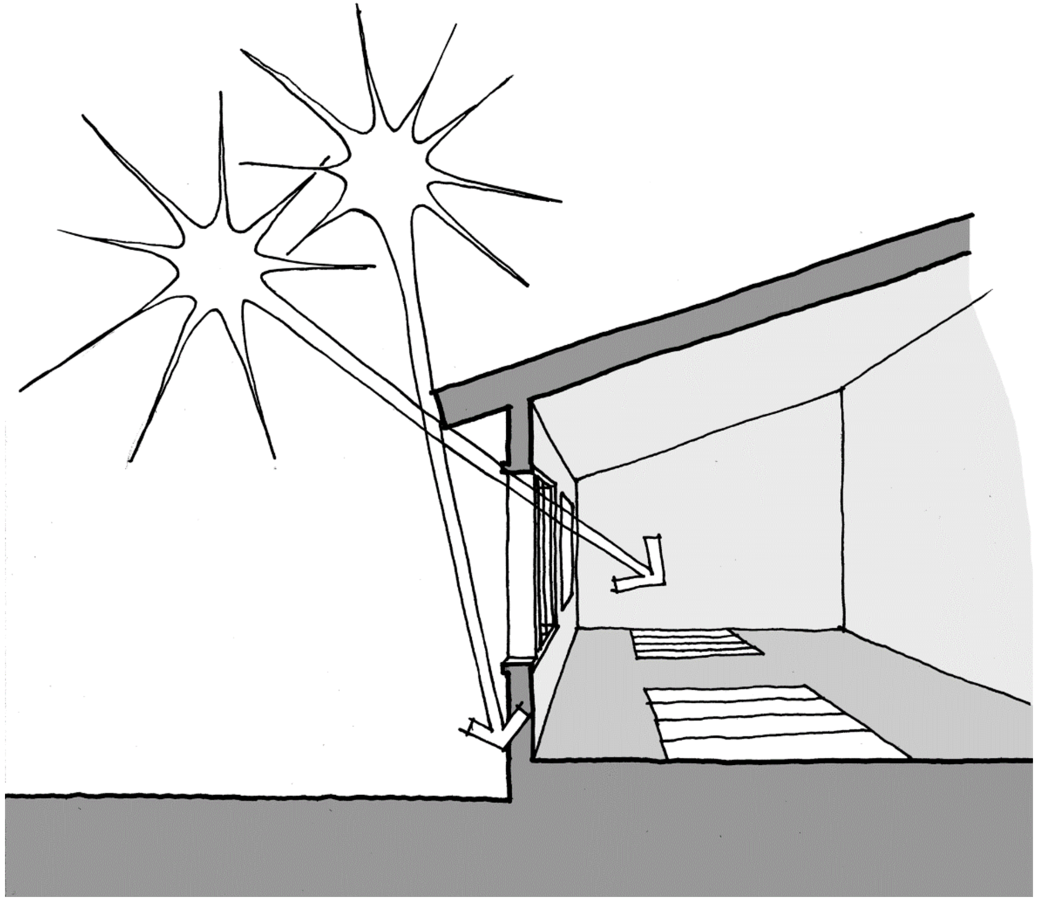
THEY'RE LEAKY!

If SHGC is too high or shading is inadequate, ZNE homes can easily overheat

Windows and shading: shading principles

Shading principles

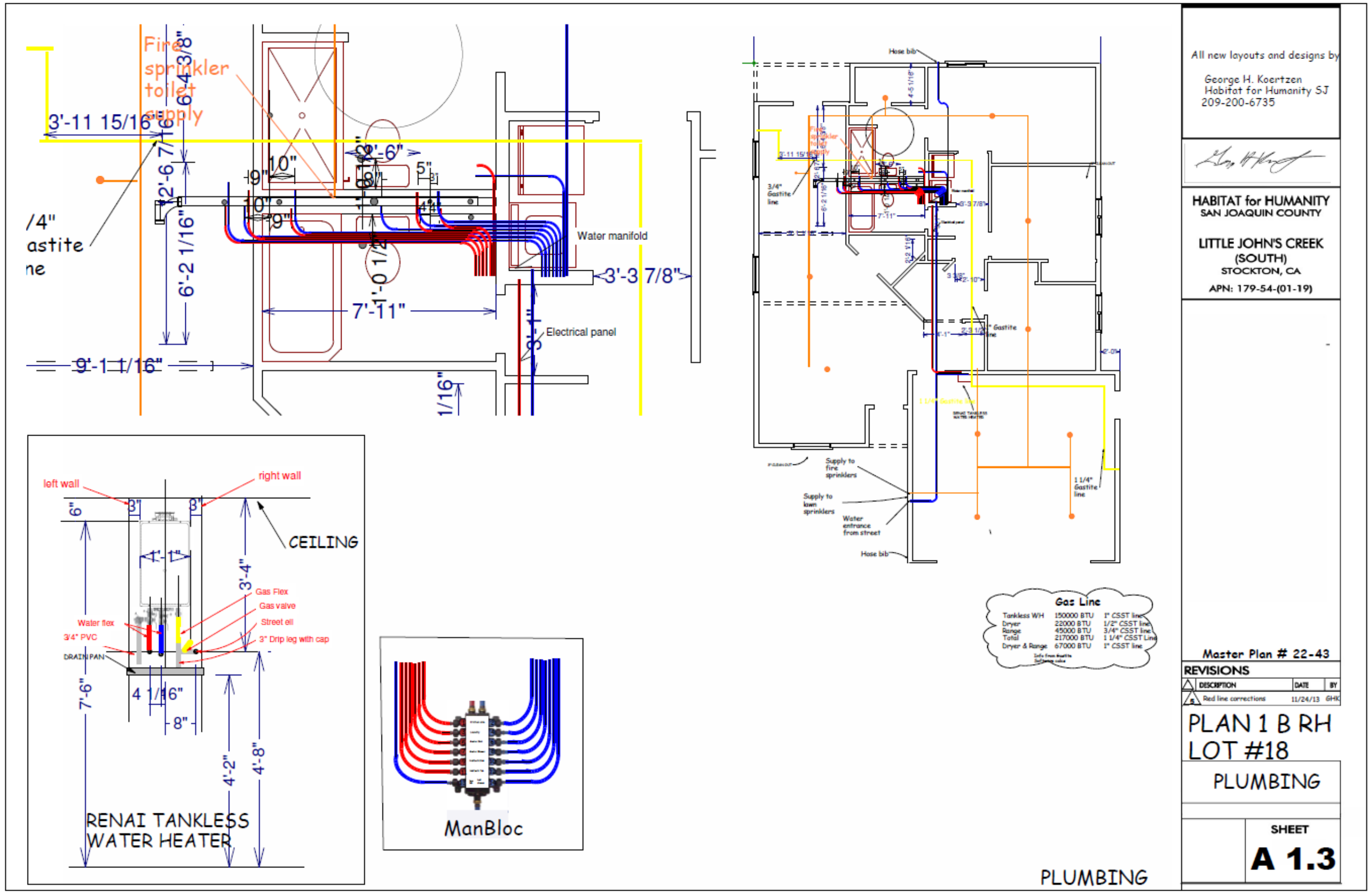
- **Overhangs have limited effect at low sun angles**
  - West & east façades
  - Spring & fall hot spells
- **The lower the glass, the harder it is to shade**
  - Occupants' knees can't enjoy the view
  - The solar heat gain is a liability



Documentation: drawings

All the usual plus:

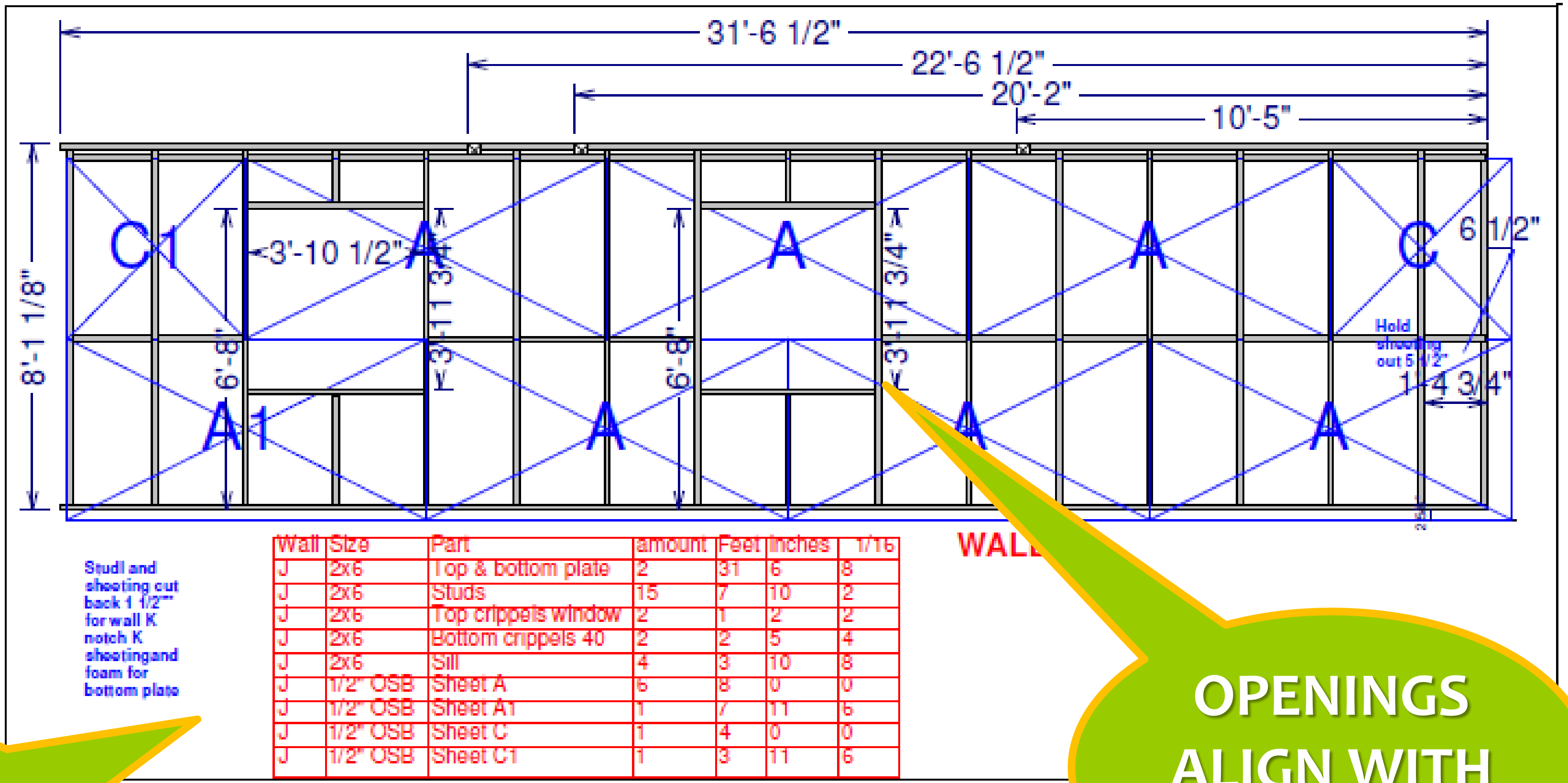
- Wall framing elevations
  - Exterior
  - Interior
- Complete mechanical plans
  - Heating & cooling
  - Ventilation
- Complete plumbing plans
  - Schematic
  - Manifold installation



Documentation: framing elevations

Advanced framing:

- Studs 24” o.c.
- Openings aligned with framing
- Windows ordered to fit spaces between studs



Wall	Size	Part	amount	Feet	inches	1/16
J	2x6	Top & bottom plate	2	31	6	8
J	2x6	Studs	15	7	10	2
J	2x6	Top crippels window	2	1	2	2
J	2x6	Bottom crippels 40	2	2	5	4
J	2x6	Sill	4	3	10	8
J	1/2" OSB	Sheet A	6	8	0	0
J	1/2" OSB	Sheet A1	1	7	11	6
J	1/2" OSB	Sheet C	1	4	0	0
J	1/2" OSB	Sheet C1	1	3	11	6

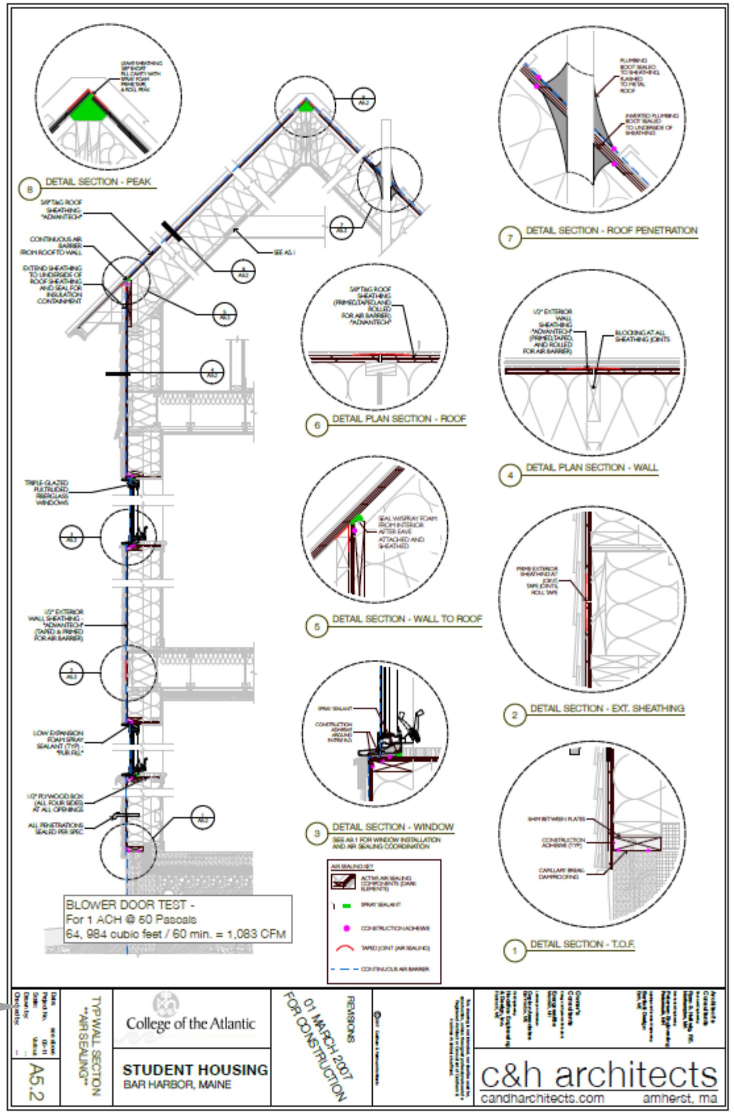
DRAWINGS SHOW EVERY WALL & EVERY MEMBER

OPENINGS ALIGN WITH FRAMING

Documentation: air leakage control

Critical tasks:

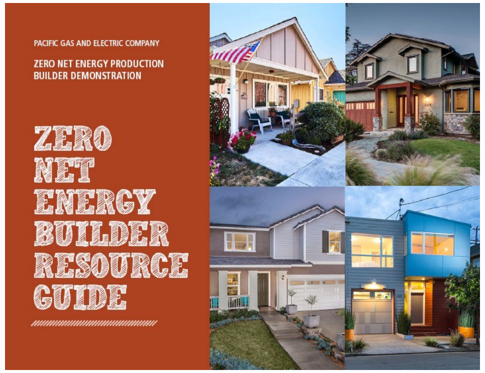
- Provide an air sealing **cross section**
- Include **details** for air sealing & exterior insulation
- Provide **specs** for air sealing, insulation installation, & other critical construction quality tasks
- Communicate **intent** to entire crew
- **Manage quality** during construction



RESOURCE (free download)
[Air sealing drawing by Coldham & Hartman Architects](#) ➔

Documentation: goals & checklists

	ITEM:	VERIFY IN FIELD:
☑	Air barriers	In place
☑	Air sealing	Comprehensive
☑	Advanced framing	Matches specs
☑	Window NFRC sticker	Match specs
☑	Cavity insulation	Properly installed
☑	HVAC load calculations	Checked
☑	Duct design	Checked
☑	Lighting	All LED/high-efficacy

