



Affordable Zero Net Energy Homes

Final Training Webinar Part 1: Fundamentals

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 21, 2022

Zero Energy/Electricity/Emissions Homes

Part 1: Fundamentals



CURRENT PROJECT



PRIOR PROJECT



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!)

Zero Energy/Electricity/Emissions Homes

Part 1: Fundamentals

ZNE background—context and value

- History of ZNE homes
- Defining ZNE
- Our starting point: the prior project 
- Current project & what we hoped to learn 

Oops –
that was
5 years
ago!

How big is the need for ZNE homes?

We have **12** years to limit climate change catastrophe, warns UN

Urgent changes needed to cut risk of extreme heat, drought, floods and poverty, says IPCC

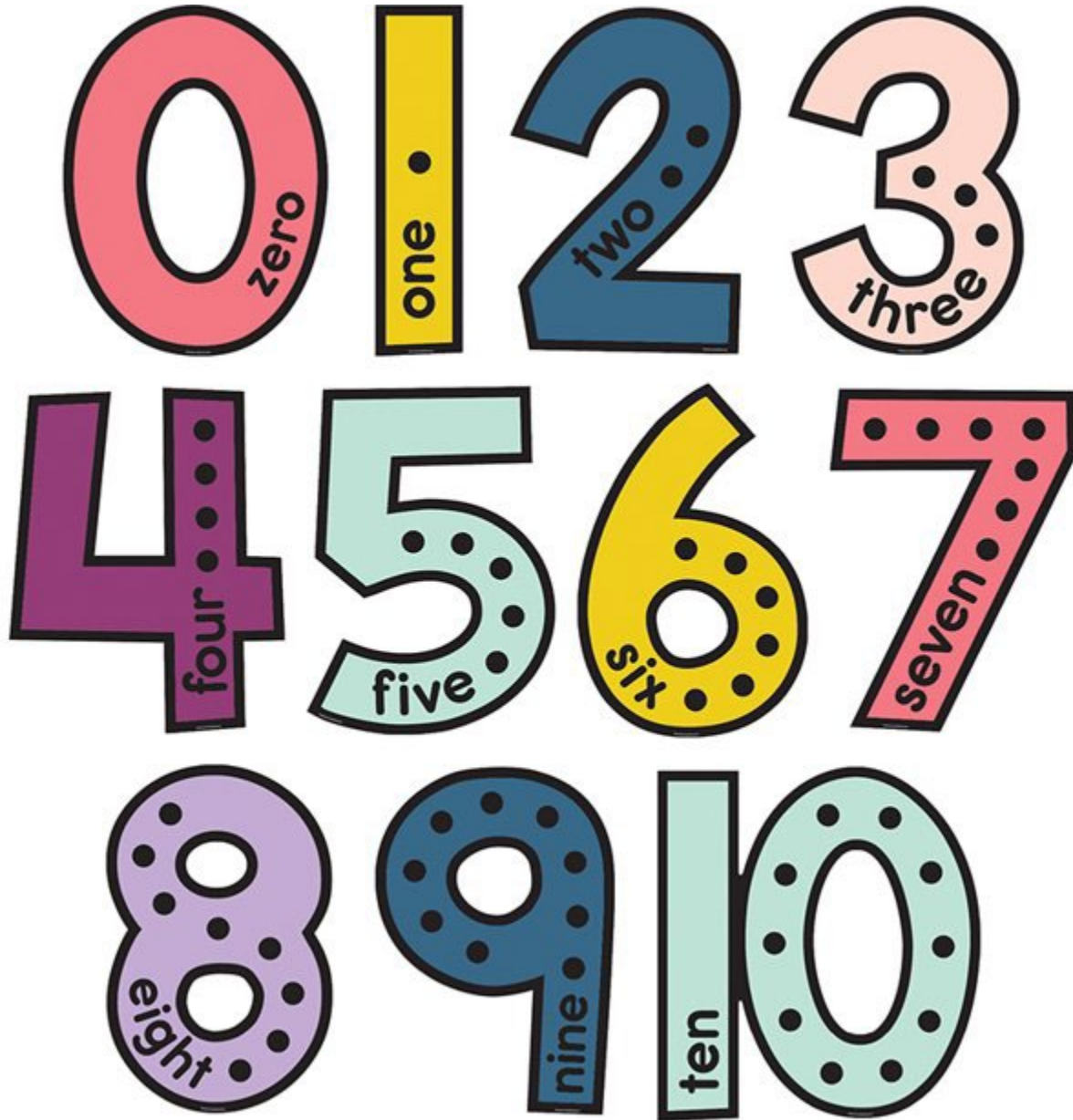
● [Overwhelmed by climate change? Here's what you can do](#)



▲ A firefighter battles a fire in California. The world is currently 1C warmer than preindustrial levels. Photograph: Ringo HW Chiu/AP

**Buildings represent
40% of
global greenhouse
gas emissions –
and of the
SOLUTION.**

~ Architecture 2030



**Ten Reasons To
Build High
Performance
ZNE Homes**

High Performance ZNE Homes:

1

ARE MORE COMFORTABLE AND AFFORDABLE than typical homes due to more *effective* enclosures that reduce stratification, and mechanical systems that are right-sized to heat and cool using less energy to meet the same loads.



Photo: Sealed.com

High Performance ZNE Homes:

- 2 ARE MORE RESILIENT** temperature swings and power outages than conventional homes (passive survivability).

