

Net Zero with Lean Tech

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APDESIGN

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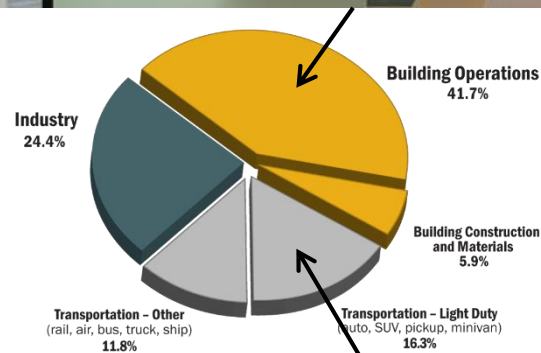
ARCHITECTURE · DESIGN · SUSTAINABILITY · PREFAB

Impact of Change



28% of total building energy use can be reduced by **daylighting** [LBNL 2012] in existing buildings. This is equivalent to an **11% reduction in total national energy consumption.**

If every U.S. vehicle was replaced by a **Prius**, this would also result in **an 11% reduction in national energy consumption.**



U.S. Energy Consumption by Sector

Source: ©2013 2030, Inc. / Architecture 2030. All Rights Reserved.
Data Source: U.S. Energy Information Administration (2012).

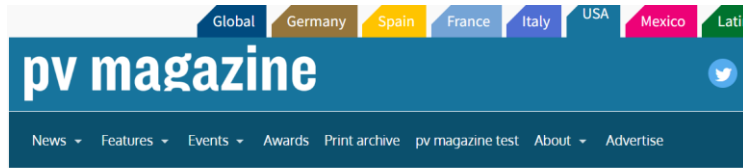


The math:

21.4 mpg ave fleet [2014] / 52 mpg new fleet ave = 70% decrease in fuel used
16.3% national energy used by vehicles - (16.3% * 70%) = 11% reduction

All building envelopes updated to IECC minimum code: 3.7% reduction in building energy consumption

Impact of Net Zero

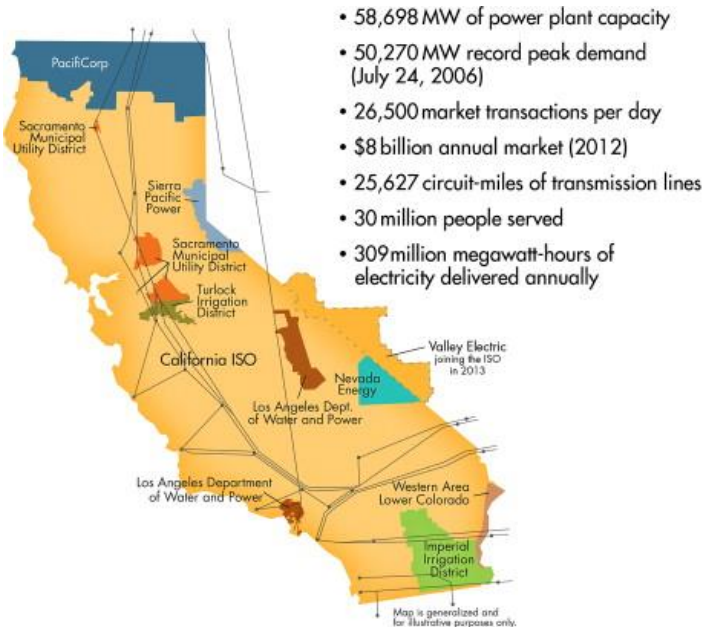


Driven by solar, California's net demand hit zero on Sunday

The CAISO region's spring solar record setting season is upon us, with solar peaking at greater than 95% of the state's demand.