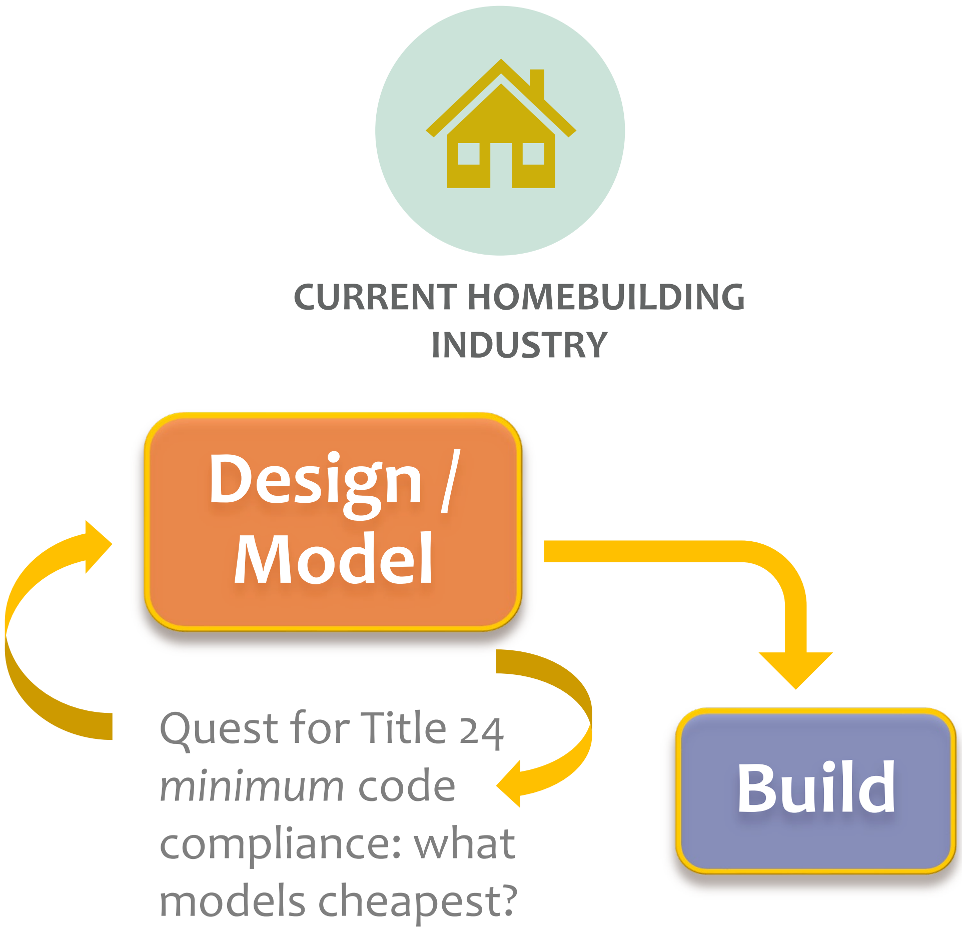


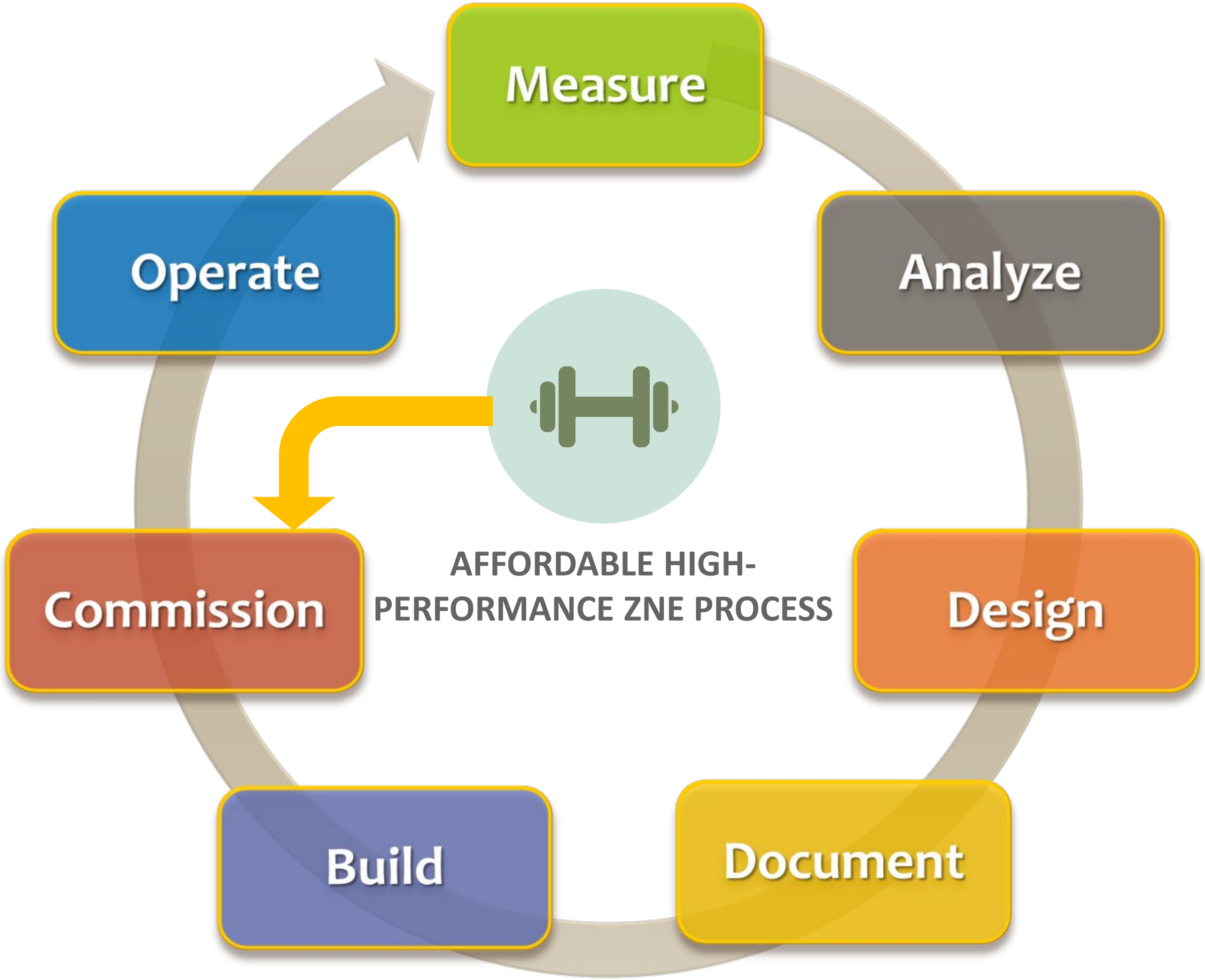
Ensure contract documents:

- **Clearly communicate your goals**
- **Specify procedures, timelines, metrics**
- **Include:**
  - Performance testing of key building features and equipment *during construction*
  - Commissioning to verify as-designed performance of all key systems *at completion*

RESOURCE:
PG&E Zero Net Energy Builder Resource Guide
(free download including many resources with live links)

Commissioning: a critical difference





Commissioning: what *is* it?

Performing tests and making adjustments needed for the system to meet all design objectives, functions, and specifications.

Building commissioning GOALS:

- To produce a building that **meets the unique needs** of its owner and occupants
- Ensure all systems are **serviced and maintained** properly
- Enable all systems to **operate as efficiently as possible**

The term **commissioning** comes from shipbuilding.

