emu

Advanced Building Science for Mainstream Construction

Building Envelope Science | Passive House Design | Air & Moisture Flow Management

Beyond Energy

Using Passive House Standards To Boost Resilience Of California's Built Environment

Building Envelope Science | Passive House Design | Air & Moisture Flow Management

Beyond Energy – Passive House For California

- Energy Efficiency + Future Proofing
- Thermal Resilience: Shelter from sudden weather events
- Indoor Air Quality: Protect from exterior pollution
- Thermal Comfort: there's a grandman in each of us

Who's Emu?

- Former Architects
- #1 hands-on Passive House training in the US
- Project consulting – "teaching hospital"

Who Are You?

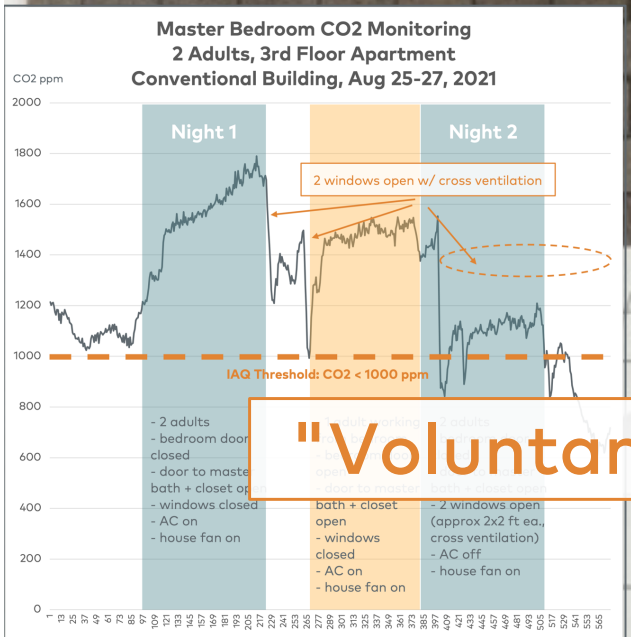
Raise your hand if:

- **You work in construction, and you are**
  1. **Architect / Designer?**
  2. **Builder / Contractor?**
  3. **Specialty (product rep, engineer, HVAC, MEP, windows...)**
  4. **Permitting, inspections, testing?**
  5. **Something else?**
- **You don't work in construction, and you're here because**
  6. **You're here by mistake, and regretting it**
  7. **You want to improve your own house**
  8. **Have a general interest in green building**

Why Do We Care About Buildings?

How much time do we spend inside buildings?

90% + of our lives



"Voluntary Prisoners Of Architecture"

How Long Does A Family Stay In A House They Just Moved Into, Before They Move Out Again?

How long have YOU lived in the house you live in now?

7 years?

25 years?

National Average: 13 Years

5 years?

"years are just numbers"?

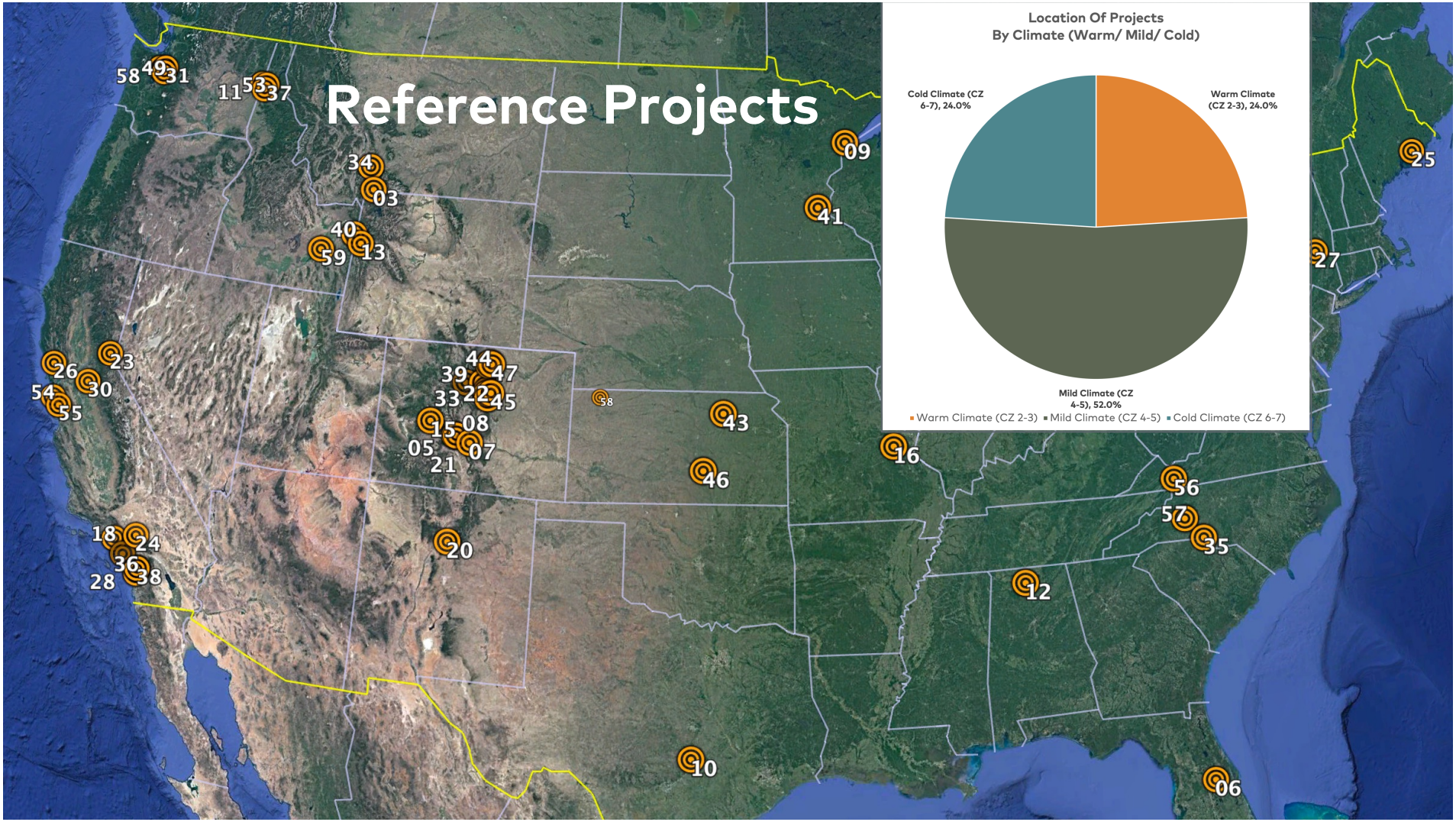
it has been 13 years in average, for the past 10 years!