APRIL 20, 2023 JOHN FITZGERALD WEAVER

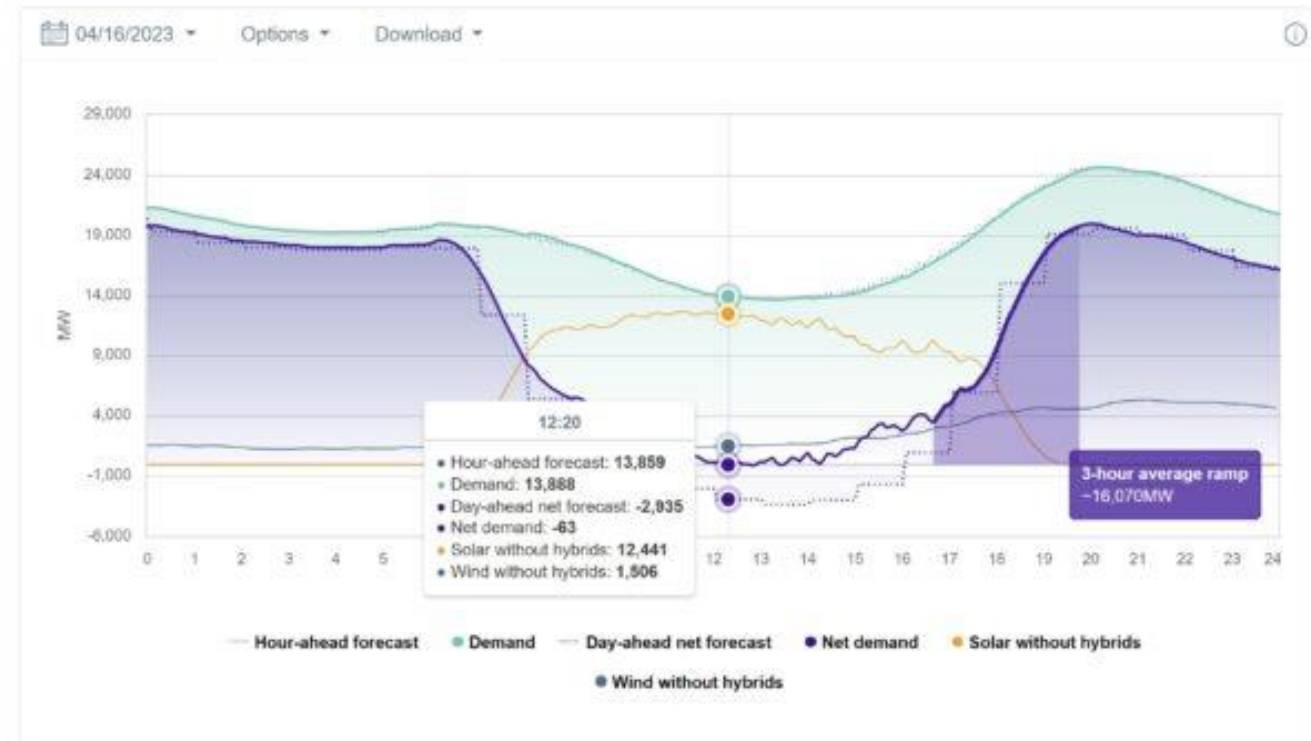
MARKETS MARKETS & POLICY CALIFORNIA



April 20, 2023 @ 12:20p: California's green energy generation offset its demand by over 100%.

Net demand trend

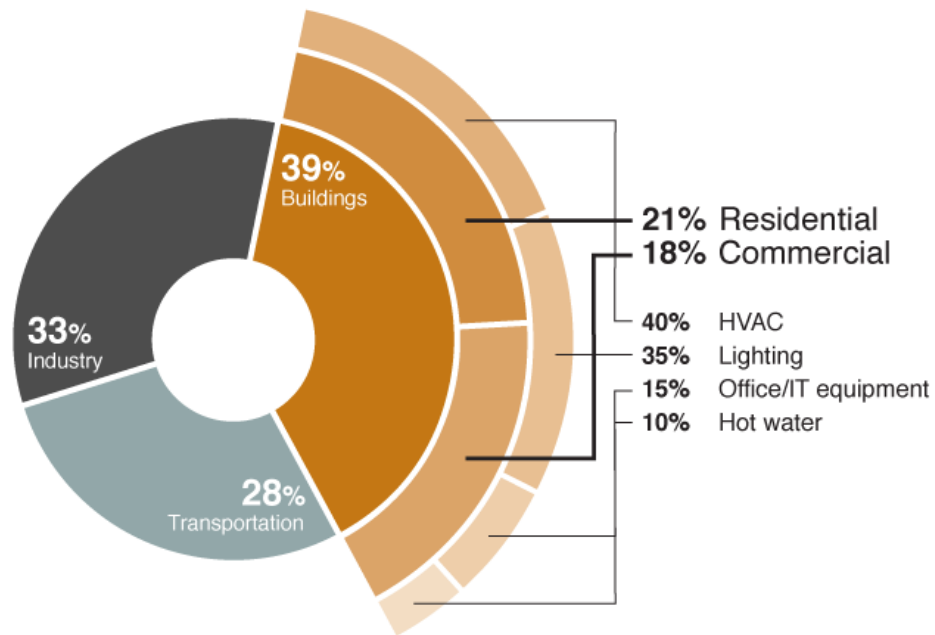
System demand minus wind and solar, in 5-minute increments, compared to total system and forecasted demand.