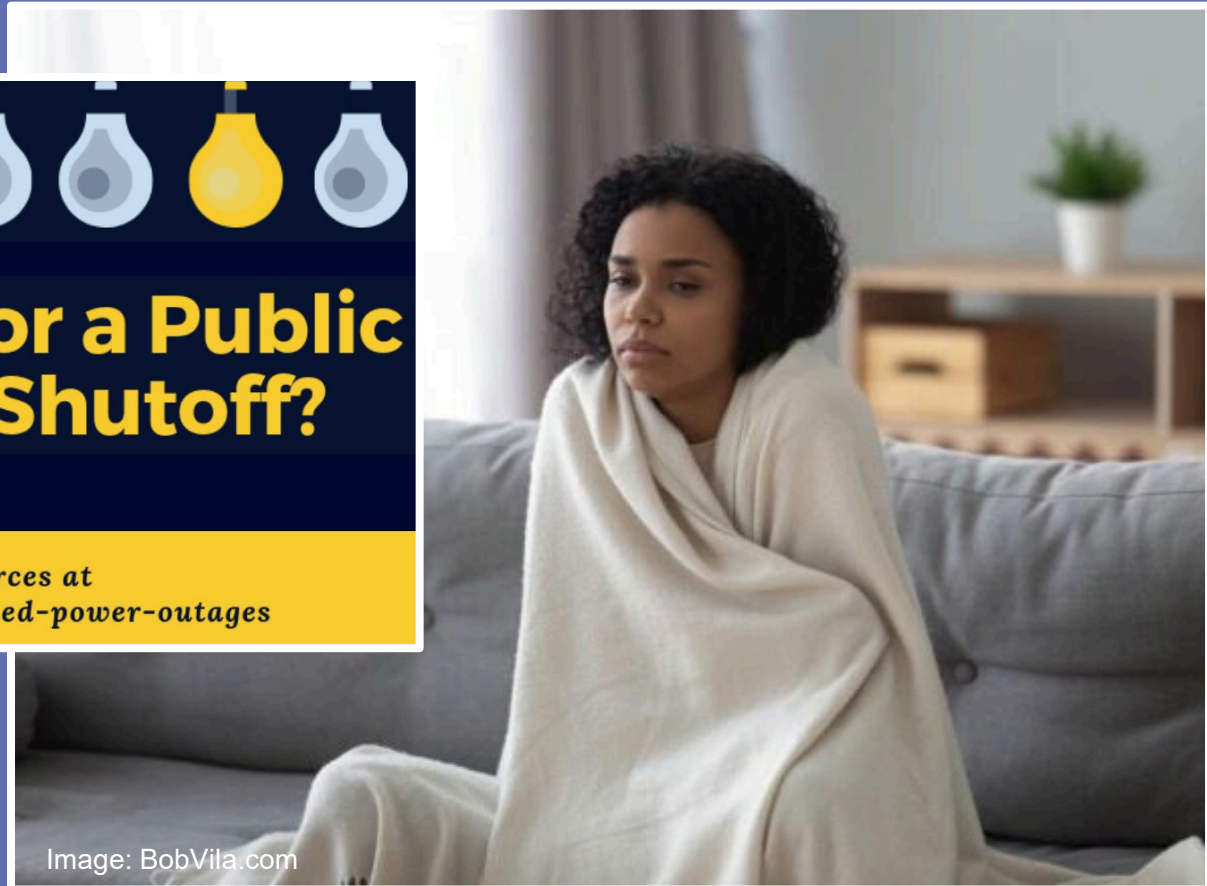


Image: BobVila.com

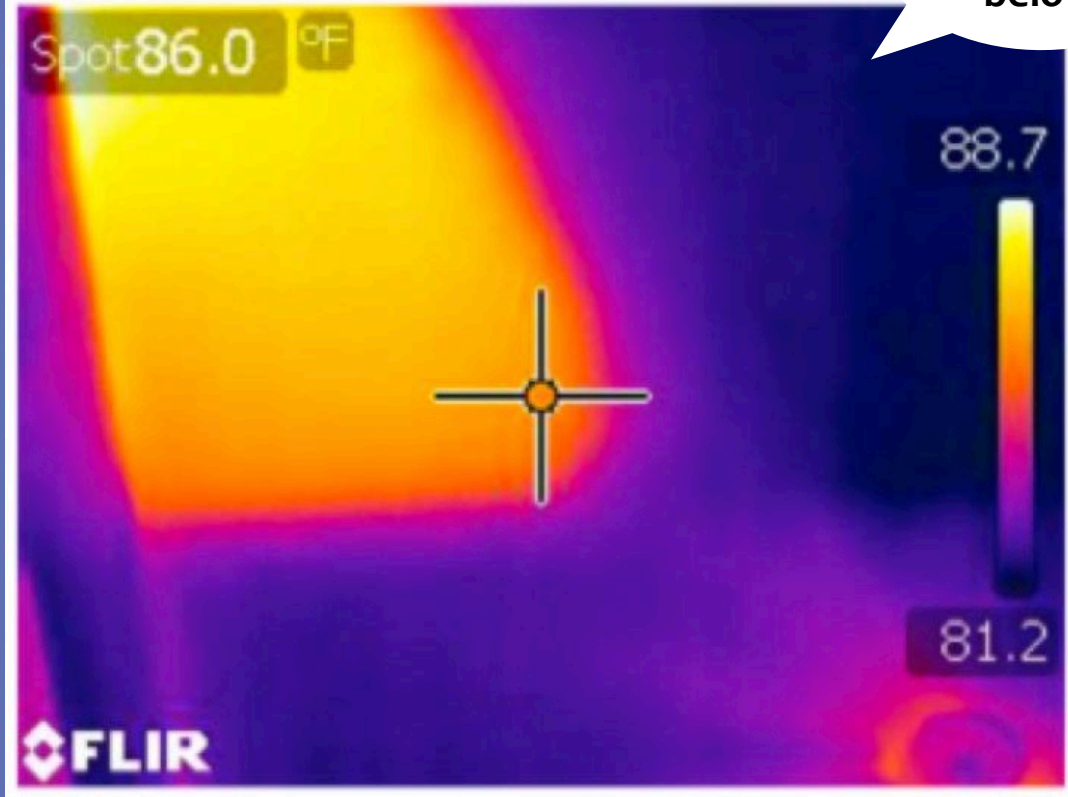
High Performance ZNE Homes:

- 3** **COST LESS TO MAINTAIN** due to reduced thermal bridging. Finishes last longer from improved drying potential and reduced dust intrusion.





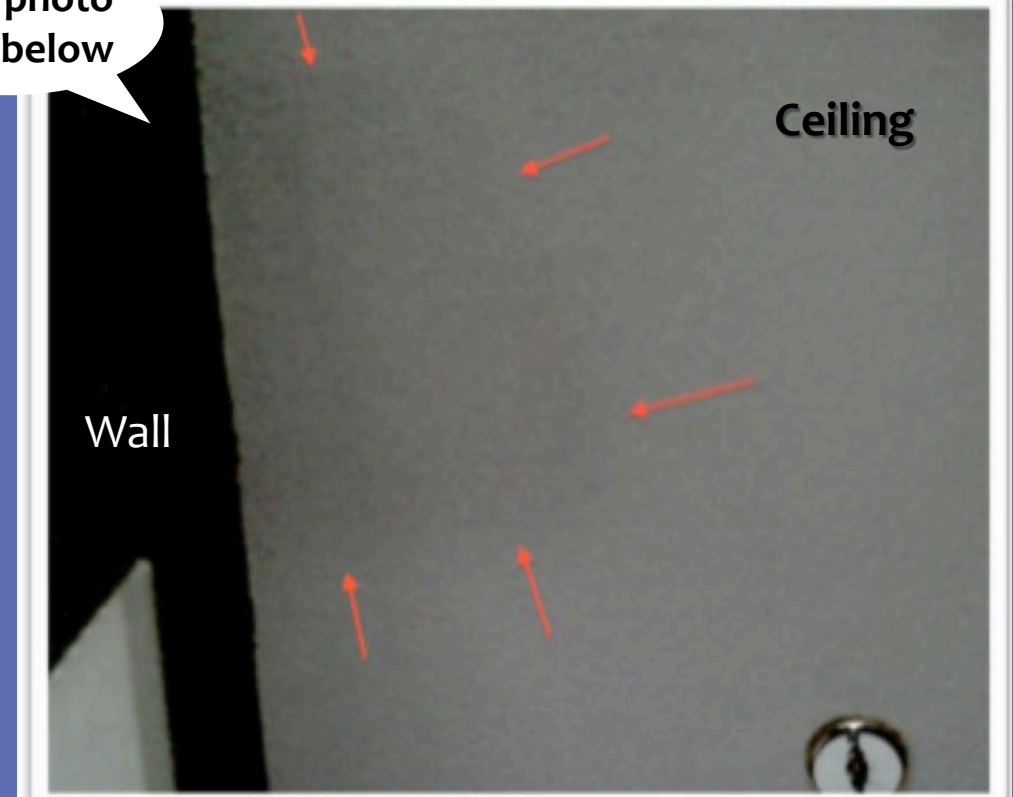
Attic insulation
missing over
section of ceiling



Infrared
image from
below

Note darkened area
(shown by red arrows)
on the otherwise white
ceiling – effect of
moisture + dust.