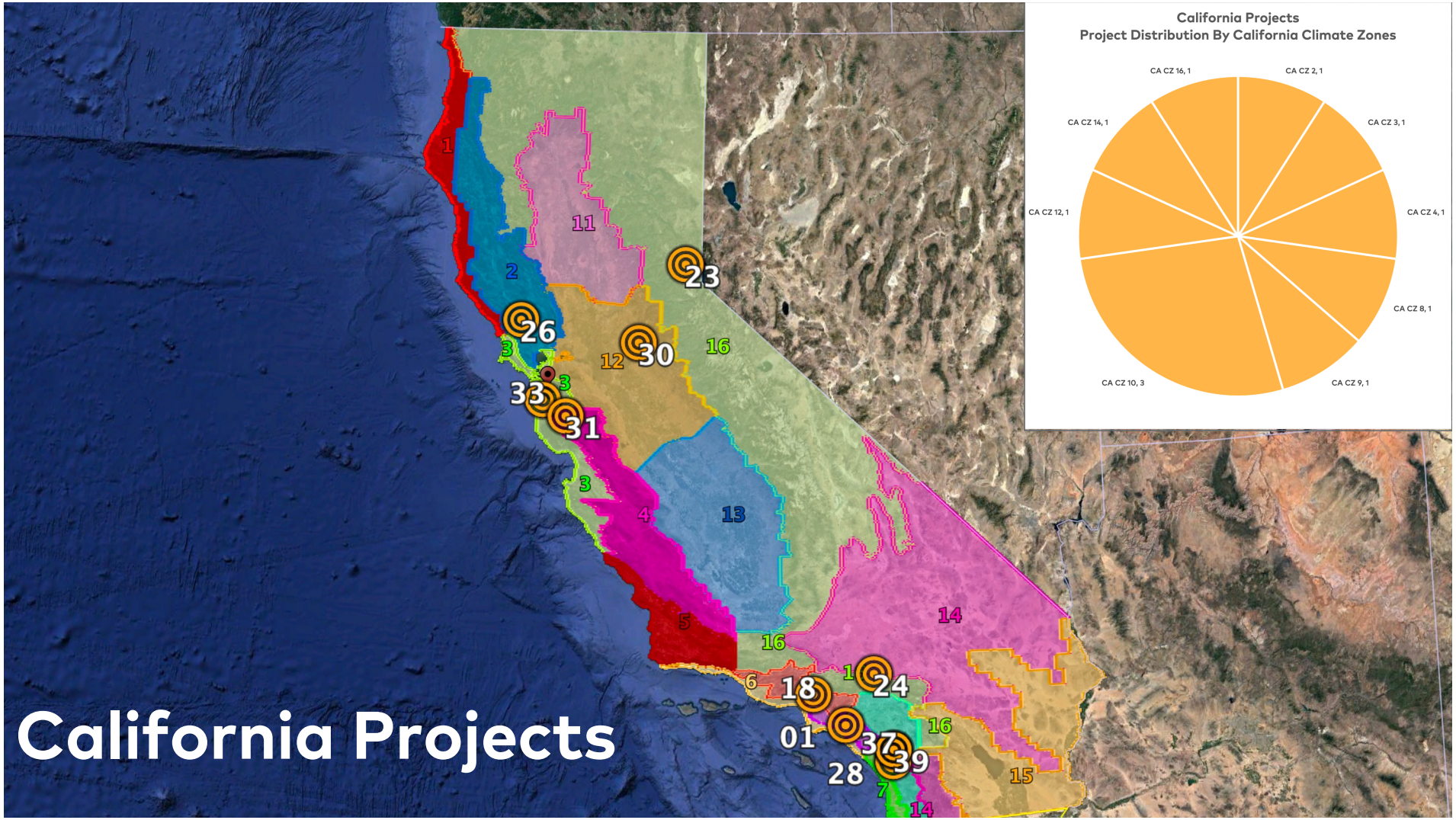
this is building science!