Home Energy Matters

Residential Energy Usage

U.S. Building Sector End Use Energy Consumption



Annual CO2 Emissions, Average U.S. Household



20,487 lbs CO2 from utilities
"Mega Homes" emit 40k to 60k lbs of CO2 versus this typical house.

[Source: 2020 RECS]

* 19% of U.S. Households Still Using Primarily Incandescent Light Bulbs

12,520 lbs CO2 from driving

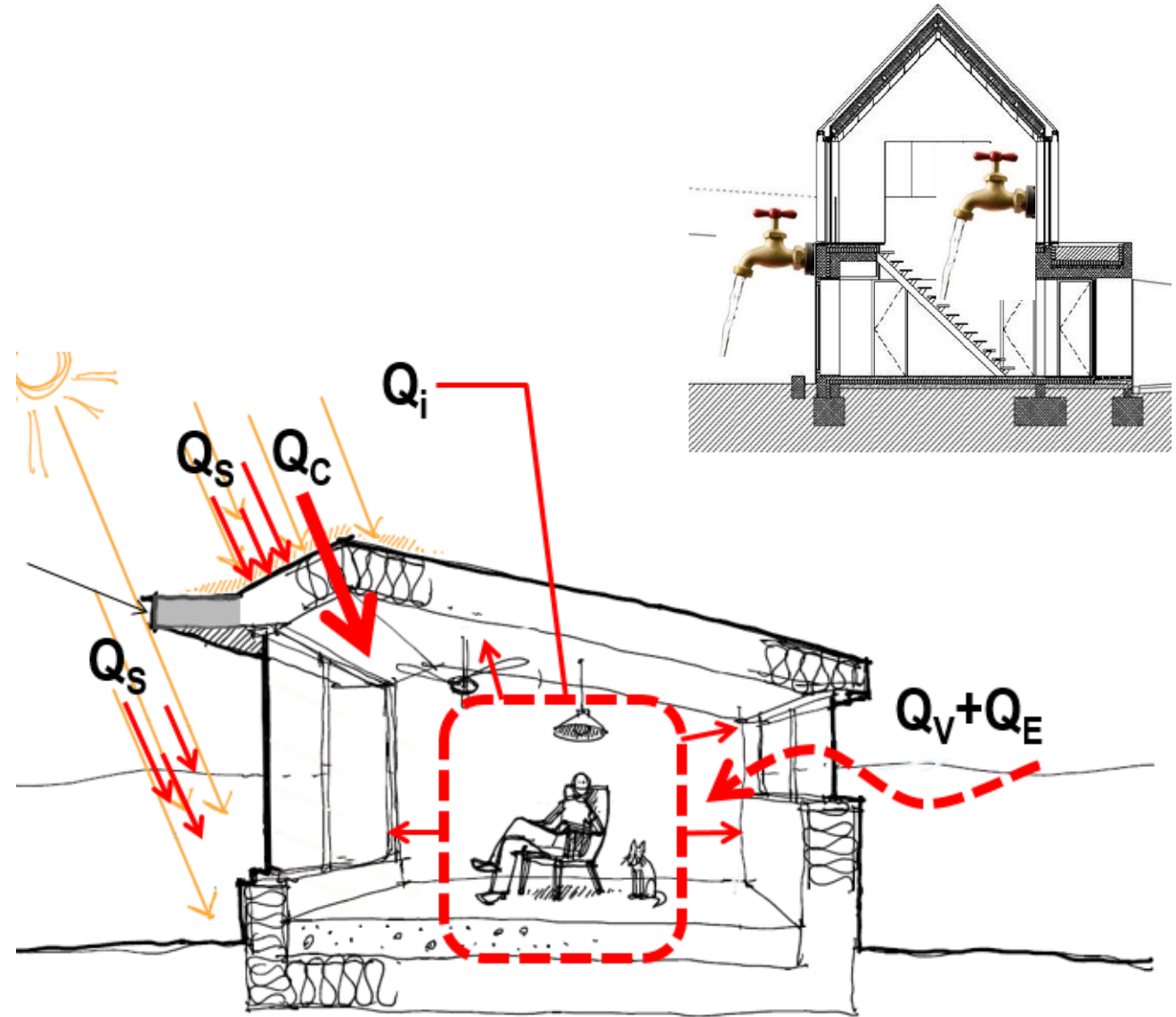
Assuming 17,815 miles driven per household @ 25.4 mpg US fleet ave