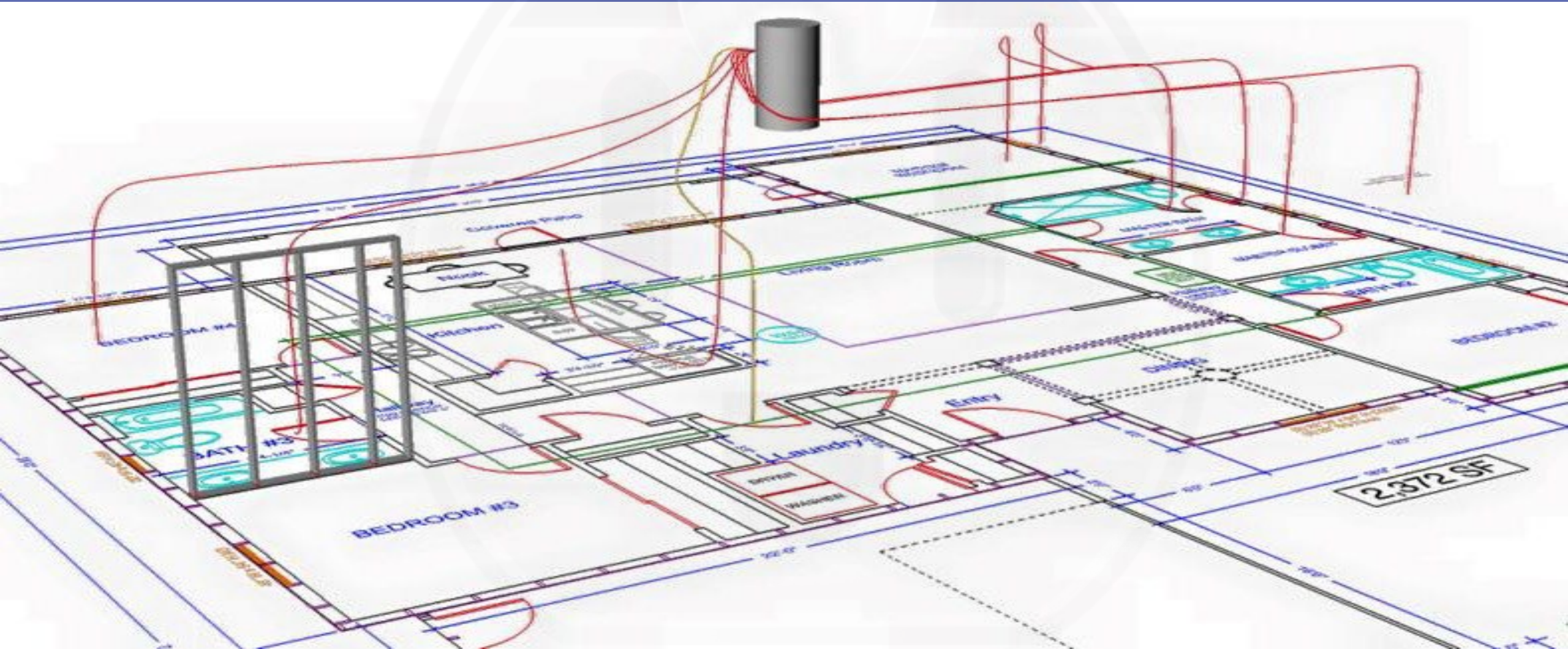
B&W photo
from below



High Performance Homes:

4

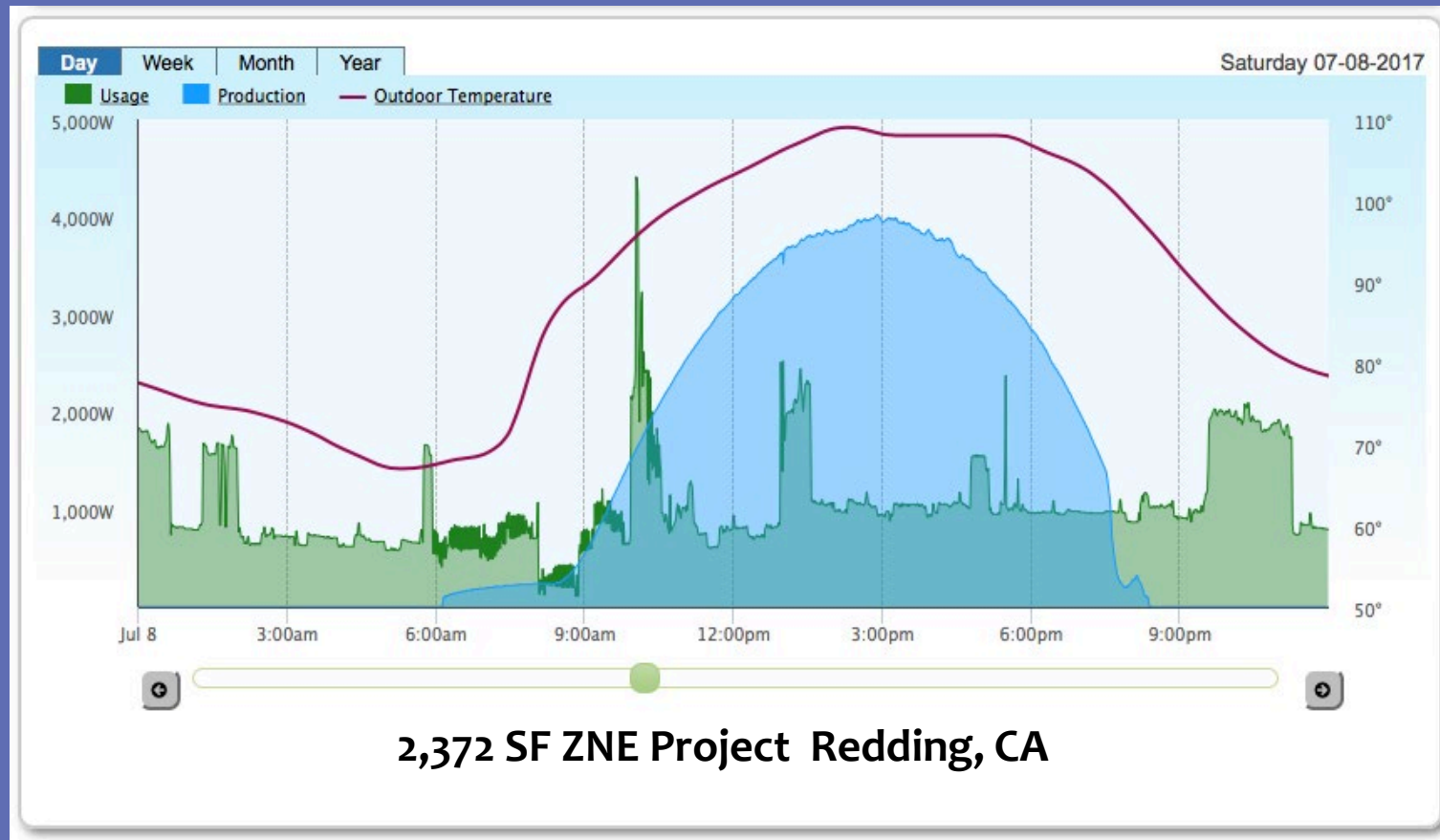
ENHANCE QUALITY OF LIFE through the efficient use of time & efficient use of expensive resources; for example, eliminating long waits for hot water.



High Performance ZNE Homes:

5

REDUCE PEAK LOADS, easing utility grid strain and using resources more efficiently – on cloudy & hot summer afternoons and cold & stormy winter nights.



High Performance Homes:

- 6** ARE A PERMANENT VALUE PROPOSITION – their value doesn't change when rate structures change.