NAHB National Association of Home Builders

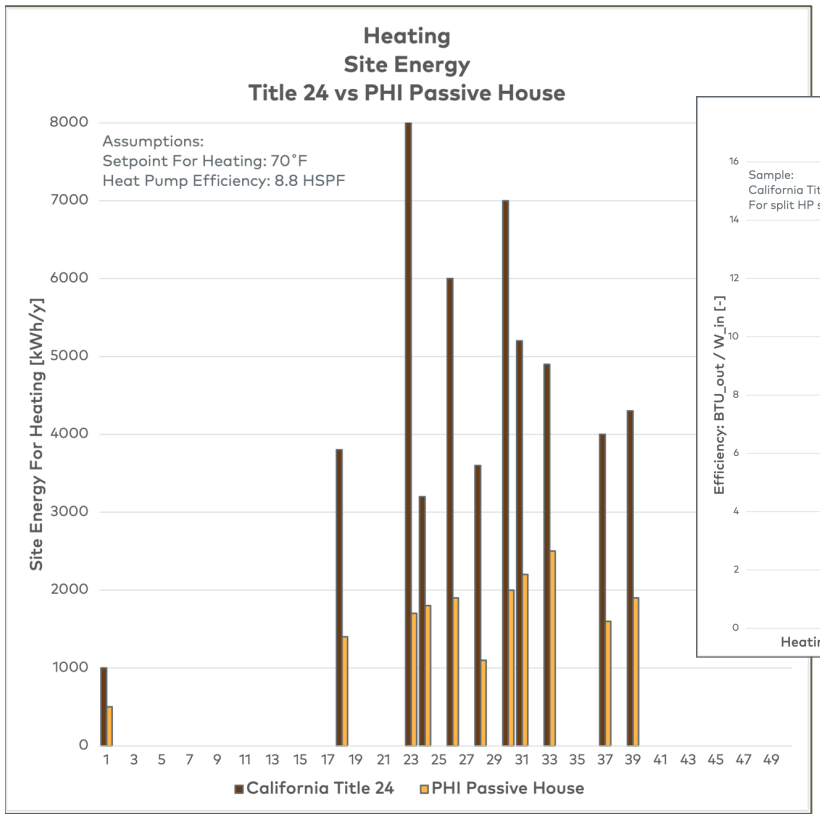
emu

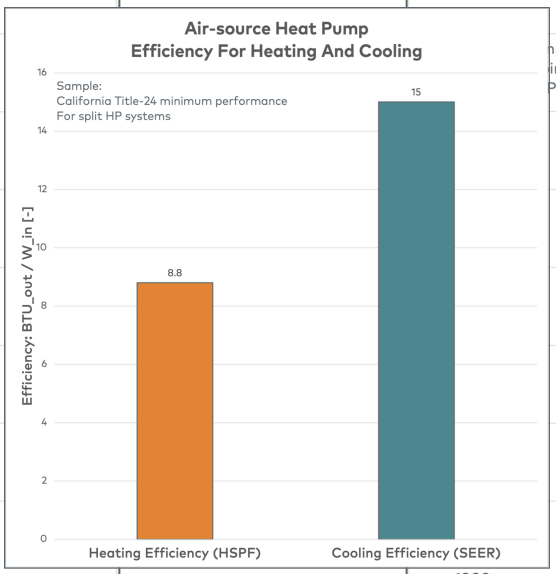
Energy + Future Proofing

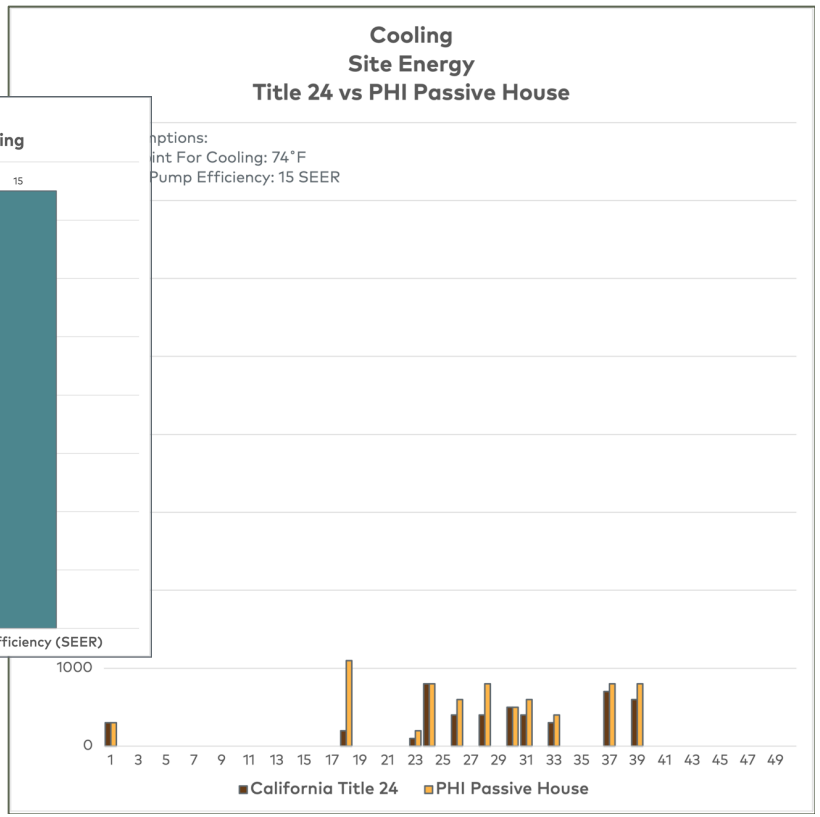

Reference Projects
Location Of Projects
By Climate (Warm/ Mild/ Cold)
Cold Climate (CZ 6-7), 24.0%
Warm Climate (CZ 2-3), 24.0%
Mild Climate (CZ 4-5), 52.0%
Warm Climate (CZ 2-3)
Mild Climate (CZ 4-5)
Cold Climate (CZ 6-7)
58
49
31
11
53
37
34
03
40
59
13
09
41
25
27
23
26
30
54
55
44
39
47
33
22
45
58
43
15
08
05
07
21
46
16
56
57
35
18
24
36
28
38
20
12
10
06


California Projects
Project Distribution By California Climate Zones
CA CZ 16, 1
CA CZ 2, 1
CA CZ 14, 1
CA CZ 3, 1
CA CZ 12, 1
CA CZ 4, 1
CA CZ 8, 1
CA CZ 10, 3
CA CZ 9, 1
California Projects

Heating vs Cooling



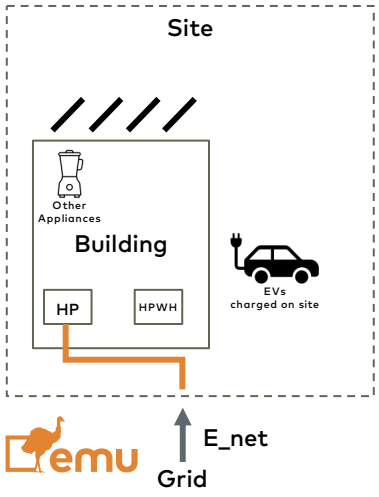


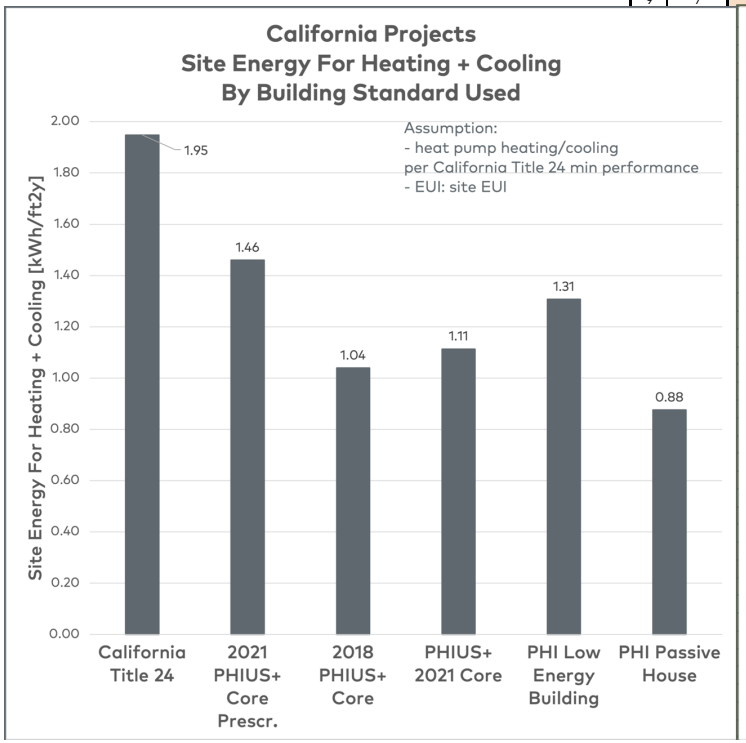


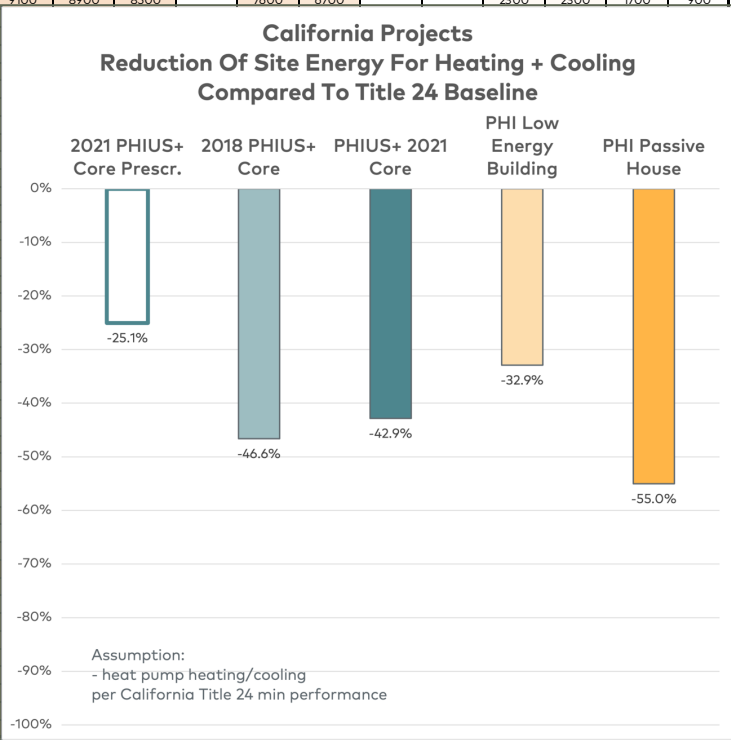
Site Energy For H+C

Heating + Cooling Demand, Final Energy (Site Energy)

Prj ID	ASHRAE Climate Zone	2018 IRC / IECC	2021 IRC / IECC	2024 IRC / IECC	California Title 24	EnergyStar 3.2	DOE ZERH v2	PGH	2021 PHIUS+ Core Prescr.	2018 PHIUS+ Core	PHIUS+ 2021 Core	PHI Low Energy Building	PHI Passive House
		kWh/y											
1	3B	1300	900	900	1300	800	800		800	600	600	1100	800
2	4C	4100	3700	3700		3200	3000		2600	1200	2300	1200	800
3	6B	5600	5500	5500		4700	4700	3700	2500	1400	2700	1000	700
4	5B	3200	2800	2800		2500	2300	1900	1800	2000	3200	1800	1000
5	6B	5100	5100	5100		4300	4300	3400	1900	1700	2600	1400	900
6	2A	2700	2700	2700		2300	2100		1900	2300	2700	2100	1900
7	6B	7800	7600	7500		6600	6500	5300		1500	2900	1300	700
8	5B	5700	5100	5200		4300	4200	3300	2500	1700	1900	1800	1200
9	7	9100	8900	8500		7600	6700			2300	2300	1700	900