[Source: 2018 US DOT Natl Household Travel Survey, 2019 EPA]

Units & Concepts



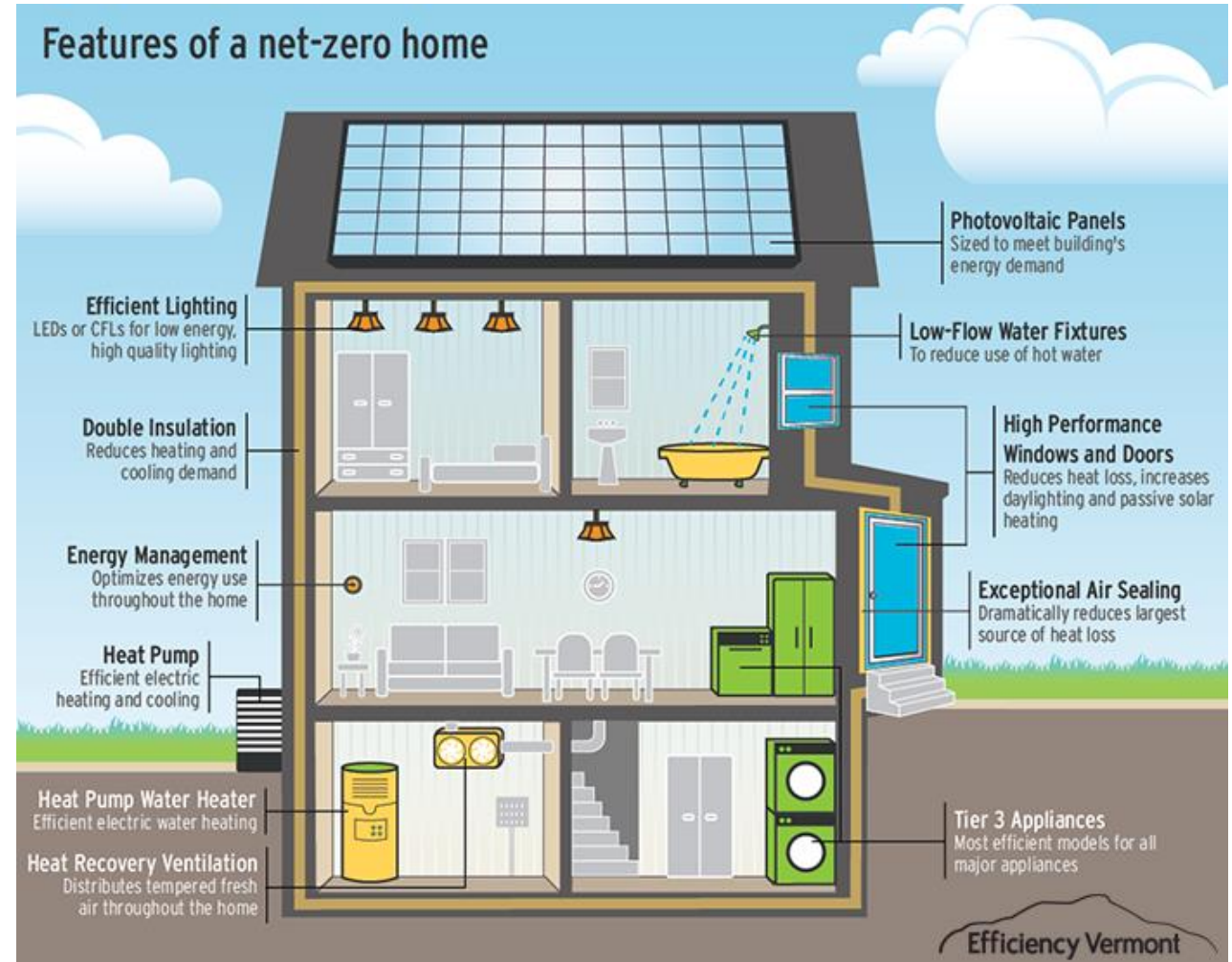