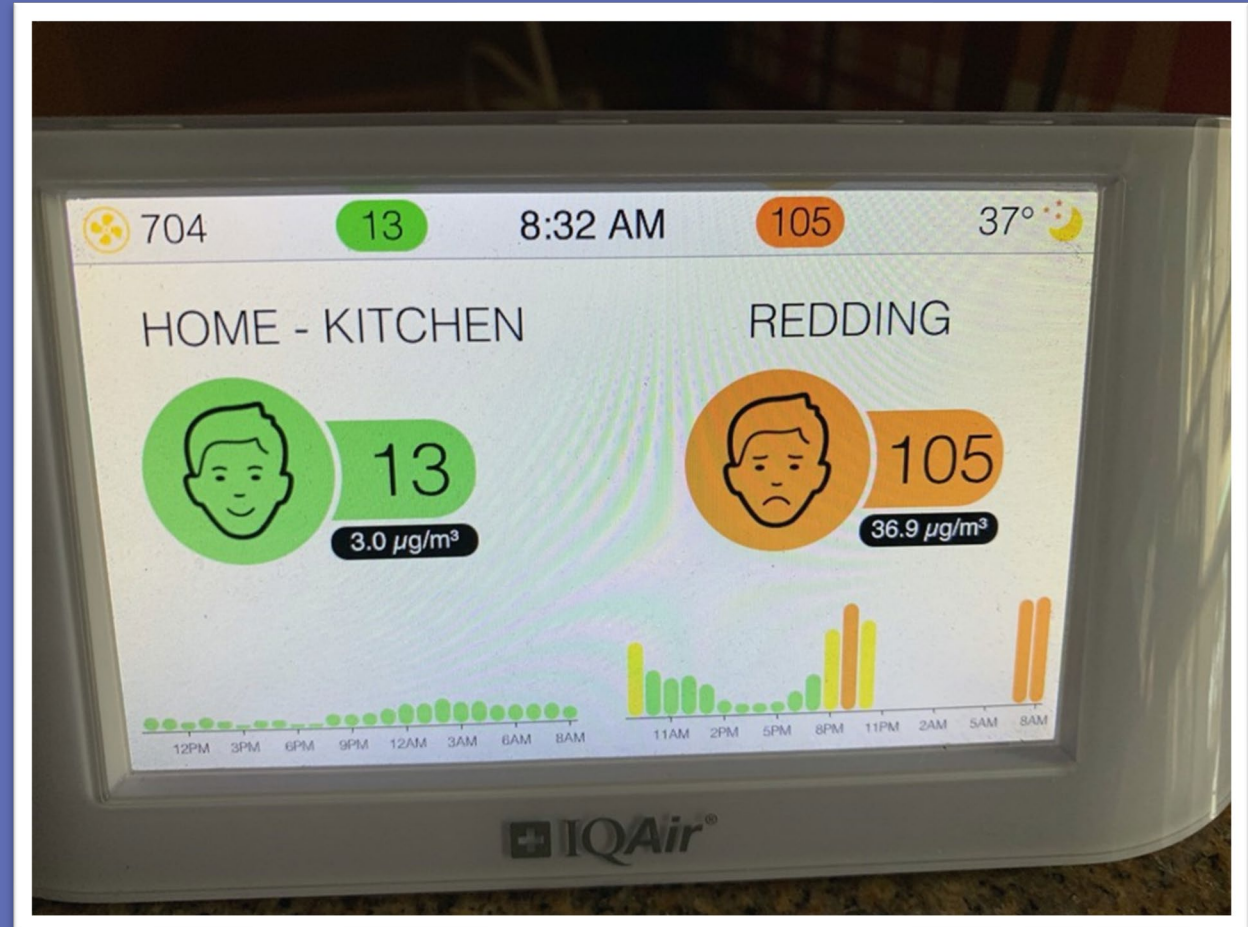
High Performance homes:

7

The only homes designed and commissioned for optimum removal and **CONTROL OF POLLUTANTS**, known asthma triggers, and moisture.



Credit: Jennifer Magrini



High Performance Homes:

8

REDUCE IRRITATION of noise and vibrations from external sources as well as installed systems, due to quality-built enclosures.



<https://www.publicdomainpictures.net/en/view-image.php?image=267879&picture=train-on-tracks-close-up>

High Performance Homes:

- 9 Return greater **FINANCIAL BENEFIT TO LOCAL COMMUNITIES** by investing more in skilled workers and less on imported technology.

*Skilled design, installation, and commissioning can reduce the amount of solar needed to reach ZNE by **up to 50%**.*



Photo Credit: Eco Performance Builders

High Performance Homes:

10

ARE MORE ATTRACTIVE AND VALUABLE than conventional new homes due to the higher efficiency, allowing use of smaller solar arrays.



Energy Docs Home Performance

ZNE with
1 solar
panel per
40sf

ZNE with 1
solar panel
per 120sf



Energy Docs Home Performance

How big is the ZNE opportunity?



February 7, 2023

Global Net-Zero Energy Buildings (NZEBs) Market
Analytics Report 2022: Market to Reach

\$63.8 Billion by 2027

“Net Zero Energy Buildings Are Not a Luxury but a Necessity”



www.ResearchAndMarkets.com

Zero Energy/Electricity/Emissions Homes

Part 1: Fundamentals

- ZNE background—context and value

History of ZNE homes

- Defining ZNE
- Our starting point: the prior project 
- Current project & what we hoped to learn 

A very short history of ZNE homes

Super-insulated homes in the US began in response to 70s and 80s energy crisis



Passivhaus (Passive House) developed in Germany in the early 1990s



In 2006, Habitat for Humanity–Metro Denver documented the first US house operating at ZNE