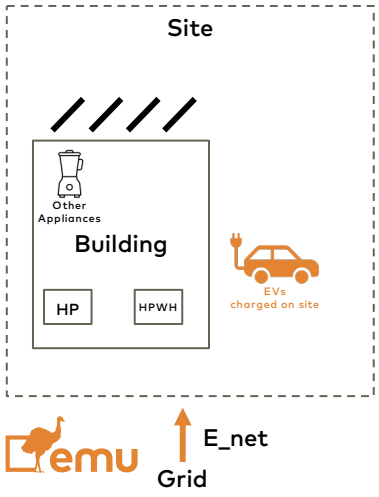


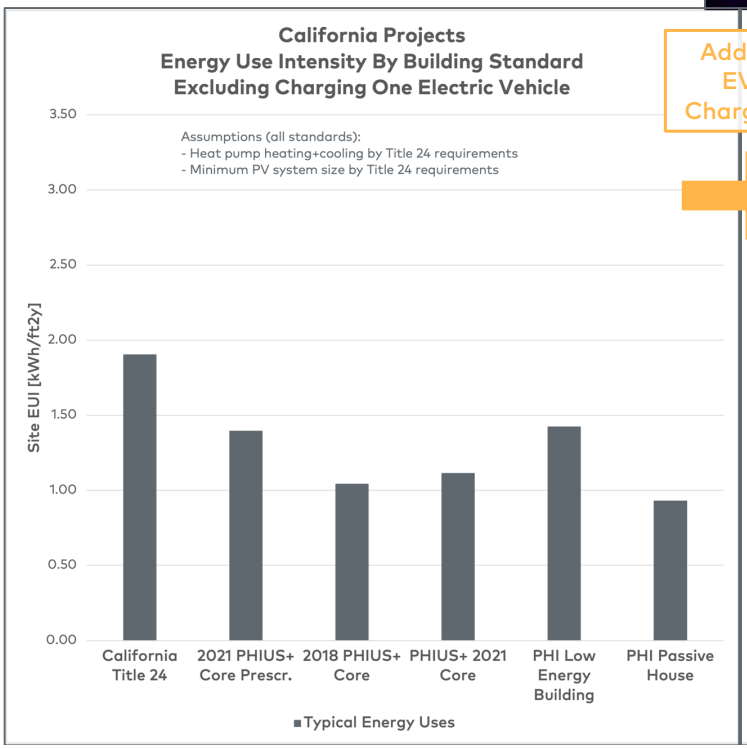




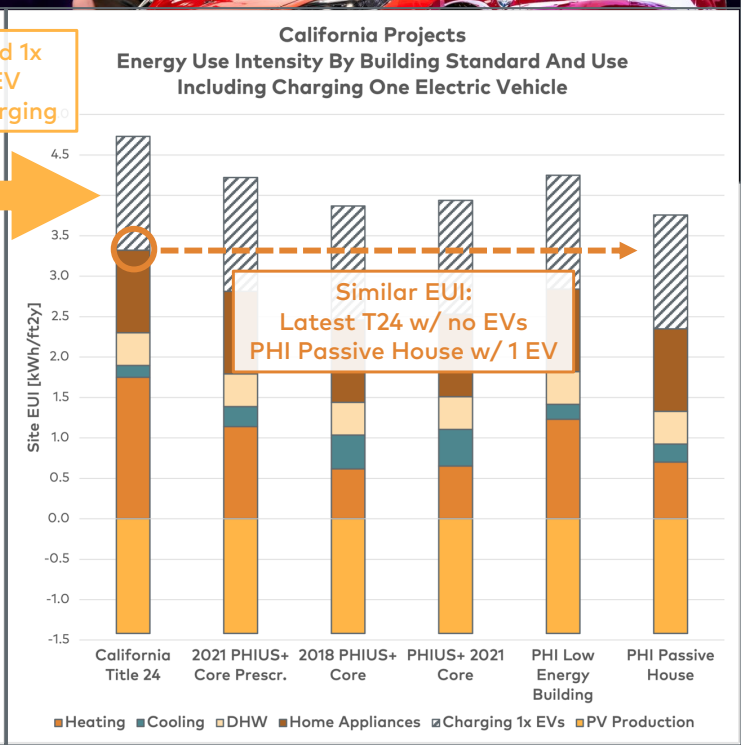
Site EUI Per Building Standard

- **Including** EV charging on site





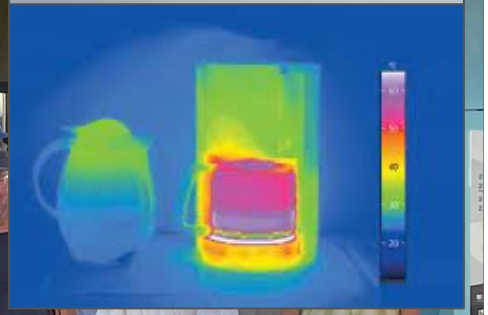
Add 1x EV Charging



Thermal Resilience

The "Yeti Cooler" Building

Keep Your Cool



Code Box:

817 lbs

60% loss

vs.

Passive House Box:

1524 lbs

29% loss

after two weeks in Denver, CO, where the average high has been 66°F

The Passive House Network Presents:

ICE BOX challenge

An interactive public installation and contest.

Keep Your Warmth

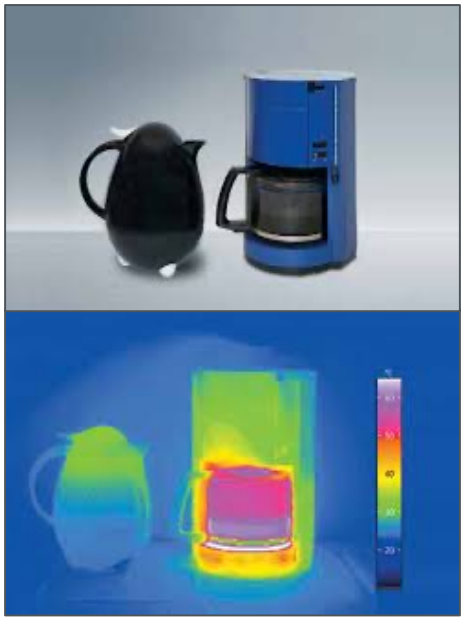
Where's The Difference?

Title 24

- Little insulation
- Thermal bridging allowed
- Low quality windows + doors
- No limit on air leaks
- Less resilient when the power goes out

Passive House in California

- More insulation
- Avoid thermal bridging
- High quality windows + ext. doors
- Airtight
- More resilient when the power goes out



Indoor Air Quality

Indoor Air Quality

Metrics

- Fresh air flow rate per occupant
- Pollutants Concentration
  - CO2
  - PM2.5 (also, PM1, PM10...)
  - VOCs
  - Radon
  - Etc.