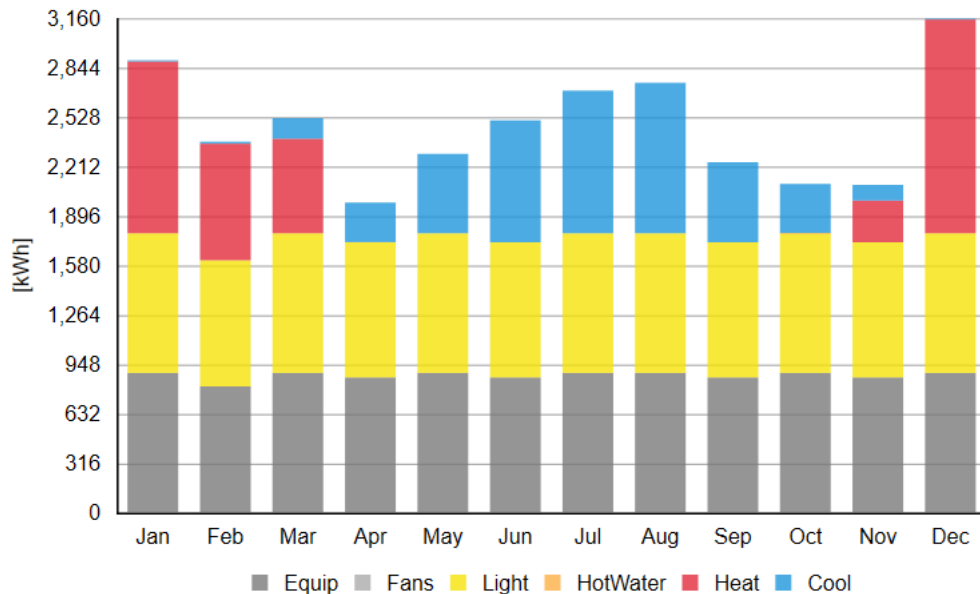
Energy Flow: Btu/h, W, kW
Energy Qty (Work):
Btu, Wh, kWh