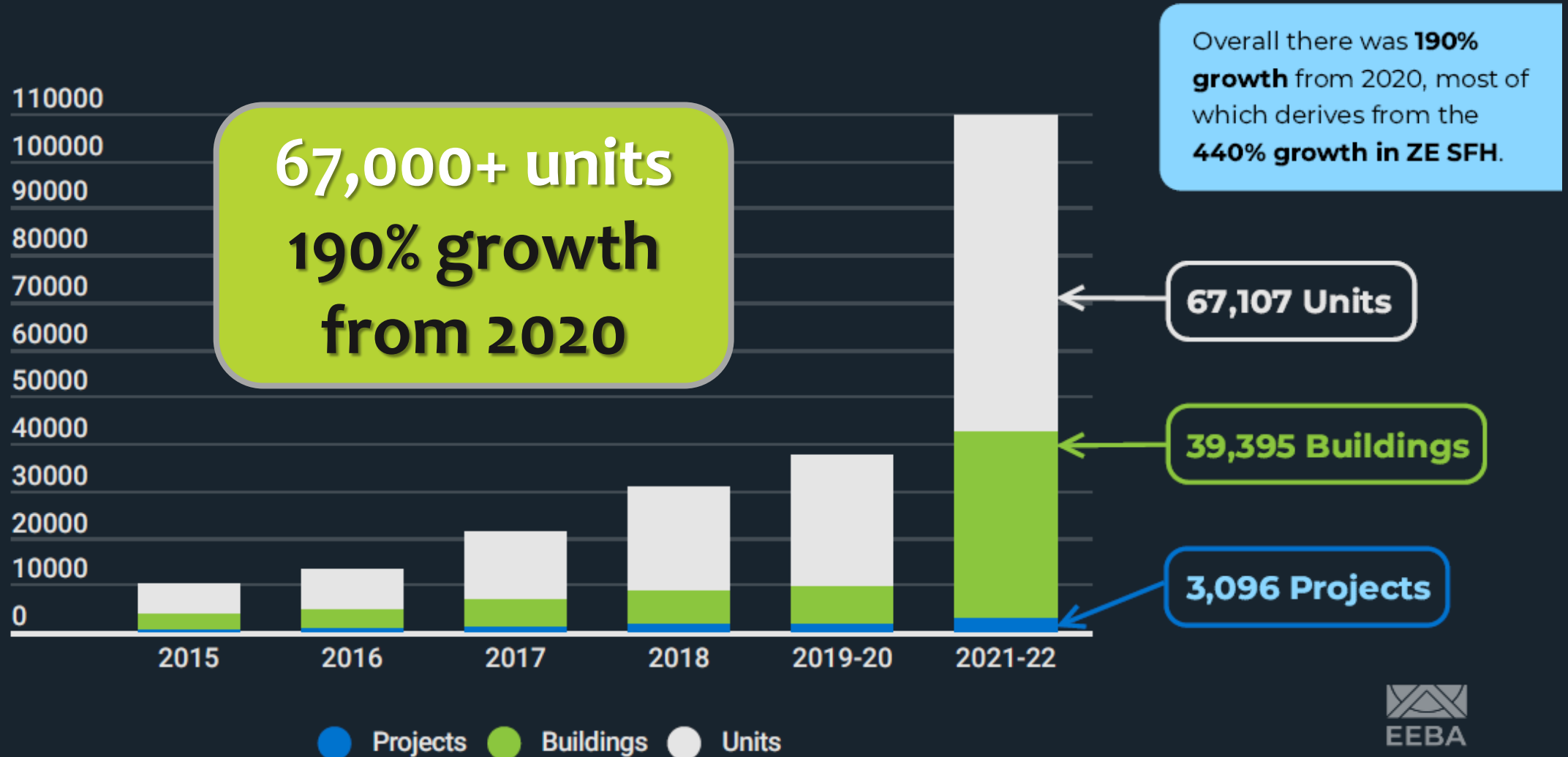


As of mid-2019, >22,000 “ZNE-ish” homes inventoried in the US and Canada



Enter projects at <https://www.eeba.org/netzero/inventory>

Growth in ZNE homes 2015-2022



ZNE homes come in all flavors

LUXURY



CUSTOM



SPEC



PRODUCTION



AFFORDABLE



MULTIFAMILY



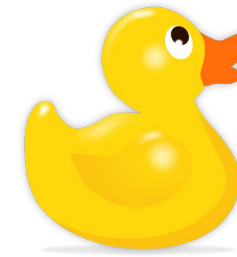
... and are built in all climates

A map of the United States with state boundaries outlined. States in the western, northern, and some southern regions are shaded in blue, while others are white. A yellow callout bubble points from the blue-shaded area in the Northeast to the text below.

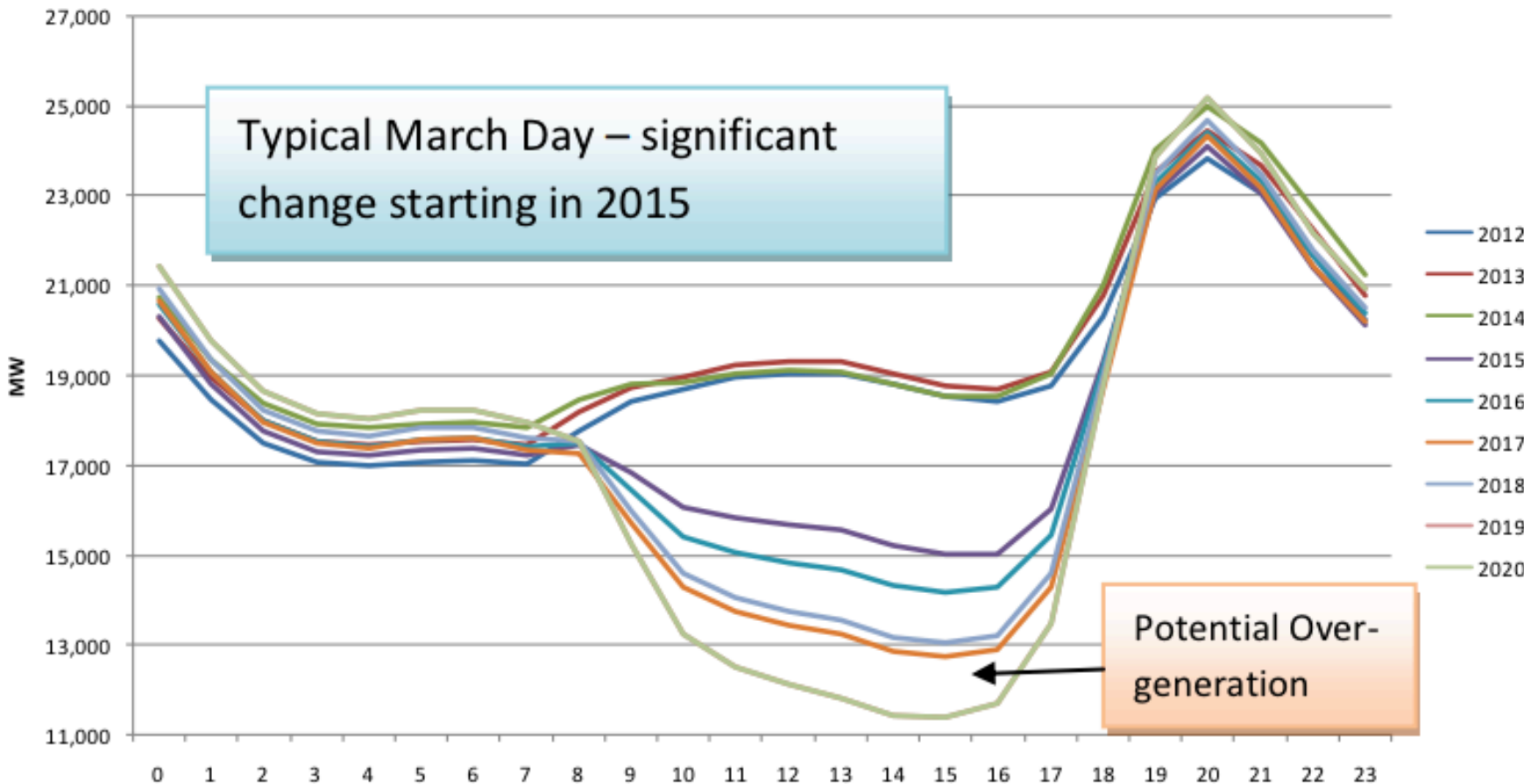
LONDON, ON
HEATING
DEGREE DAYS
~6,300

but ideas about ZNE
have been evolving...

The 'duck curve' phenomenon has changed how we think about “net”



CALIFORNIA ELECTRIC GRID HOURLY LOAD PROFILES, 2012 - 2020



- *Annual* ZNE doesn't balance production with consumption
- A clean energy future relies on achieving that balance

'Decarbonization' may be coming soon to a town near you!

As of February 27, 2023:
73 local governments in CA
either incentivize or
mandate all-electric new
construction—

- ~5,400,000 people
- ~13% of CA population



POLL

Identify the TRUE statement(s) below.

- A.** Outside California, ZNE housing is a niche phenomenon.
- B.** It's really difficult to build affordable ZNE homes.
- C.** There's a lot of opportunity in creating ZNE homes.
- D.** Most ZNE homes are custom / bespoke projects.

POLL

Identify the TRUE statement(s) below.



- ☐ A. Outside California, ZNE housing is a niche phenomenon.
- ☐ B. It's really difficult to build affordable ZNE homes.
- ☒ C. There's a lot of opportunity in creating ZNE homes.
- ☐ D. Most ZNE homes are custom / bespoke projects.