Preventative Measures

- Remove source of pollution (e.g. remove gas cooktop)
- Continuous fresh air supply
- Filtration (also, UV treatment)
- Air sealing building

Indoor Air Quality - in this presentation

Metrics

- Fresh air flow rate per occupant
- Pollutants Concentration
  - PM2.5 (causes cancer)

Preventative Measures

- Continuous fresh air supply
- Filtration
- Air sealing building

IAQ: Air Tightness

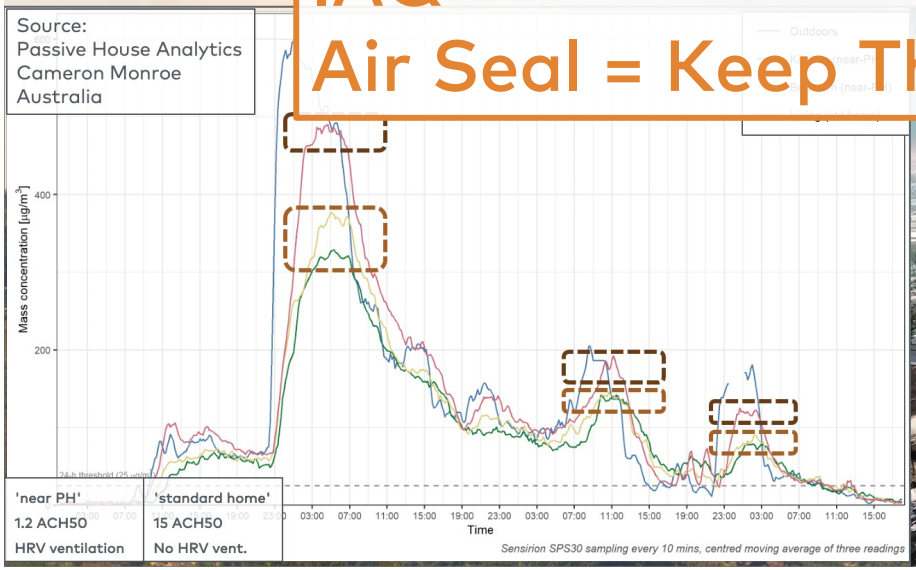
Australia

- Wildfire near Melbourne
- PM2.5 monitoring
- EnerPHit Regular Home

Colorado

- Marshall Fire
- Interview with Mark Attard on how air tightness saved their home from smoke damage

IAQ
Air Seal = Keep The Bad Stuff Out



Air Tightness Requirements

California Title 24:
Actually ∞ Air Leakage Allowed
(the only standard considered not to set a limit)

ACH50

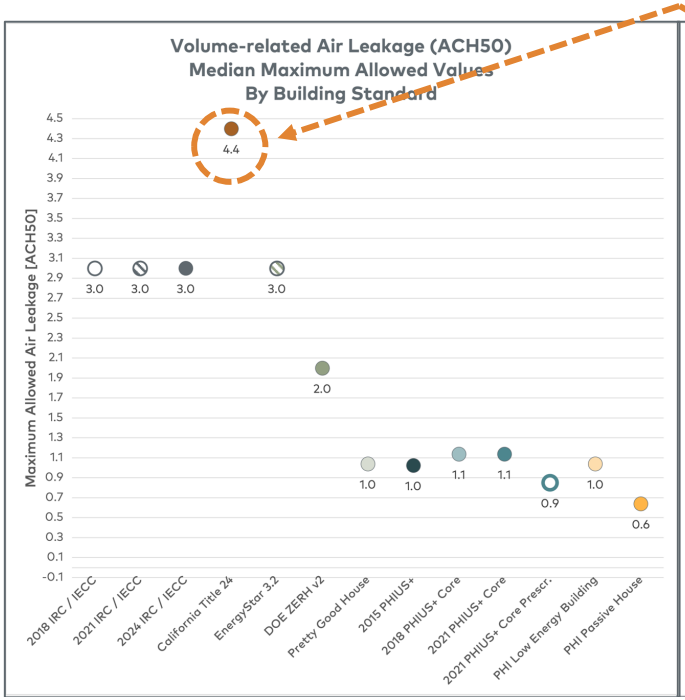
(volume-related metric)

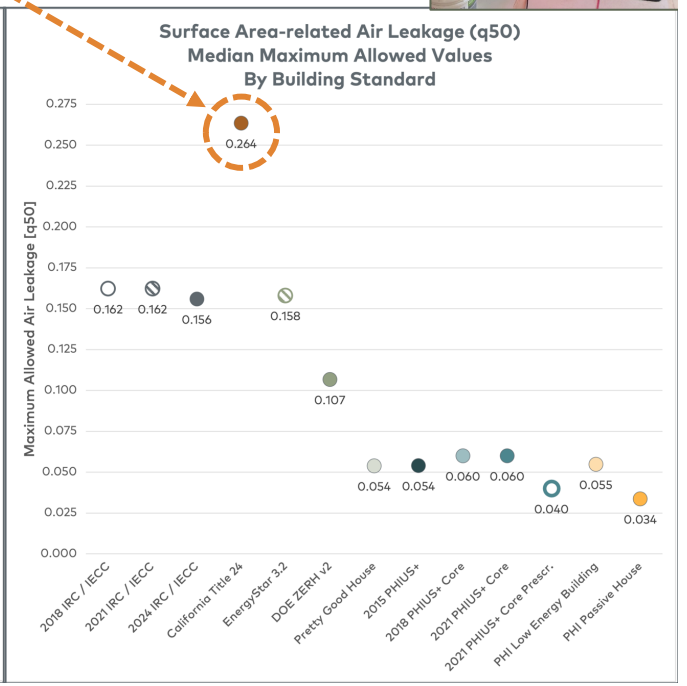
- most common metric in the US
- harder to meet in small buildings
- not as indicative in large buildings

q50

(surface-area related metric)

- less common in the US
- more strict on large buildings
- more lenient on small buildings
- more lenient on poorly designed buildings (i.e. buildings with high form factor)