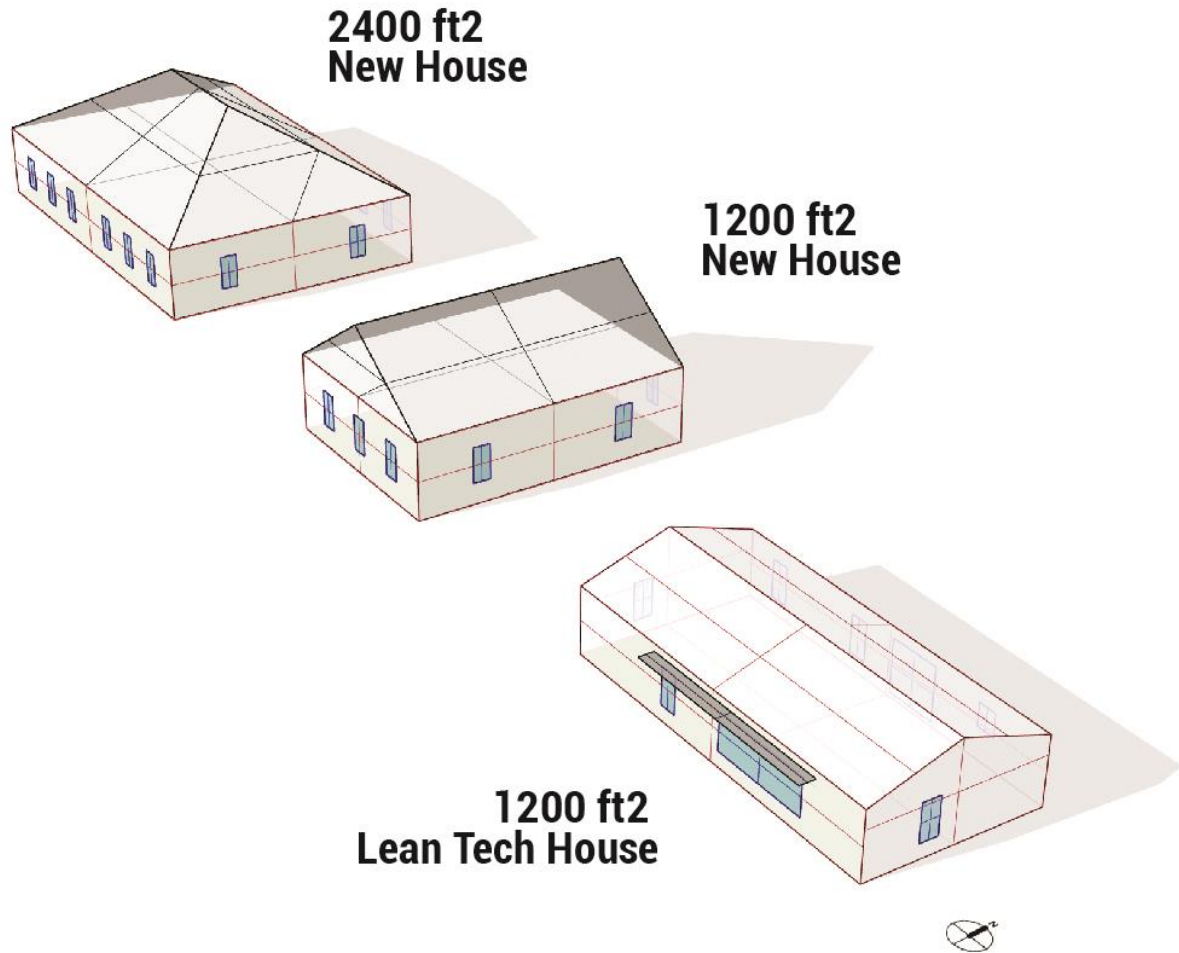
How Homes Use Energy

1. Space Heating
2. Space Cooling
3. Lighting
4. Equipment & Water Heating
5. Fresh Water Utilization

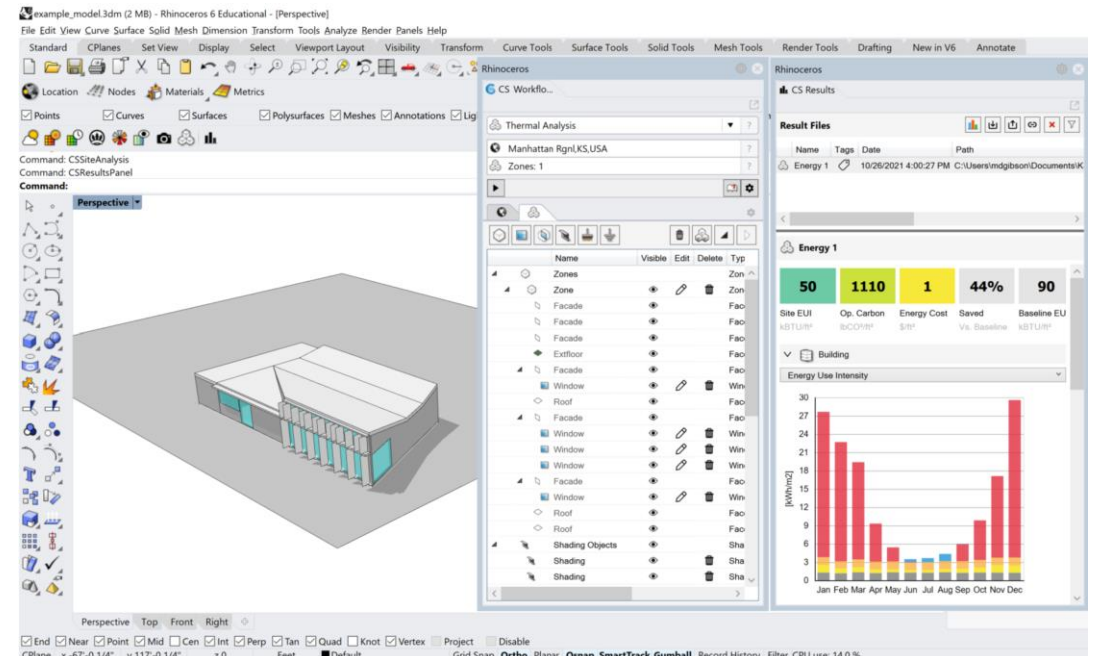
Typical 2400 ft² House, MHK Climate