Zero Energy/Electricity/Emissions Homes

Part 1: Project Description

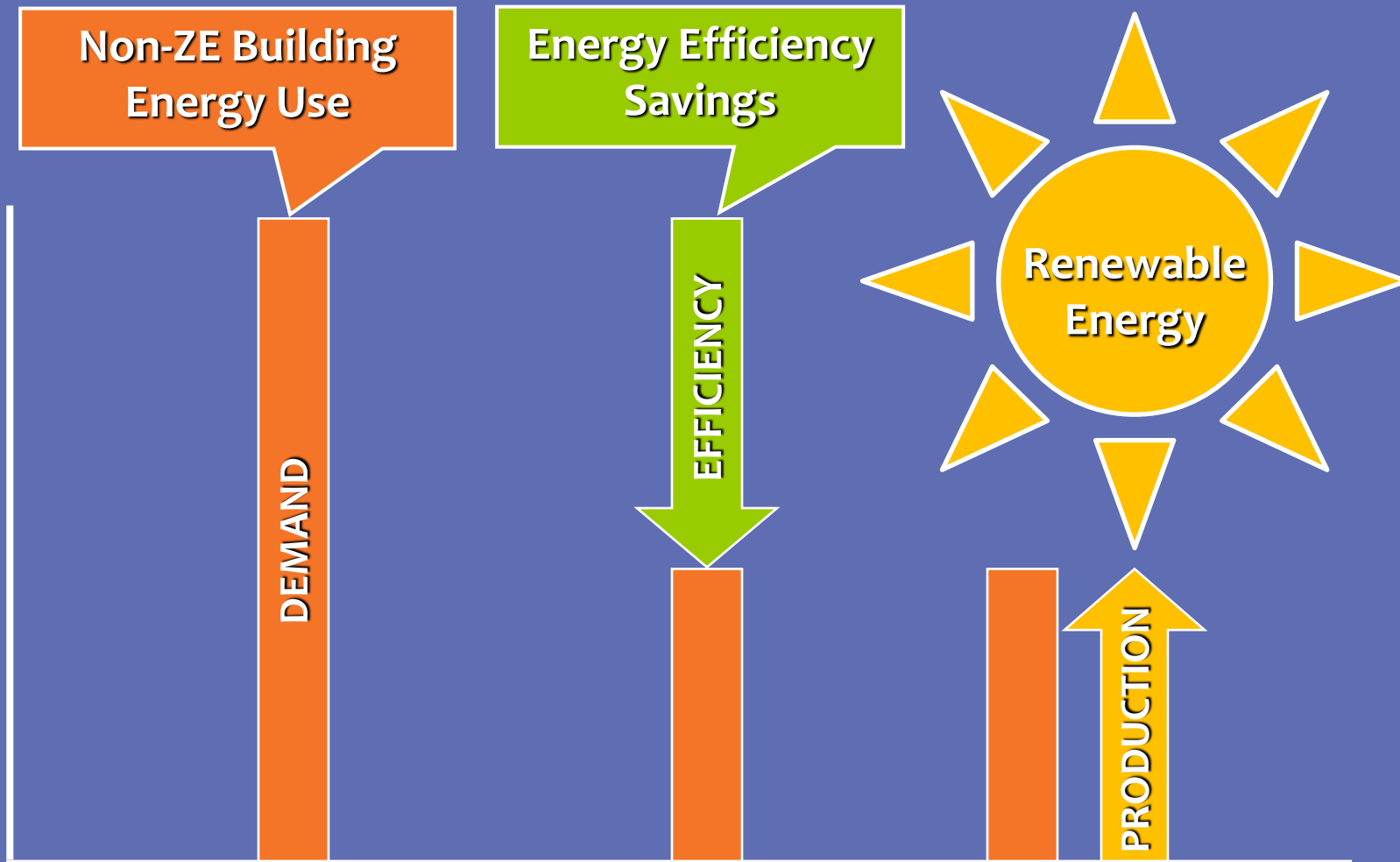
- ZNE background—context and value
- History of ZNE homes

Defining ZNE

- Our starting point: the prior project 
- Current project & what we hoped to learn 

In simplest terms, Zero Net

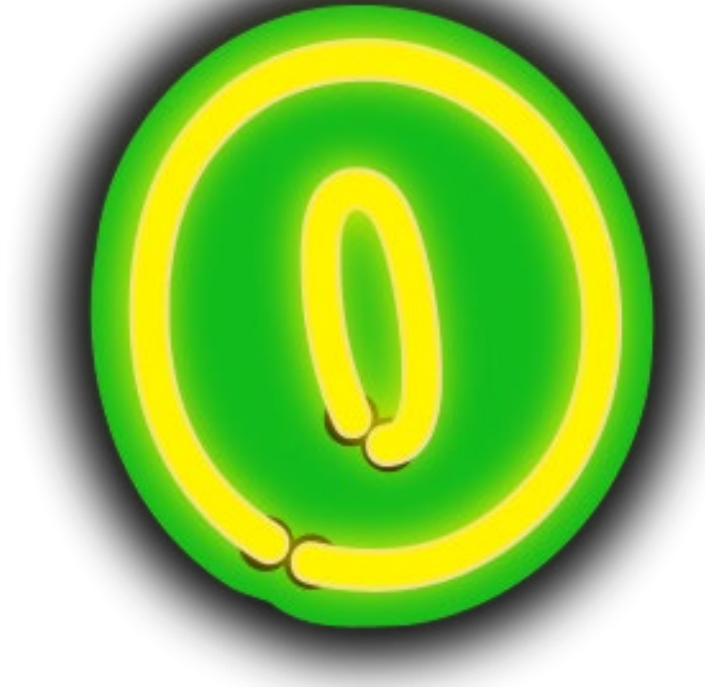
**Electricity
Energy
Emissions** means
(ZNE)



optimizing
EFFICIENCY
to balance
DEMAND and
PRODUCTION
on an annual
basis

(although there are
several more specific
definitions)

Absolute ZERO isn't always achievable, *BUT*

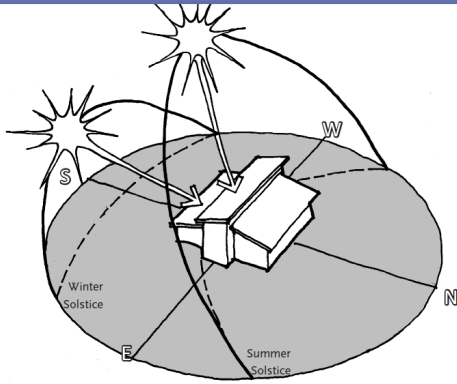


It's compelling because it is a powerful driver for
EFFICIENCY

The foundation for all definitions: ZNE-ready

1

Efficient form & orientation



2

High performance enclosure



3

Super-efficient mechanical systems



4

Best-in-class electric devices

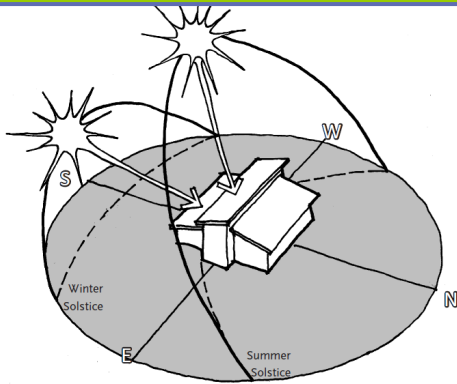


A home that is **designed, built, and commissioned** efficiently enough to operate at ZNE with addition of a renewable energy system

ZNE-ready + renewable energy = ZNE

1

Efficient form & orientation



2

High performance enclosure



3

Super-efficient mechanical systems



4

Super-efficient electric devices



5

Renewable energy system*




=

ZNE

* To achieve ZNE, renewable energy production must meet the home's total annual energy usage – including ALL FUELS.

What does the **E** stand for?