A commissioned ship is one deemed **ready for service.**

Before being awarded this title, however, a ship—or a home's systems—must pass several **milestones.**

Commissioning: benefits

1. Higher worker productivity (use checklists!)
2. Systems last longer
3. Project goals and projections are realized
4. Installing technician data feedback- learn what works and what doesn't
5. System designer feedback—save money, increase installation efficiency/ correct modeling assumptions
6. Smart operators/owners are happier, more comfortable, higher quality of living

HVAC System Commissioning: Task Description	
Project Name:	
Date:	
Outside Air Temp (F):	**Inside Temp Average (F):**
Note: This phase assumes the system is fully wired, welded, evacuated, confirmed leak free, charge released, and ready to run.	
	Verify proper air flow speed is set on control board per manufacturer instructions
	Verify that all supply outlets and return air grilles are installed
	Temporarily tape air handler unit door seal to be air tight
	Perform duct leakage testing to ensure air distribution system has "LO" leakage
	Un-tape the supply and return outlets. Convert DuctBlaster to FlowBlaster.
	Verify all takeoff dampers at plenums are set in the full open position
	Install a clean return air filter in each return location
	Turn on the unit and adjust temp setting to ensure it remains on
	Adjust all supply outlets for proper throw into the unoccupied zone
	Measure all supply* airflows, recording each on the Manual J/D (*or return)
	Compare the total measured airflow to the target airflow
	If above is good, continue. If not, modify system airflow, then re-measure
	Verify that measured system airflow matches target system airflow
	Compare individual room airflows to room design target airflows
	Identify room airflows that are >20% from room target airflow
	Starting with largest airflow amount over target, adjust down to target
	Re-measure all airflows after adjusting any individual ones. Enter on design.
	Lock each supply damper at the plenum as they are adjusted. End with all locked.
	Record each FINAL supply airflow on manual J design, erasing all previous ones.
	Calculate the total of all supply airflows, and record final number on design
	Measure the airflow at each return air location and record on design
	Measure and record total external static pressure on design
	Individually close each room door, test and record pressure across each
	Finally, measure the "fan only" supply outlet airflows and record on design
	When finished, turn off air handler
	Turn on exhaust system (fans), measure and record airflows
	Examine exhaust fan settings and set to meet BAS (if 80+ CFM recorded above).
	Break down airflow measuring tools and put away
Install outdoor disconnect, and/or turn on breaker to establish unit power	
	Turn system on in cooling mode (as weather appropriate).
	Ensure proper temperatures for subcooling verification test
	(Proper temps are house at maintained above 70F, and outdoor above 55F.)
	Ask installation crew the measured line set length and if any charge was weighed in
	Purge gauges of any air and set up refrigerant scale
	Install refrigeration gauges and insulated temperature sensors on outdoor unit
	Weigh in proper charge for line set length per manuf. instructions
	Let system run for 15 minutes minimum and record pressure and temp numbers
	Ensure system is operating at proper speed for charging (typically LOW 2-speed)
	After 15 minutes, compare readings to manufacturer targets

Commissioning: what systems need it?

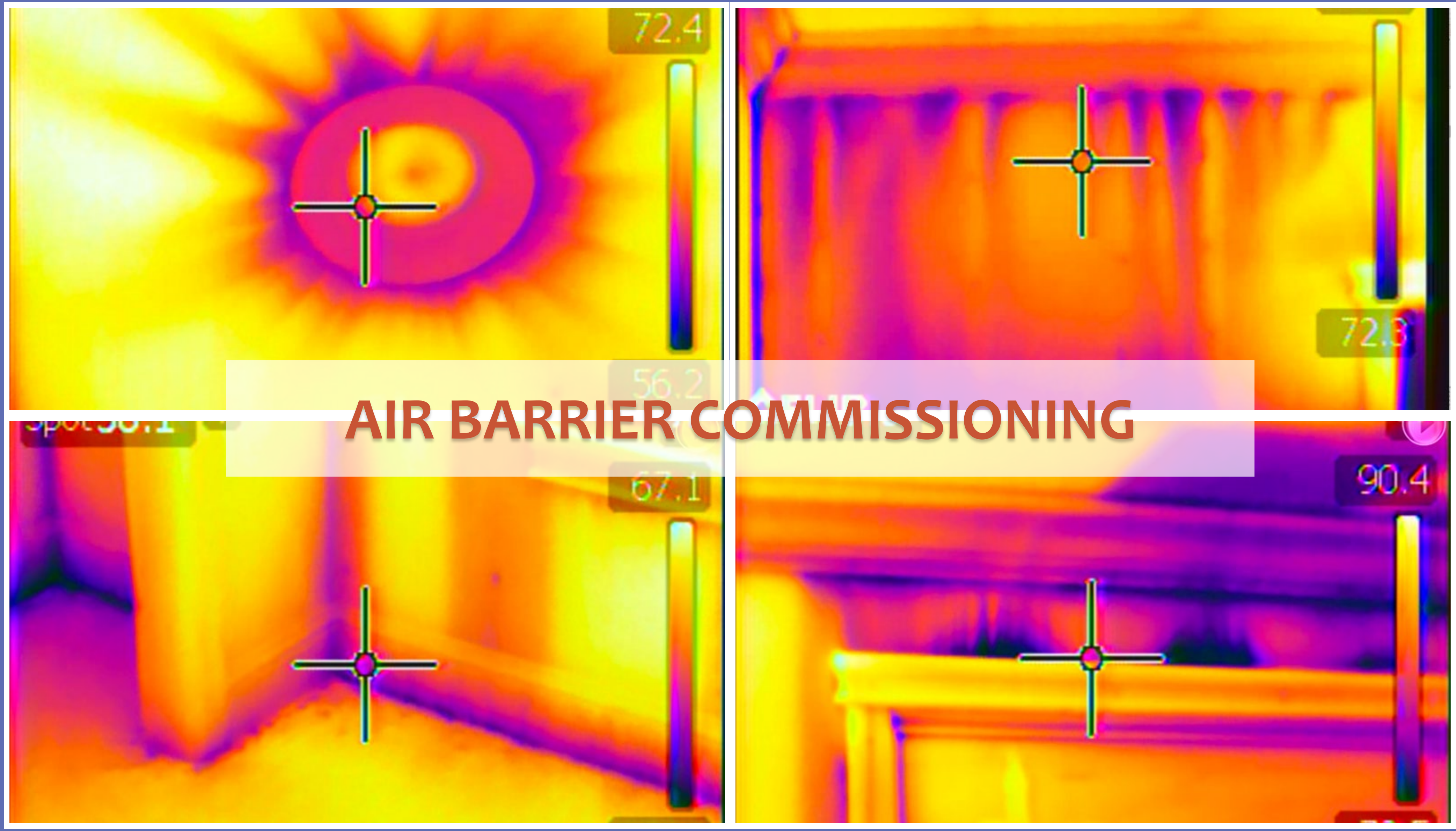
- Heating units
- Cooling units
- Ducted distribution systems
- Ventilation systems
- Water heaters
- Hot water distribution
- Air barriers
- Thermal barriers
- Solar PV systems
- Etc.

Credit: Rick Chitwood

AIR BARRIER COMMISSIONING

Recessed can light air leakage

Air leakage inside wall between top plate & drywall



Air leakage through gaps at bottom of wall

Air leakage behind window head casing (not caulked)

What systems normally *get* **commissioned?**

- ~~Heating units~~
- ~~Cooling units~~
- ~~Ducted distribution systems~~
- ~~Ventilation systems~~
- ~~Water heaters~~
- ~~Hot water distribution~~
- ~~Air barriers~~
- ~~Thermal barriers~~
- ~~Solar PV systems~~
- ~~Etc.~~

HVAC PERFORMANCE OUTCOMES	TYPICAL NEW HOME	HIGH-PERFORMANCE ZNE HOME
Equipment Sizing (Btuh)	80,000	9,000
Equipment Efficiency (AFUE & COP)	97.5%	414%
Fan Power (Watts)	319 [2]	75
Hourly Operating Cost ($) [1]	1.13	0.13
External Static Pressure (inches WC)	0.92	0.20
Interior Stratification °F	30	3
Distribution System Losses	18,000	0 [3]

1. Gas at $1.35/therm, electricity @ $0.156/kWh

2. Heating mode only – cooling much higher
3. When fully inside conditioned space

HVAC Loads

Habitat for Humanity, Stockton

Loads are *tiny* because the enclosure is **excellent.**

ZNE homes are superbly insulated and extremely airtight, with excellent windows, so **they lose and gain much less heat** than conventional homes.

HVAC LOADS - 1,200 FT² ZNE HOME		
	Heating (Btu/h)	Cooling (Btu/h)
Living	2,562	2,876
Master BR	1,301	1,002
Kitchen	1,267	2,254
Hall/Storage	1,118	1,306
Bedroom 1	870	1,016
Bedroom 2	663	958
Master Bath	559	316
Bath 1	103	90
Other Equipment	366	291
Humidity		603
Total	**8,809**	**11,006**

Real-World Zero Net Energy Homes for California, 2020a

POLL

What is the ideal order for considering the following during design?

A. 1: Floor plan | 2: Roof design | 3: Systems design

B. 1: Roof design | 2: Floor plan | 3: Systems design

C. 1: Systems design | 2: Floor plan | 3: Roof design

D. None of the above

POLL

What is the ideal order for considering the following during design?