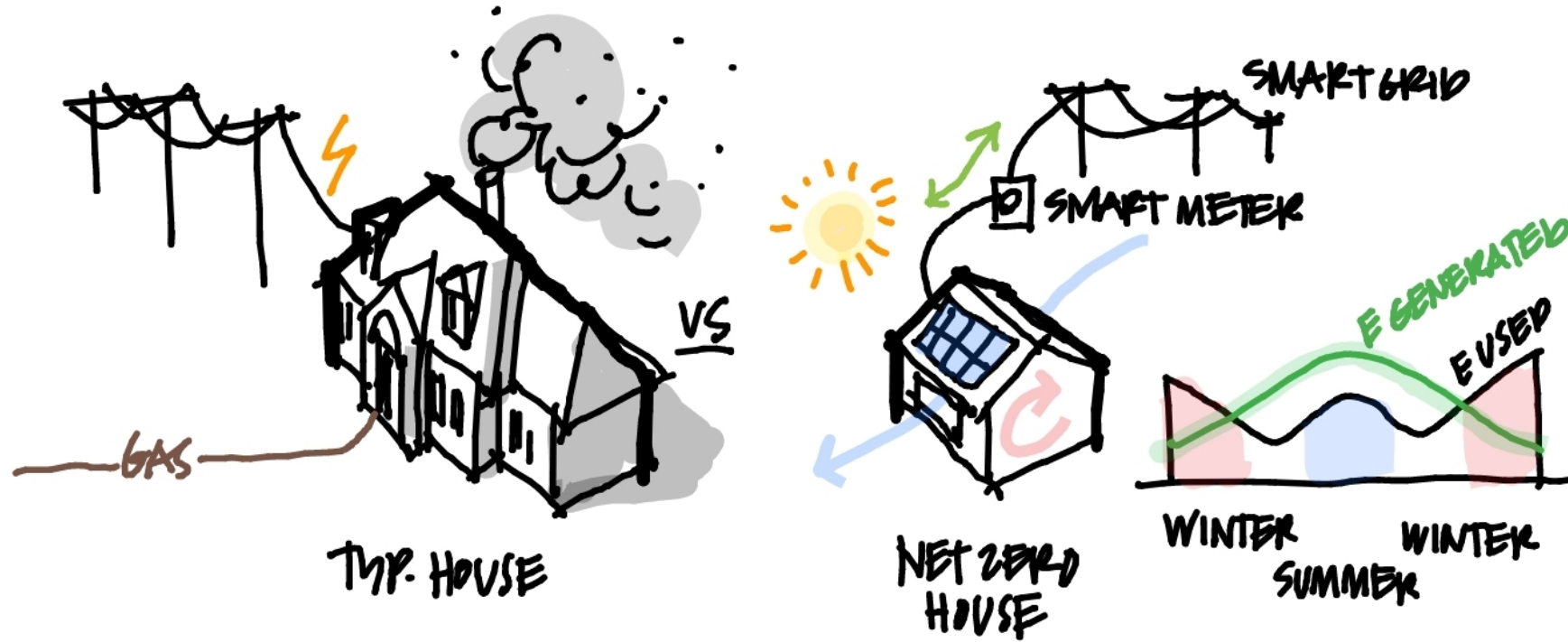
Modeling Overview



This study: used Climate Studio (DOE2 Energy Modeler in Rhino) to simulate incremental energy efficiency improvements in three different house models.



Getting to Net Zero (Site Energy Basis)