IAQ Example

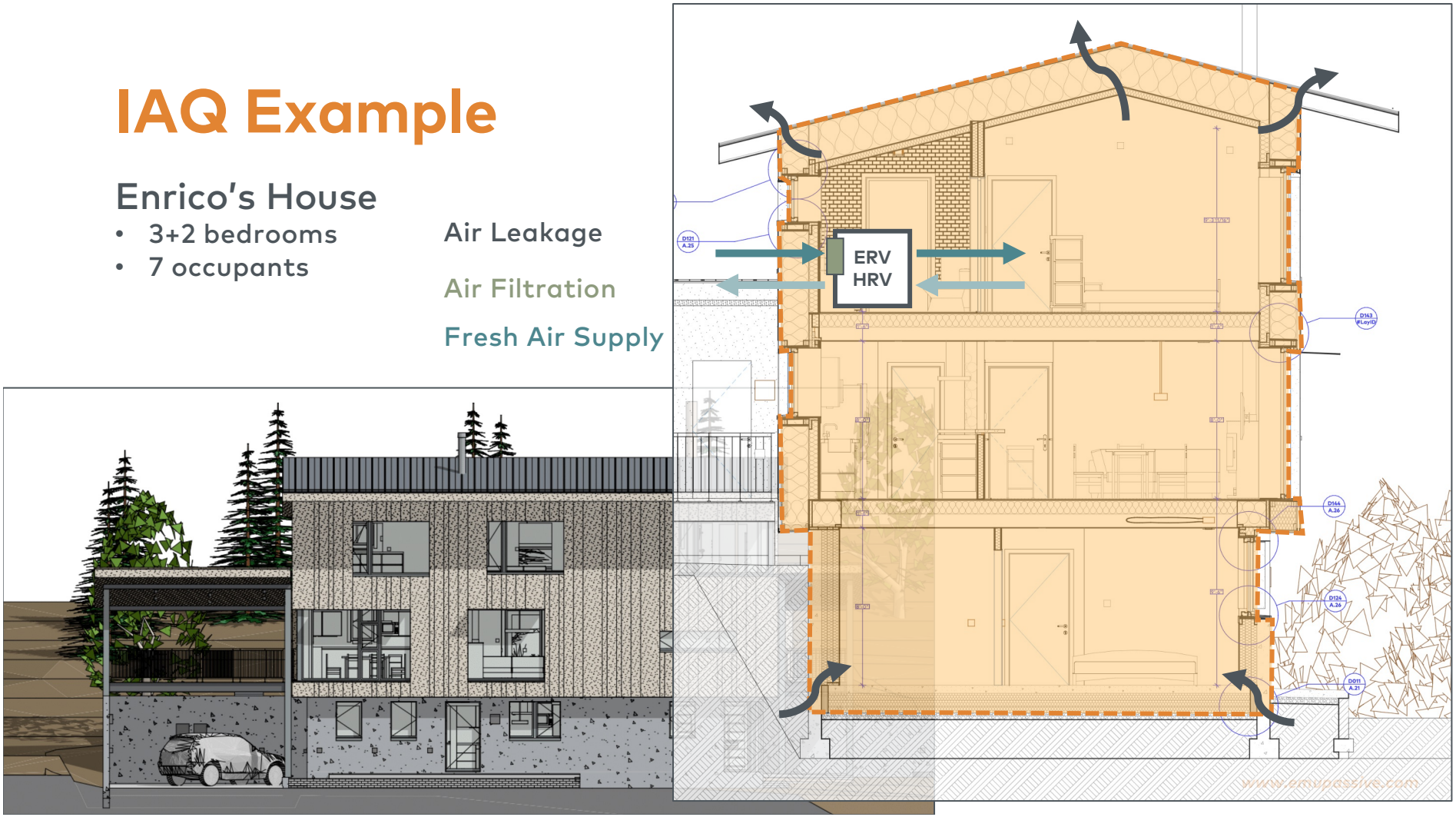
Enrico's House

- 3+2 bedrooms
- 7 occupants

Air Leakage

Air Filtration

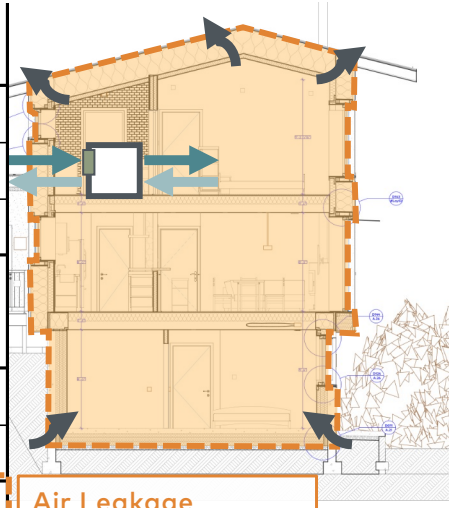
Fresh Air Supply



Example: Enrico's House

Treated floor area		TFA	247.76	m2	2666	ft2	Per PHI requirements
Net Air Volume		BDT Volume	694	m3	24505	ft3	
Occupancy		Bedrooms	5	Occupants	7		ASHRAE 62.2 (2 dw. units)
		2021 IECC	**2022 Title 24**	**2021 Phius Core**	**PHI Low Energy Bldg**	**PHI Passive House**	
Air Leakage	ACH50 Limint	3	none	none	1	0.6	ft3/ft3*2
	q50 Limit	none	none	0.06	none	none	surface-related ft3/f2*h
	Volume-specific ACH50 Modeled	3.0	5.0	1.1	1.0	0.6	Calculated for Enrico's house project size
	Surface-specific q50 Modeled	0.165	0.274	0.060	0.055	0.033	
	Resulting ACH15	0.6	1.1	0.2	0.2	0.1	Air Changes Per Hour
	Air Leakage Airflow In Normal Conditions (5Pa delta)	264	440	96	88	53	cfm at 5Pa
Fresh Air Supply	Fresh Air Supply (continuous)	24	132	130	124	124	cfm *
	Filtration	none	MERV13	MERV8	MERV13	MERV13	Min. required filtration grade By bldg standard
	Label filtration grade (PM2.5)	none	85%	20%	85%	85%	Min PM2.5 Filtration Per ASHRAE 52.2
Indoor Air Quality	Fresh Air Supply Per Bldg Occupant	3	19	19	18	18	cfm/person
	Effective Filtration Grade (weighted average)	0.0%	19.7%	11.5%	49.6%	59.6%	PM2.5 Based on supply, filtration, and ACH50
*	IECC: bath fans 24-hr avg						

Building Standards Considered



Air Leakage Allowed By Bldg Standard

Resulting Air Leakage in "normal" conditions (5 Pa delta)

Fresh air supply required by bldg. standard

Filtration of resh air supply required by bldg. standard

Effective filtration: combo of ACH50, supply rate, and nominal filtration

IAQ: Minimum Air Filtration By Standard

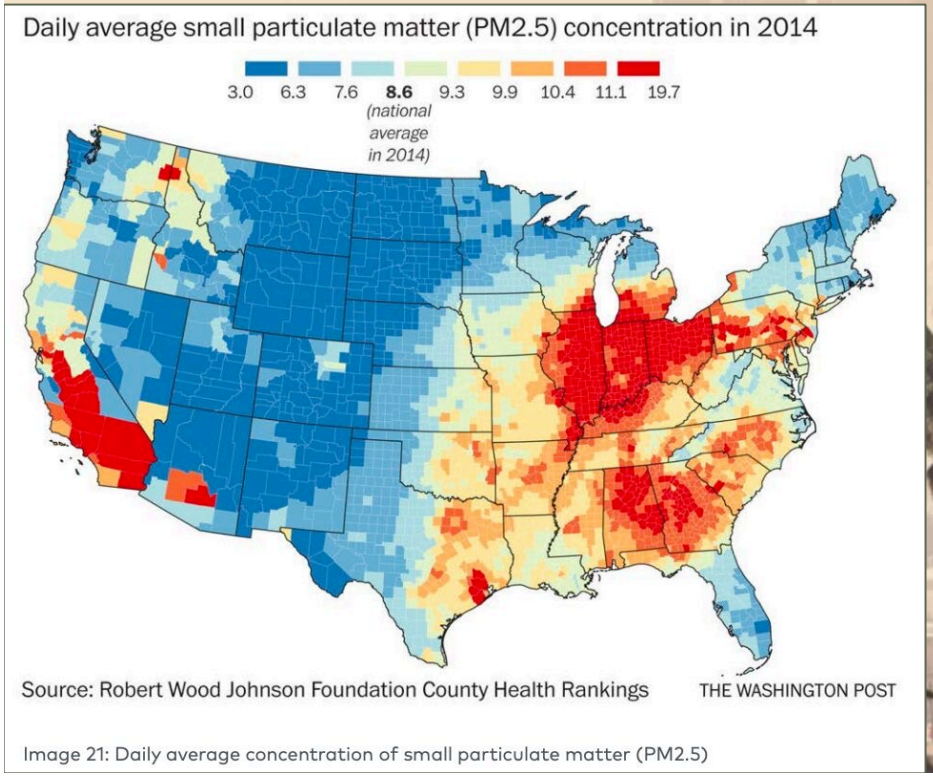


Image 21: Daily average concentration of small particulate matter (PM2.5)