A. 1: Floor plan | 2: Roof design | 3: Systems design

B. 1: Roof design | 2: Floor plan | 3: Systems design

C. 1: Systems design | 2: Floor plan | 3: Roof design

D. None of the above

POLL

What is the largest home that can be kept very comfortable year-round (70°F heating & cooling) **with just a 3/4-ton heat pump?**

(Outdoor design temps: heating 30°F, cooling 102°F)

A. 800 SF (2 bed, 1 bath, 8' ceilings)

B. 1,200 SF (3 bed, 1 bath, 8' ceilings)

C. 1,600 SF (3 bed, 2 bath, 8' ceilings)

D. 2,000 SF (4 bed, 2 bath, 9' ceilings)

E. 2,400 SF (4 bed, 3 bath, 9' ceilings)

E. All a high performance new ZNE home needs is a 3/4-ton mini-split!

Stockton	Redding
HDD 2,702	**HDD 8,800**
CDD 1,470	**CDD 8,800**
1,200 sf	**2,400 sf**

Equipment, electrical & refrigerant line sets:

~$1,500

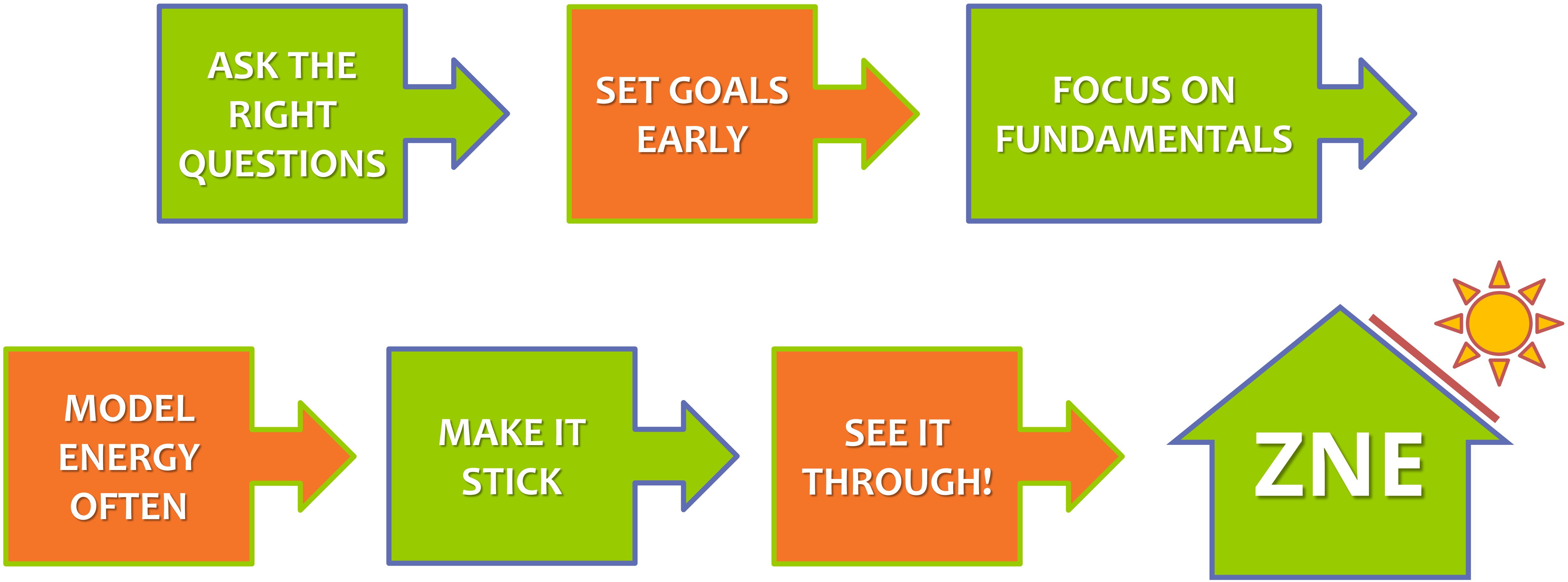
Credit: Rick Chitwood

Zero Energy/Electricity/Emissions Homes

Part 2: Project Outcomes & Lessons Learned

- Energy performance
- What’s different about ZNE homes
- **Process takeaways**
- High-level lessons learned
- Resources

Process takeaways: Key steps for getting to ZNE



Getting to ZNE affordably requires asking the right questions—

Rocky Hill Co-Housing Community, Northampton, MA

Making Choices Instead of Paying Premiums for Greener Buildings

By Bruce Coldham

It is often presumed that "green" resourceful building involves a cost premium. This is not a universal truth. Though it is reasonable to assume that a superior product should come at a premium, good performance-enhancing design is more a matter of examining design goals and objectives with a view to redirecting investment. On this basis, a performance enhancement can be seen as favoring one option over another—a choice rather than a cost premium. Unfortunately, due to the rather extreme conservatism in the building industry, many choices are never made explicit. They are never discussed, never offered.

In this article I will address a particular residential opportunity for improving green resourceful building performance by means of conscious choice rather than cost premium. It involves improving the thermal envelope at the expense of committing to a central heating system. Let's begin with three questions:

1. Can compact, open-planned houses with well designed, well constructed, thermally-efficient building envelopes achieve a reasonable standard of comfort by relying solely on the natural convection air circulation within the house to distribute heat throughout the interior spaces?
2. Can a single space heater located in the first floor living space provide comfortable heating for the whole house?
3. Can the envelope upgrade cost be covered by savings generated by the elimination of the heating ducts/pipes and the associated fans/pumps?

The evidence of recent projects completed by our office is that we can confidently answer YES to each of these three questions.

With the savings from *not* investing in central heating, we are able to afford better windows (at least up to a U value

http://www.candharchitects.com/making-choices-instead-of-paying-premiums/

"How do we achieve ZERO within budget?"

NOT
~~"How much EXTRA will it cost?"~~

Some builders are building ZE at **$0 premium** or even **saving$!**

Set goals early

- Quantify performance targets, e.g.:
  - Zero net electricity? energy? emissions?
  - Energy use intensity (EUI)
- Choose fuel source(s)
  - Mixed-fuel or all-electric?
  - Clean renewable energy – solar, other?
  - Onsite and/or offsite?
- Ensure commitment at every stakeholder level

Focus on fundamentals

Efficient form & orientation

- **Keep the form as simple as possible** to make it easy to detail & build a high-performing **thermal enclosure**
- **Accommodate** high-performance **heating, cooling, & water heating equipment** *in conditioned space*
- **Design large, rectangular, south/west-facing roof planes** for the **solar array**
- **Shade your windows** – easiest on the **south façade**; use trees east & west

REALLY HARD to waterproof, insulate, & air seal!
LITTLE space for PVs.

Focus on fundamentals
High-performance enclosure

- **Framing** – minimize thermal bridges
- **Cavity *and* exterior insulation**
  - Choose low-carbon materials: wool, mineral wool, cork, etc.
- **Barriers** – maintain continuity of air, vapor, & moisture barriers
  - Specify target air leakage rate
  - Test to ensure performance

Provide comprehensive specifications, details, & performance testing for all assemblies

Focus on fundamentals
Super-efficient mechanical systems

Key factors for heating, ventilating, air conditioning, and water heating:

- Locations of equipment and distribution systems
- Proper sizing – ***no rules of thumb!***
- Equipment efficiency
- Distribution system design
- Installation quality/commissioning
- Contractors with experience in high-performance, low-load systems

Essential tasks:

- **Load calculations**
- **Equipment sizing based on the calcs**
- **Complete system specs**

Focus on fundamentals

Best-in-class electric devices

Select best-in-class "plug loads"