It depends on **how much** renewable energy (RE) you're producing onsite (or buying) —

E stands for:	If RE supplies 100% of the home's annual:	And:
ENERGY	ENERGY use – including ALL FUELS	 Title 24-2019
ELECTRICITY	ELECTRICITY use only	
EMISSIONS	ELECTRICITY use – and there is no in-home gas combustion	The home is 100% ELECTRIC & uses or buys 100% ZERO-EMISSIONS GRID POWER (or is off-grid)

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E stands for:	If RE supplies 100% of the home's annual:	And:
ENERGY	ENERGY use – including ALL FUELS	Our “ZNE” focus today
ELECTRICITY	ELECTRICITY use <i>only</i>	
EMISSIONS	ELECTRICITY use – and there is no in-home gas combustion	The home is 100% ELECTRIC & uses or buys 100% ZERO-EMISSIONS GRID POWER (or is off-grid)

Emerging components of ZNE homes

Battery storage



Electric vehicles



Performance monitoring devices



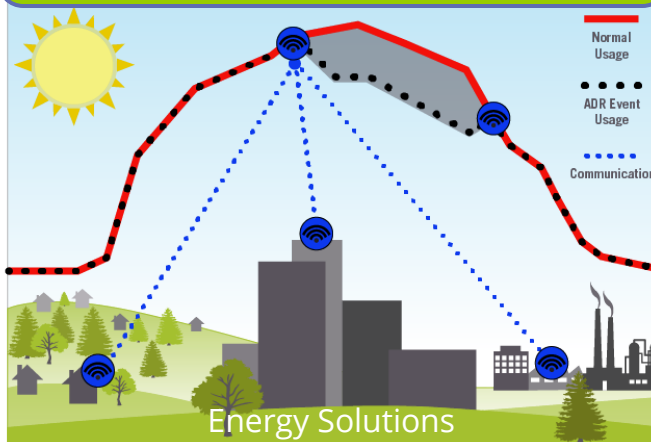
- Real-time data
- Actionable information

All-electric-ready service panel

Solar-ready + circuits for:

- Water heater
- Clothes dryer
- Induction range
- Heater/air conditioner
- EV charger

Demand response



Zero Energy/Electricity/Emissions Homes

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 **Our starting point: the prior project** 

- Current project & what we hoped to learn 



Habitat for Humanity, Stockton, CA

First ZNE home (before current research project)



George Koertzen
Project Manager



Unskilled
Students &
Homeowners

Photos: Rick Chitwood, Chitwood Energy Management



Project Objectives

- Help production builders achieve ZNE, affordably
- Reduce barriers to the design, construction, and operation of ZNE homes in California
- Inform PG&E's future program offerings



HVAC Highlights

- Air handler in conditioned space
- Ducts in conditioned space
- Ducted $\frac{3}{4}$ -ton mini-split heat pump
 - SEER 24.5, HSPF 12.5
- 2 ERVs supply continuous fresh air
- High-performance bath exhaust fans
 - Humidity & occupancy controls
- Installation quality assurance (measured performance)

7 ft hallway
soffit for ducts
& mini-split



Smallest Available HVAC Used



**¾-ton
mini-split
heat pump**

Industry Standard	Stockton House	PG&E Redding Project*
500-800 sf/ton	1,600 sf/ton	2,400 sf/ton

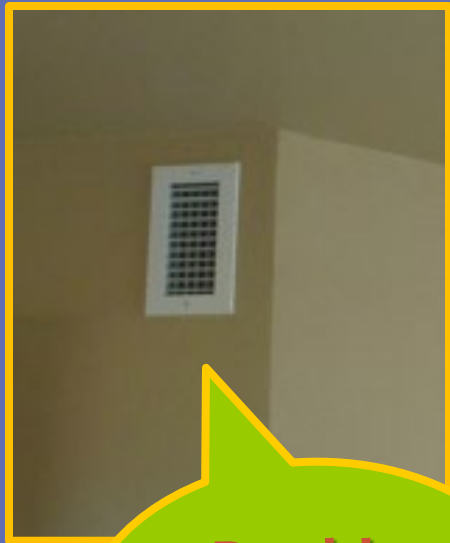
* A larger home, in a hotter climate

- Sizing based on extensive field testing funded by CA Energy Commission
- All available equipment is **too large** for small low-load CA homes – Stockton house load is 6,000 Btu/hr or **½ ton**



Low-pressure Duct Design

(minimizes static pressure to keep fan watt draw very low)



**Double-
deflection
supply grille**

- Double-deflection supply grilles with air-foil blades
- Straight supply boots
- Short supply ducts
- Oversized supply ducts
- Oversized return grille (20" x 30")
- A filter grille that will accept a 2-inch-thick filter



Installation Quality Assurance & Commissioning

- ZERO commissioning = industry standard
- Diagnostic testing ensures proper performance
- Commissioning site visit by consultants confirmed **all HVAC equipment performed to spec**

NOTABLE!

CA Energy Commission-funded research on 240 new HVAC systems found

100% failed

to meet manufacturers' static pressure requirements



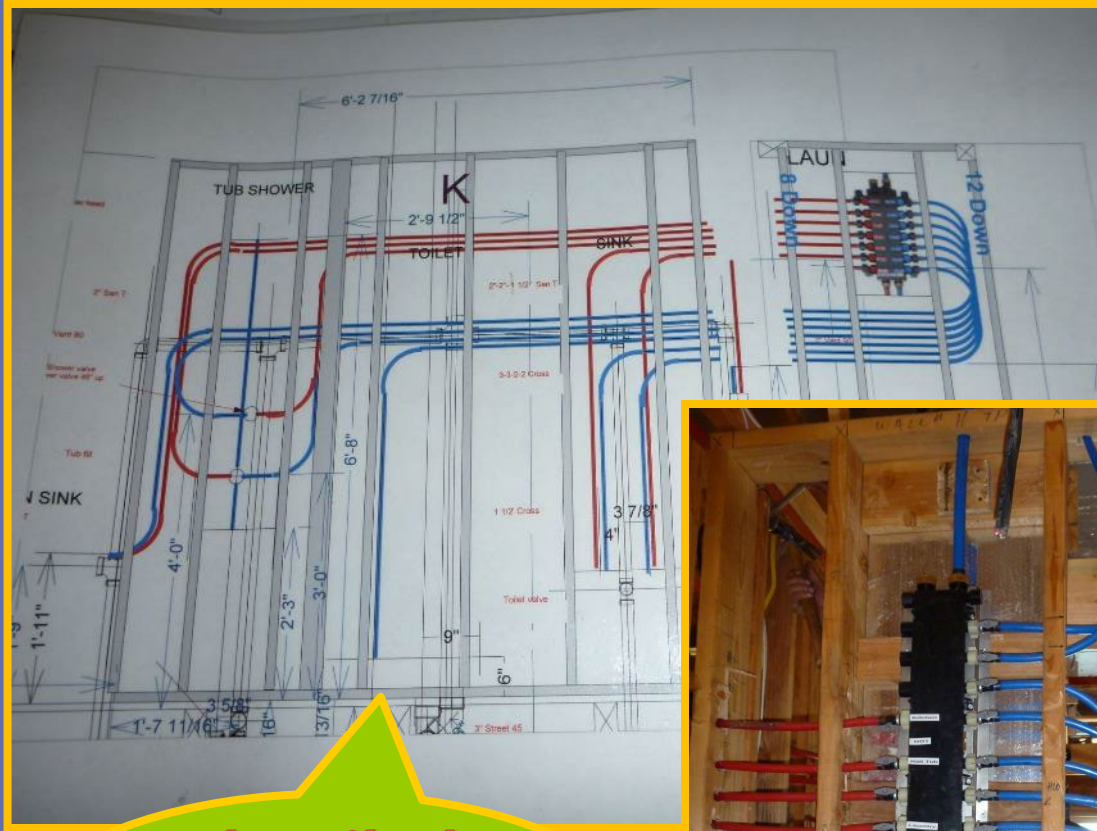
DHW & Electrical Highlights

- Tankless gas water heater
 - EF.82 (EF .93 was recommended; budget prevailed)
- Extremely compact DHW layout
- 100% LED lighting
- HVAC “System Off” switch near thermostat
 - Eliminate standby loss during swing seasons
- Electric vehicle circuit in garage

Longest hot
water run = 12'