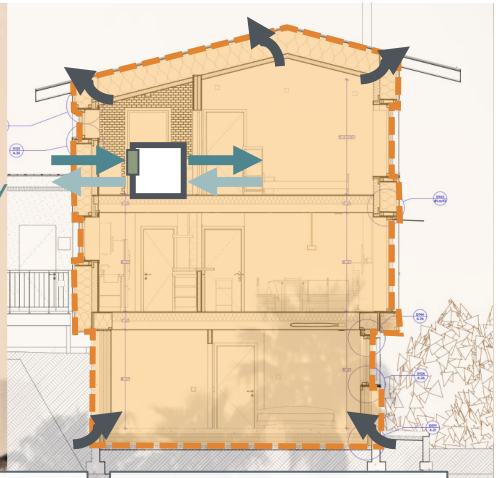
Minimum Air Filtration Required By Standard

Building Standard	Minimum Filtration Required	MERV Minimum Required Filtration Grade µm (micron)		
		0.3-1.0	1.0-3.0	3.0-10.0
2018 IRC / IECC	NR	-	-	-
2021 IRC / IECC	NR	-	-	-
2024 IRC / IECC	NR	-	-	-
California Title 24	MERV13	≥ 50%	≥ 85%	≥ 90%
EnergyStar 3.2	MERV6	-	-	≥ 35%
DOE ZERH v2	MERV8	-	≥ 20	≥ 70%
Pretty Good House	NR	-	-	-
2015 PHIUS+	MERV8	-	≥ 20	≥ 70%
2018 PHIUS+ Core	MERV8	-	≥ 20	≥ 70%
2021 PHIUS+ Core Prescr.	MERV8	-	≥ 20	≥ 70%
PHIUS+ 2021 Core	MERV8	-	≥ 20	≥ 70%
PHI Low Energy Building	MERV13	≥ 50%	≥ 85%	≥ 90%
PHI Passive House	MERV13	≥ 50%	≥ 85%	≥ 90%

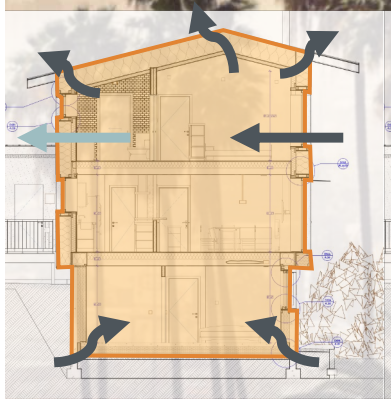
IAQ Example

Enrico's House

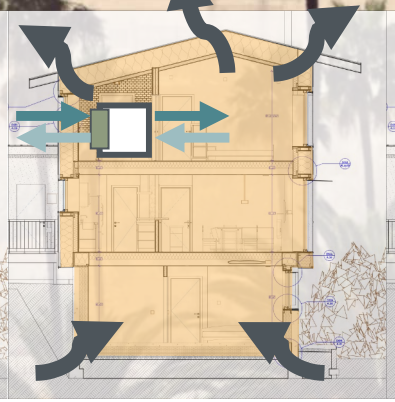
Air Leakage
Air Filtration
Fresh Air Supply



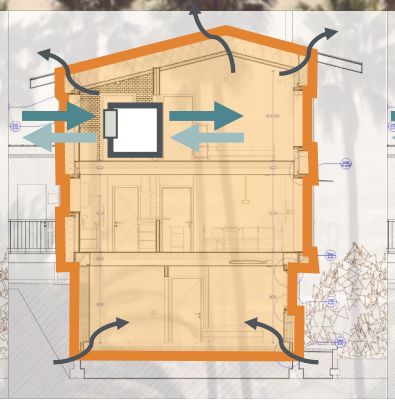
2021 IECC
- ACH50 ≤ 3
- Filtration: no req.
- Supply: bath fans



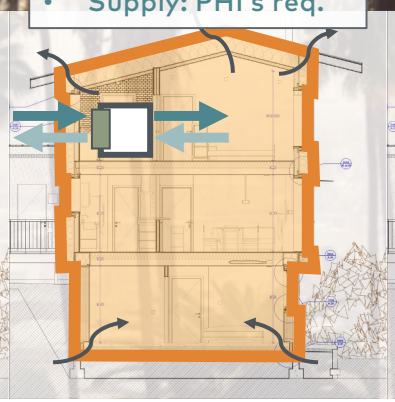
Title 24
- ACH50 ≤ no req.
- Filtration: MERV 13
- Supply: ASHRAE 62.2



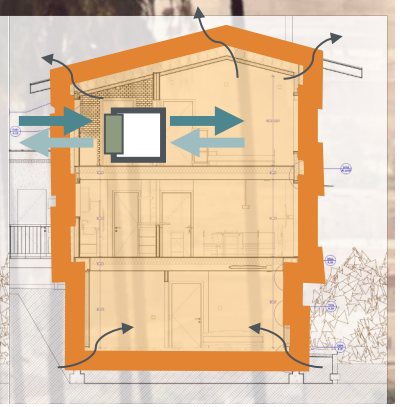
2021 Phius
- ACH50 ≤ 1.1
- Filtration: MERV 8
- Supply: Phius' req.



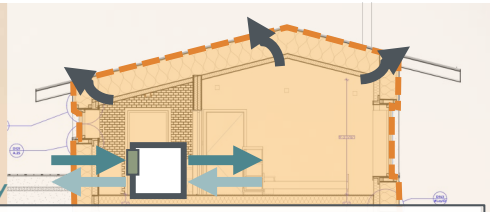
PHI Low Energy Bldg
- ACH50 ≤ 1.0
- Filtration: MERV 13
- Supply: PHI's req.



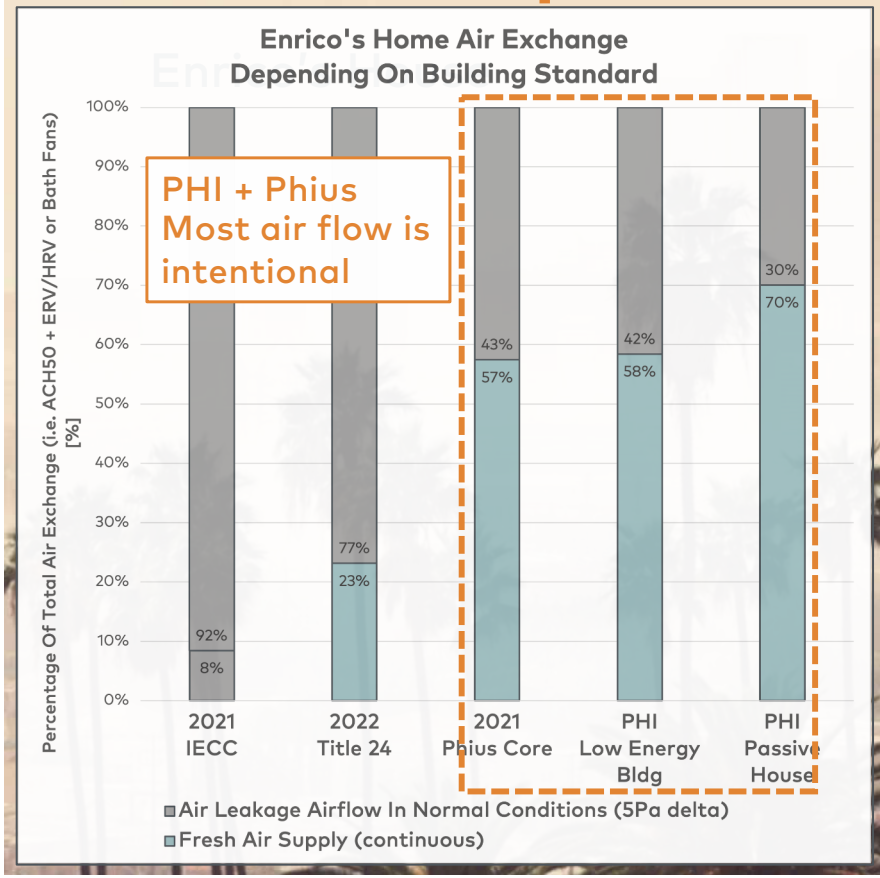
PHI Passive
- ACH50 ≤ 0.6
- Filtration: MERV 13
- Supply: PHI's req.