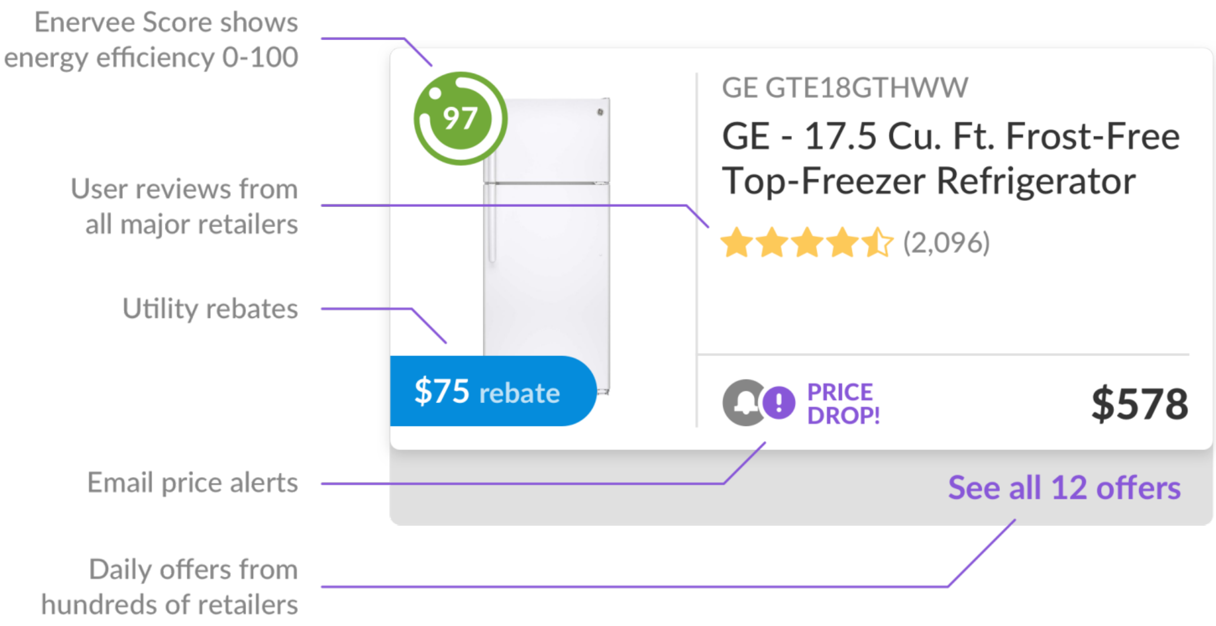
- Lighting
- Appliances
- Electronics

Listings at:

Energystar.gov/products/most_efficient

Cee1.org

marketplace.pge.com ↓



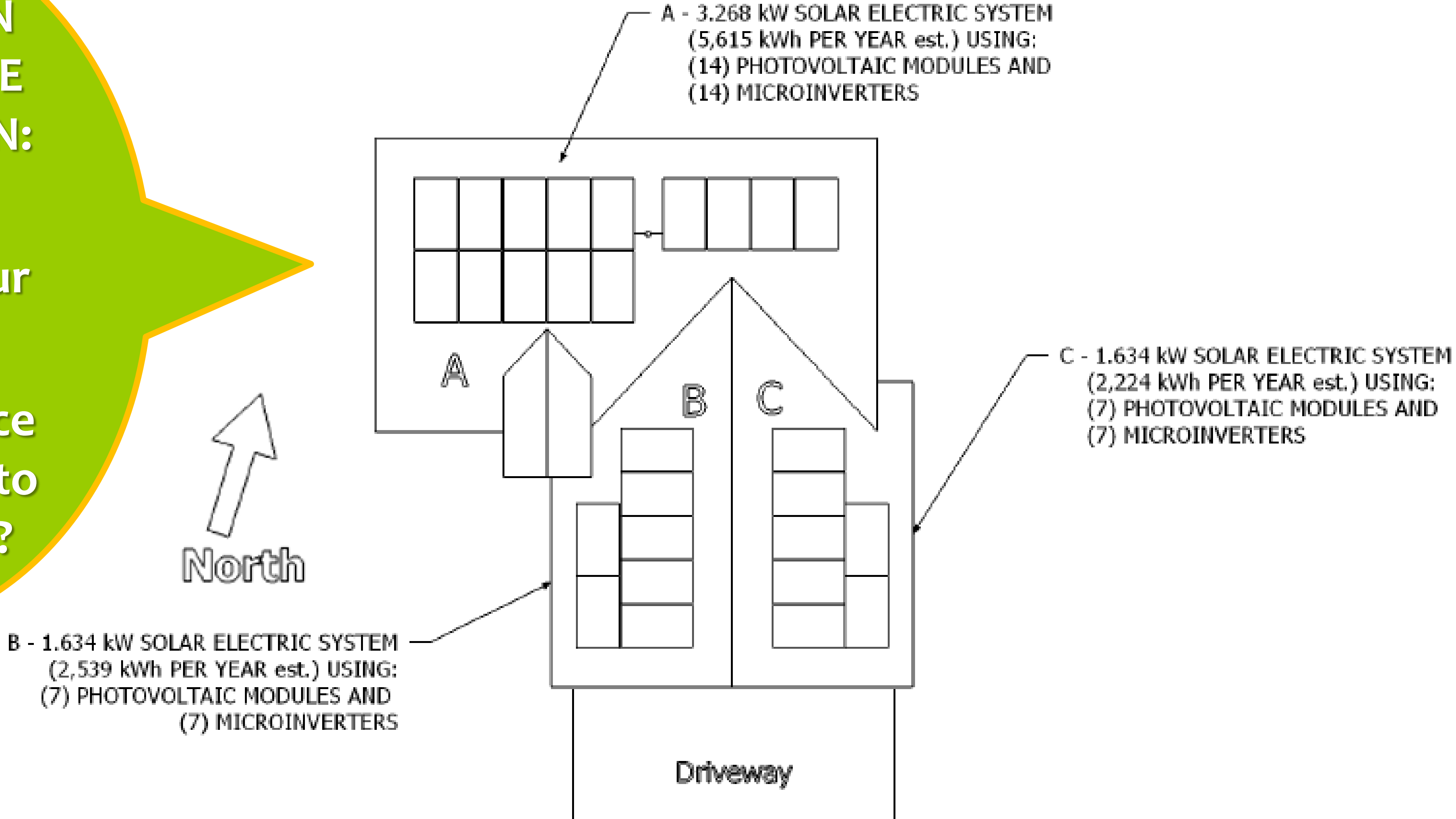
Focus on fundamentals

Renewable energy

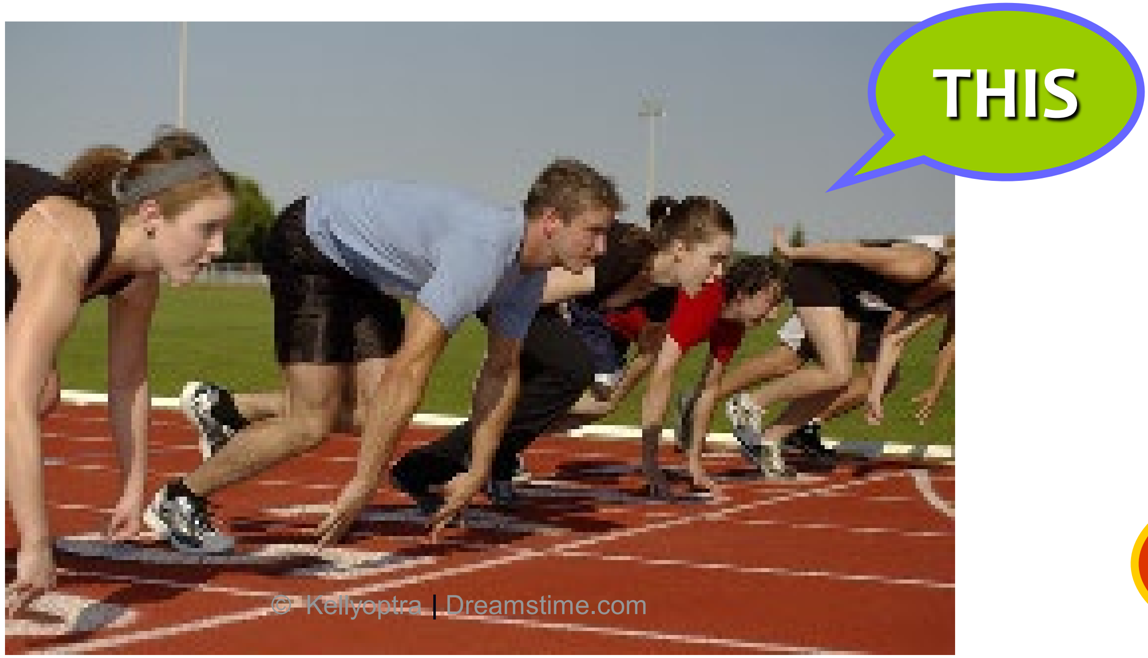
CHECK DESIGN PERFORMANCE EARLY & OFTEN:

How much energy will your project use?