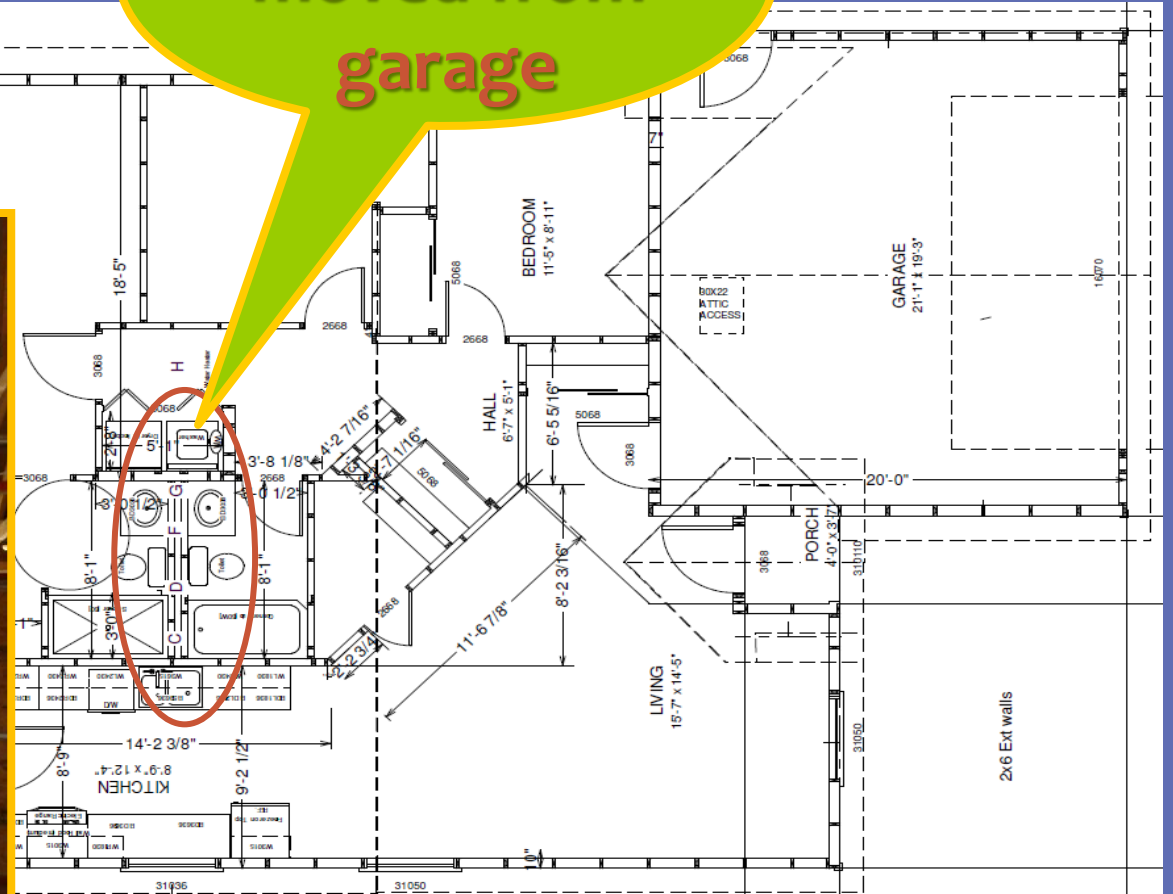
Extremely Compact Hot Water Layout



**detailed
schematic
provided**



**water heater
moved from
garage**





Enclosure Highlights

- Attic R-42, walls & floor R-21
- R-5 rigid insulation on walls
- 24" OC, single top plates
- Windows U.28, SHGC .20
- Windows fit within framing module; no extra lumber needed



12% framing factor
(CA average: 35.5%)



No Extra Framing at Exterior Wall Intersections

- All studs shown on plans



60-ft LVL top
plates, no
lapping needed

Two-Stud Corners



★ Raised-heel Trusses

- Less blocking
- Reduced thermal bridging



Engineered Headers



Installed with screws
to allow removal for
insulation installation



No plumbing
in exterior
walls



Studs stacked
& pre-drilled

All Wiring at Studs & Plates

★ Infiltration Reduction Strategies

- No recessed lights
- Fixed windows at appropriate locations
- Hatches don't penetrate insulated assemblies



Knee wall
above
garage

Air Sealing

- Preliminary blower door after ceiling drywall
- Smoke testing



* Temporary doors sealed at preliminary; not sealed at final.



What Did All This Cost?

It *saved* \$3,000!

Plus 50%
lumber
reduction!

ZNE measures increased some costs, reduced others
(selected features shown)

Feature	Before	After	Materials	Labor**
Framing	2x4 @ 16" o.c.	2x6 @ 24" o.c.		-\$300
Wall insulation	R-11	R-21		-\$100
Air leakage	4.75 ACH50	1.53 ACH50	+\$400	+\$800
HVAC	A/C + gas furnace	¾-ton mini-split		-\$2,000
Ducts	Standard	Compact	-\$100	-\$500
DHW distribution	Standard	Compact	-\$70	-\$400
Lighting	50-50 CFL + incand't	100% LED	+\$390	

** Estimated at \$25/hr

POLL

Identify the TRUE statement(s) below.

- A. Advanced framing isn't worth the effort.
- B. Achieving a low air leakage rate costs extra.
- C. If it weren't for Habitat's volunteers, achieving ZNE would be expensive.
- D. A 3/4-ton mini-split will work in most climates ... *if* you do a good job with the enclosure and HVAC system design.

POLL

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- Our starting point: the prior project ★

 **Current project & what we hoped to learn** ★



Current Project: **All Electric vs. Mixed Fuel** **SAME STREET, SAME ORIENTATION**



Mixed Fuel Demo House



All Electric Demo House

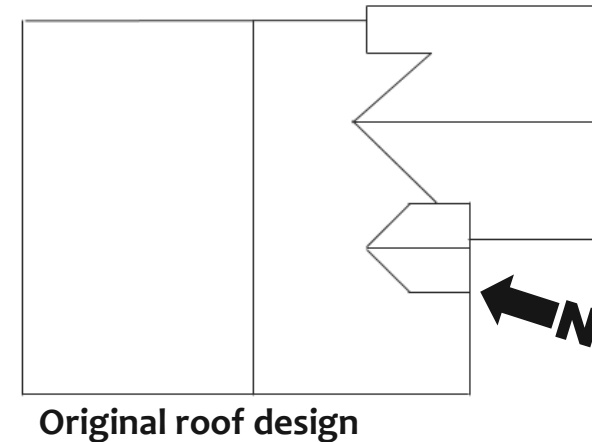




Current Project: **All Electric vs. Mixed Fuel**

NEXT-GEN IMPROVEMENTS

- **New roof design**
 - Fits larger PV array
 - Better solar exposure – SW instead of SE
- **Upgraded water heater & appliances**





Current Project: All Electric vs. Mixed Fuel SPACE CONDITIONING



All Electric Demo House



Heat + cool:
Fujitsu mini-split
heat pump
FAOU9RLFC with
air handler
FARU9RLF



Mixed Fuel Demo House

Heat: iFlow air
handler iFLH-16000



Cool: Trane air conditioner
T4TTL6018A1000A with ADP
evaporator coil TG35636D175B2222AP



Current Project: All Electric vs. Mixed Fuel WATER HEATING



All Electric Demo House



Sanden tank
GAUS-160QTA
with outdoor unit
GUS-A45HPA



Mixed Fuel Demo House



Navien
NPE-180S



Current Project: **All Electric vs. Mixed Fuel** **COOKING**



All Electric Demo House



Frigidaire
FGIF3036TF



Mixed Fuel Demo House



Frigidaire
FGGF3036TW



Current Project: **All Electric vs. Mixed Fuel**

WHAT CAN WE LEARN?



All Electric Demo House

How will these houses differ?



Mixed Fuel Demo House

1. Energy use
2. Comfort impacts
3. Occupant impacts
4. Utility costs
5. ~~Capital costs~~
6. ~~Labor costs~~

Find out what we learned!

Join us for Part 2 ~
March 24

11:30 am – 1:00 pm

***Thank
you!***



AnnEdminster.com

- Zero energy consulting
- Design team facilitation
- 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.

**With special
thanks to project
superintendent
extraordinaire
George Koertzen!**

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

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