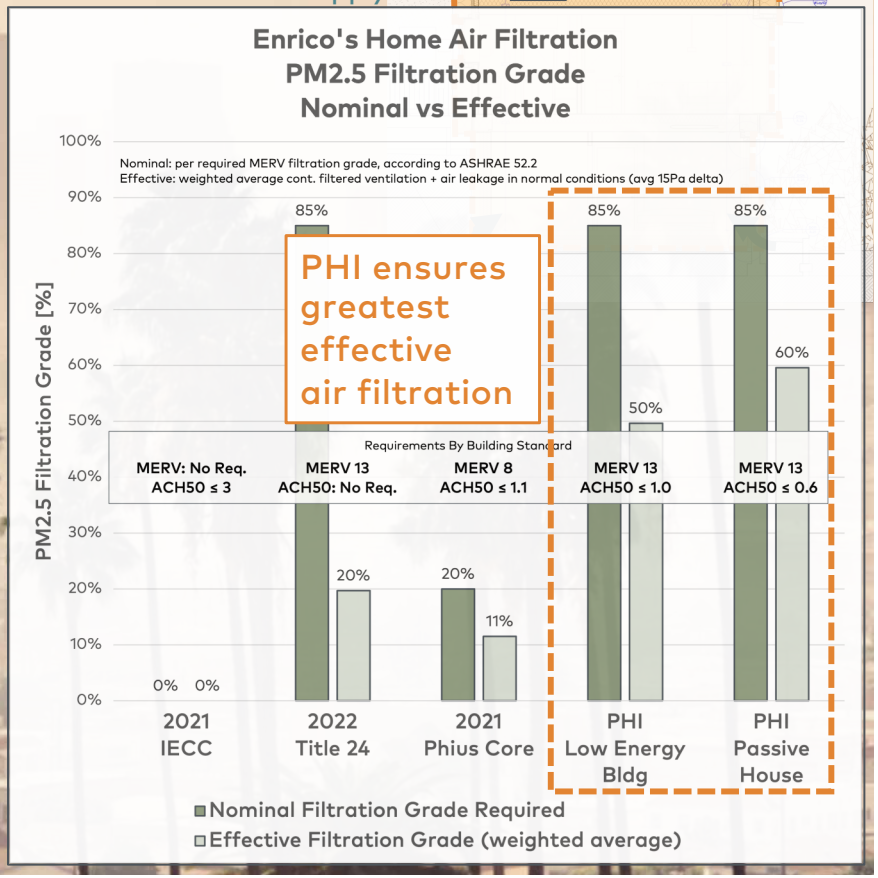
IAQ Example



Enrico's Home Air Exchange Depending On Building Standard



Enrico's Home Air Filtration PM2.5 Filtration Grade Nominal vs Effective

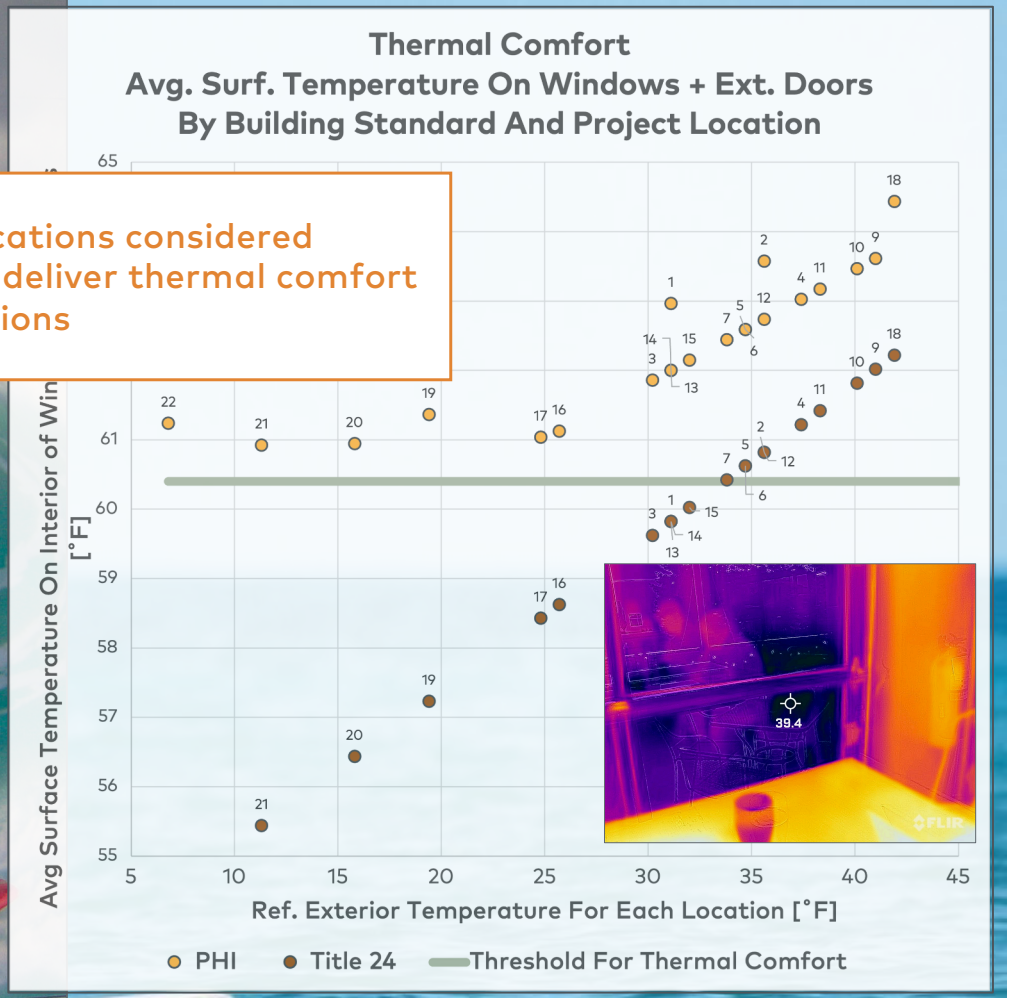


Thermal Comfort

Why Do We Care About Windows?

Title 24 ≠ Comfort

- 22 California locations considered
- **Title 24 fails** to deliver thermal comfort in **half** the locations



Conclusions

Beyond Energy – Passive House for California

- Regardless of certification goals, **Passive House provides tools** to enhance **durability and resilience** of the building stock
- **Well insulated** and **air-sealed buildings** remain considerably more **livable when the grid fails**
- **Filtered fresh air supply** + **air sealing** protects people from exposure to **exterior pollutants** (e.g. PM2.5, wildfire smoke, etc.)
- Even in sunny California, **windows and exterior doors** impact the **thermal comfort level** inside buildings

Want To Learn More?

Passive Design/Build™ Boot Camp

San Luis Obispo, CA, Sep 30 – Oct 4
(funded by 3C-REN)

Passive Design/Build™ Boot Camp

Berkeley, CA, Oct 21-25
(PH California scholarships available)

www.emupassive.com

Thank You!