Can you produce enough onsite to meet demand?



Energy modeling: use it as a **DESIGN** tool



Model EARLY and OFTEN—

not just for code compliance!

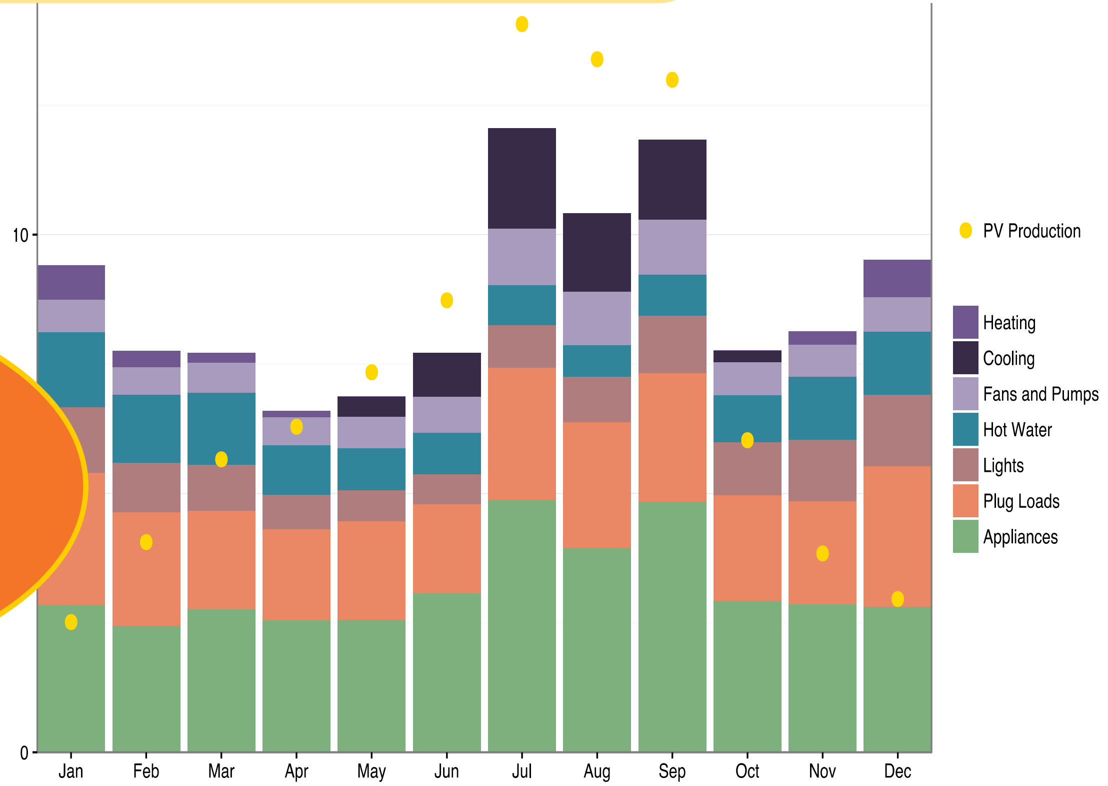
Energy modeling: check goal progress often

The main value of energy modeling is to compare RELATIVE IMPACTS of different options

(not to predict actual energy use)

- Develop a design concept, model that baseline
- Test alternatives – evaluate effect of one variable at a time on:
  - ✓ energy performance
  - ✓ constructability & **cost**
  - ✓ other aspects of design
- Test different combinations

Most of the cost is in the initial model; after that, iterations are quick and easy!



Graph: Resource Refocus LLC

Energy modeling: prioritize investments

Evaluate COSTS and BENEFITS (KBtu/sf-yr/$)

	MARINE				HOT-DRY				COLD			
	San Francisco				Palm Desert				South Lake Tahoe			
	Suburban		Urban		Suburban		Urban		Suburban		Urban	
Influence of Parameter	**Range**	**Ranking**	**Range**	**Ranking**	**Range**	**Ranking**	**Range**	**Ranking**	**Range**	**Ranking**	**Range**	**Ranking**
Home orientation	5.7	**5**	2.7	**7**	8.0	**4**	3.9	**5**	3.9	**6**	4.1	**6**
HVAC	11.4	**4**	13.0	**3**	2.8	**7**	24.7	**6**	15.8	**4**	20.7	**2**
Roof insulation	4.3	**6**	3.0	**6**	5.5	**6**	8.6	**7**	5.2	**5**	[illegible]	[illegible]
Wall insulation	19.0	**2**	14.0	**2**	19.5	**3**	25.0	**4**	24.2	**3**	19.1	**3**
Window SHGC	18.1	**3**	6.5	**4**	19.9	**2**	87.0	**1**	36.3	**2**	0.3	**7**
Window U-values	35.4	**1**	48.4	**1**	22.6	**1**	44.2	**2**	48.6	**1**	54.8	**1**
Window area	1.9	**7**	6.0	**5**	6.7	**5**	27.9	**3**	2.0	**7**	9.1	**4**

MOST influence

LEAST influence

NOTE: No universal conclusions should be drawn from this chart; it is used to illustrate the importance of using energy modeling to understand project-specific variables.

Figure 4-23 (p. 125), *Energy Free: Homes for a Small Planet*

Make it stick

Contract documents hold everyone's feet to the fire

Draw, detail, calculate, size, & SPECIFY:

- Mechanical equipment *and distribution systems!*
- Framing & insulation
- Barriers
- Assemblies
- Testing requirements

See it through!

QUALITY MANAGEMENT is the responsibility of the **CONSTRUCTION CREW**—not the HERS rater!

Monitor performance *during* construction!

See it through!

Complete drawings & specs are a good start, but then you need to

- Test as you go
- Fix as needed
- **Commission!!!**
- Verify on completion

Sample report—commissioning done at Habitat for Humanity ZE demonstration home in Stockton

Download report at https://www.etcc-ca.com/reports/zero-net-energy-production-builder-demonstration.

Table 4-3. Sample mechanical and enclosure commissioning report, Stockton, CA[11]

MINI-SPLIT

Daikin heat pump model RXS09LVJU, ¾ ton, SEER 24.5, HSPF 12.5
Daikin ducted air handler FDXS09V95, 30' line set (no refrigerant adjustment required)
Wired thermostat Daikin ENVi, web-enabled

Duct leakage	13 CFM_{25} (hard to seal return)
Duct leakage to outside	0 (not measurable, less than 9 CFM_{25})
Check for refrigerant leaks	450 psi overnight test, 92-micron evacuation
Static pressure	+7.7 Pa (hard to measure, poor plenum access)
Fan watt draw	50 watts (high fan speed, 10-watt resolution)
Total air flow	378 CFM (high fan speed, sum of the supplies)
Room air flows (CFM)	
▪ Living	104
▪ Kitchen	51
▪ Master bedroom	95
▪ Bedroom 2	56
▪ Bedroom 3	72
Bedroom pressurization with air handler fan on high	
▪ Master bedroom	+2.5 Pa
▪ Bedroom 2	+1.8 Pa
▪ Bedroom 3	+2.8 Pa

ENERGY RECOVERY VENTILATORS

Panasonic FV-04VE1 (2 units, each rated 40 CFM exhaust, 30 CFM supply, continuous operation)

	Hall ERV	Living Room ERV
Static pressure	-21.0 Pa/+11.3 Pa	30.9 Pa/+9.6 Pa
Fan Watt draw	24.3 Watts	22.2 Watts

BATHROOM EXHAUST FANS

Panasonic FV-11VQC5

	Master Bath	Hall Bath
Rated fan speed (not selectable)	110 CFM	100 CFM
Humidity set-point	70% RH	70% RH
Occupany timer set-up	turn off 5 minutes after occupant leaves	turn off 5 minutes after occupant leaves
Standy by Watt draw	0.6 Watts	0.7 Watts
Watt draw when operating	22.2 Watts	22.4 Watts
Static pressure	+19.3 Pa	+17.1 Pa
Measured air flow	111 CFM	109 CFM

ENCLOSURE

Air infiltration	330 CFM_{50}
Air infiltration, ventilation system sealed	250 CFM_{50}, 1.53 ACH_{50}
House pressures when exhaust fans are on:	
▪ Single bathroom fan	-12.8 Pa
▪ Both bathroom fans	-30.6 Pa
▪ Both bathroom fans + kitchen range hood	-36.2 Pa
Non combustion appliances in conditioned spaces	

MEASUREMENT EQUIPMENT

- Fan Wattage – Kill-A-Watt P3 installed at electrical panel
- Air handler Wattage – Extech 380940 clamp-on watt meter, 10-watt resolution
- Exhaust air flow – The Energy Conservatory Exhaust Fan Flow Meter
- Supply air flow – The Energy Conservatory Flow Blaster power flow hood
- Manometer – The Energy Conservatory Digital pressure gauge, DG-700

Zero Energy/Electricity/Emissions Homes

Part 2: Project Outcomes & Lessons Learned

- Energy Performance
- What's different about ZNE homes
- Process takeaways
- **High-level lessons learned**
- Resources

Getting to ZNE affordably means

Designing with the end in mind—

You want to …	■ Keep the PV cost as low as possible
And therefore …	■ Achieve extremely low energy loads
That means …	■ Simplify the form, minimize corners
And …	■ Design & build a high-performance enclosure
And …	■ Design, install, & commission high-performance systems

Critical **Design** Considerations

- **Be willing to change**
  - Optimize orientation, roof design, and building form
- **Enclosure approach**
  - Fine-tune specs & details for optimum performance
- ***Design* for your building systems**
  - Factor in your HVAC and DHW system layouts
- **Mechanical product selection**
  - Choose appropriate (low) capacity HVAC

Construction Focus Areas

- **Trades execution**
  - Make sure you have a committed team
  - Brief all team members on goals
  - Facilitate excellent cross-trade coordination
- **Quality management**
  - Active management is needed!
  - Commission all active systems!
  - Problem-solve as a team

Innovation

- **Collaboration**
  - Design—confer and iterate to optimize solutions
  - Specification—learn from suppliers & manufacturers
- **Education**
  - Take free classes from utilities, regional energy networks, community choice aggregators
  - Learn from early adopters
  - Read CASE* studies

***"Copy And Steal Everything!"**

~ Dennis Creech

POLL

What is Commissioning?

A. Bringing something newly produced into working condition.

B. Performing compliance testing, e.g., having a HERS rater measure duct leakage.

C. Performing tests and making adjustments needed for the system to meet all design objectives, functions, and specifications.

D. The process of collecting user manuals and warranty information for building occupants.

POLL

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Zero Energy/Electricity/Emissions Homes

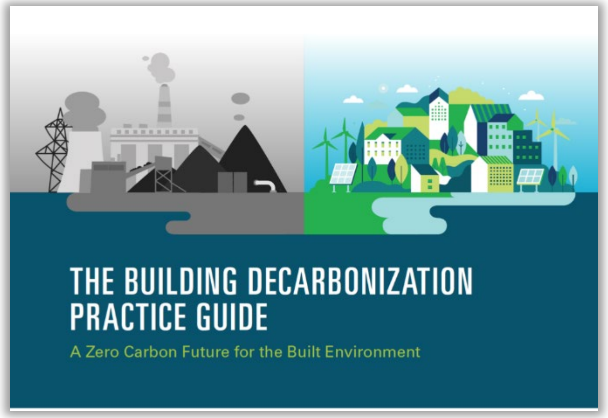
Part 2: Project Outcomes & Lessons Learned

- Energy Performance
- What’s different about ZNE homes
- Useful lessons learned
- Process takeaways
- **Resources**

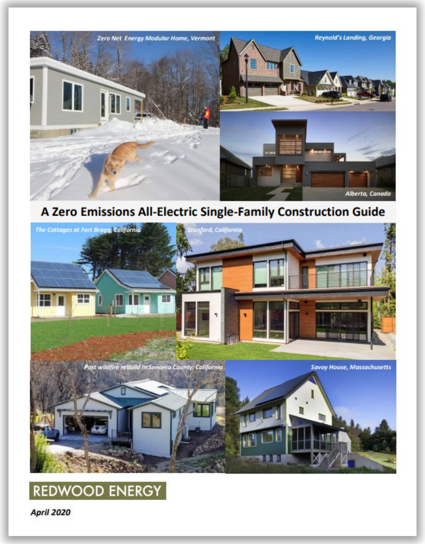
ZNE Information Resources

**All-Electric
Home Retrofit Guide**
Download here

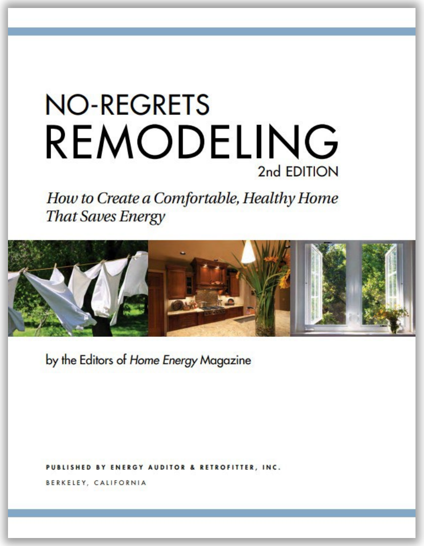
The Switch Is On
Incentives & contractors here



Building Decarb Practice Guide
Download here

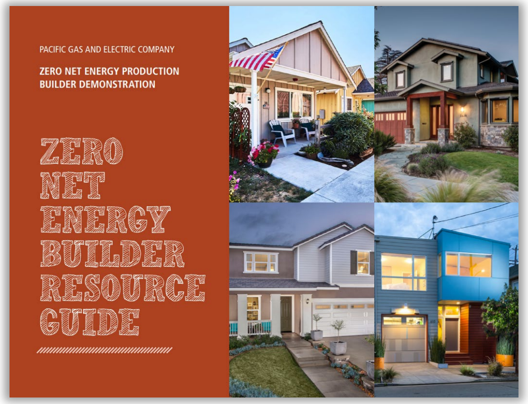


**All-Electric
New Home Guide**
Download here

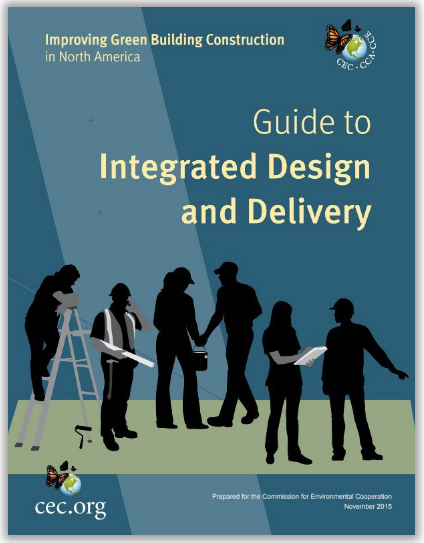


Download here

ZNE Primer for Architects
Download here



ZNE Builder Resource Guide
Download here



Download here

RESOURCES

- **PG&E Residential Code Readiness Project: Redding, CA, Site Monitoring Report**
  - https://title24stakeholders.com/wp-content/uploads/2019/06/final_code_readiness_report_redding.pdf
- **Efficiency Characteristics And Opportunities For New California Homes**
  - https://efiling.energy.ca.gov/GetDocument.aspx?tn=65226&DocumentContentId=10844
- **ASHRAE Handbook – Fundamentals**
  - https://www.ashrae.org/technical-resources/ashrae-handbook/description-2017-ashrae-handbook-fundamentals
- **Real-World Zero Net Energy Homes for California 2020**
  - https://www.gti.energy/wp-content/uploads/2021/05/Real-World-ZNE-Homes-for-California-January-2021.pdf
- **Architectural Compactness and Hot-Water Delivery, Gary Klein**
  - https://www.jlconline.com/how-to/plumbing/architectural-compactness-and-hot-water-delivery_o

Thank you!

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AnnEdminster.com

- Zero energy consulting
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- Writing, research, advocacy

ON BEHALF OF THE PROJECT TEAM:

- California Energy Commission
- Southern CA Gas Co.
- GTI Energy
- Frontier Energy
- Habitat for Humanity of San Joaquin County
- Rick Chitwood
- Lew Harriman
- Mike MacFarland, Energy Docs
- Bruce King, P.E.

Slides available at https://www.gti.energy/affordablezne/