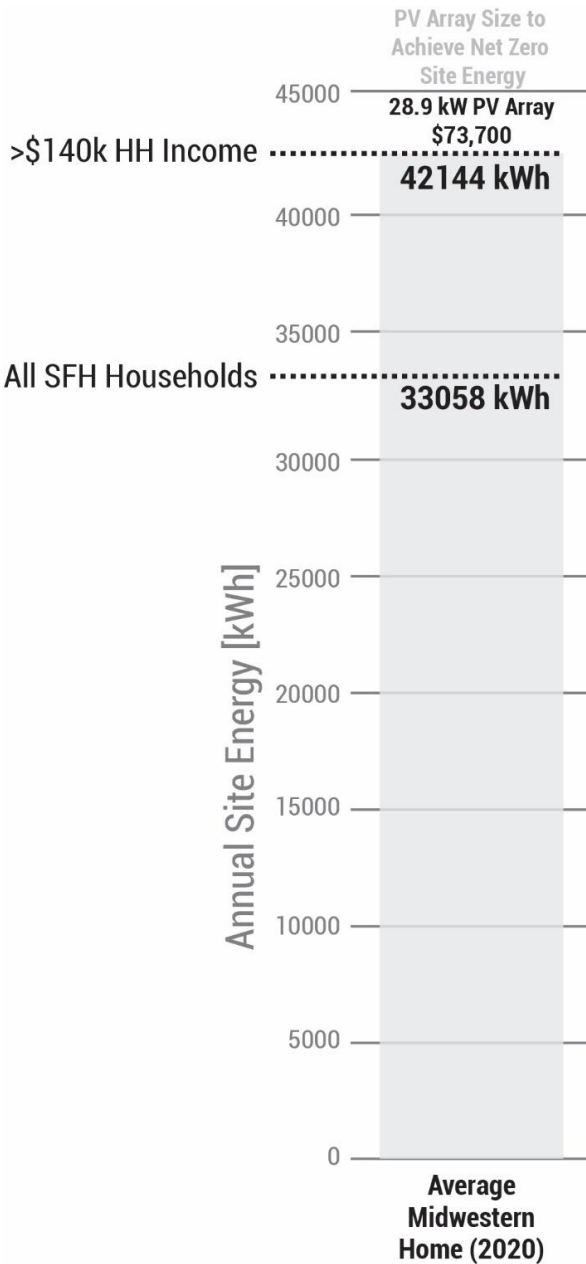


Annual energy used is offset by energy generated on site.

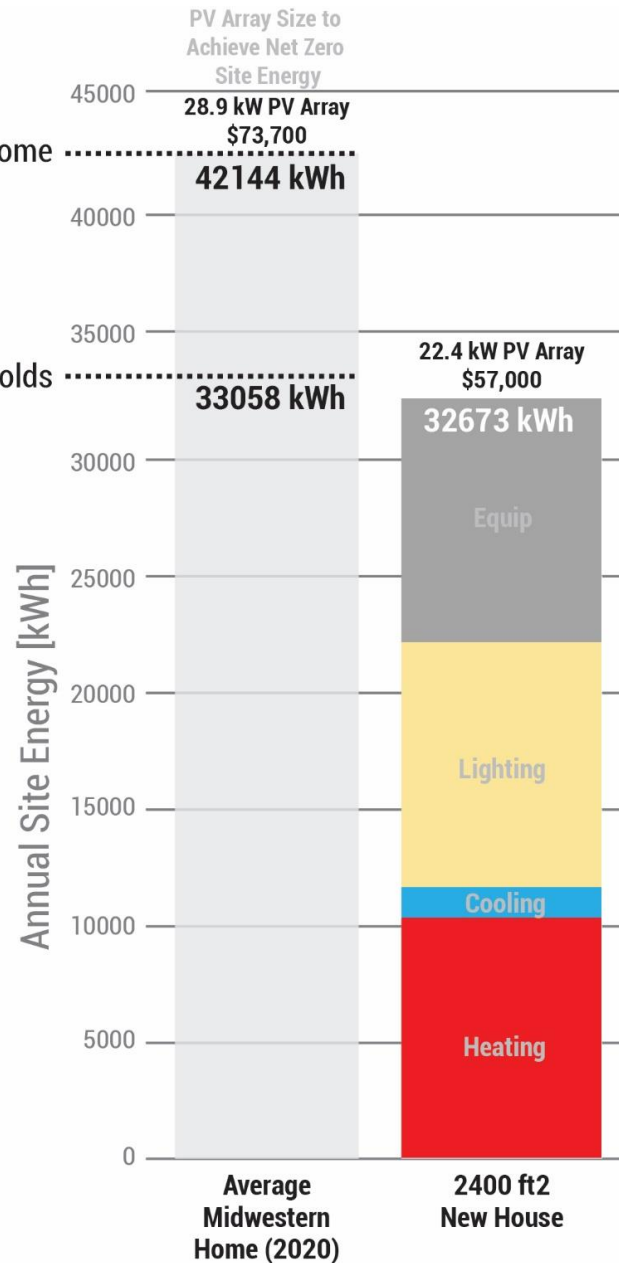
Smart meter allows energy to flow in either direction (net metering) and utility credits customer for surplus energy fed back into the grid.

Typical Midwestern Home

Data from 2020 RECS

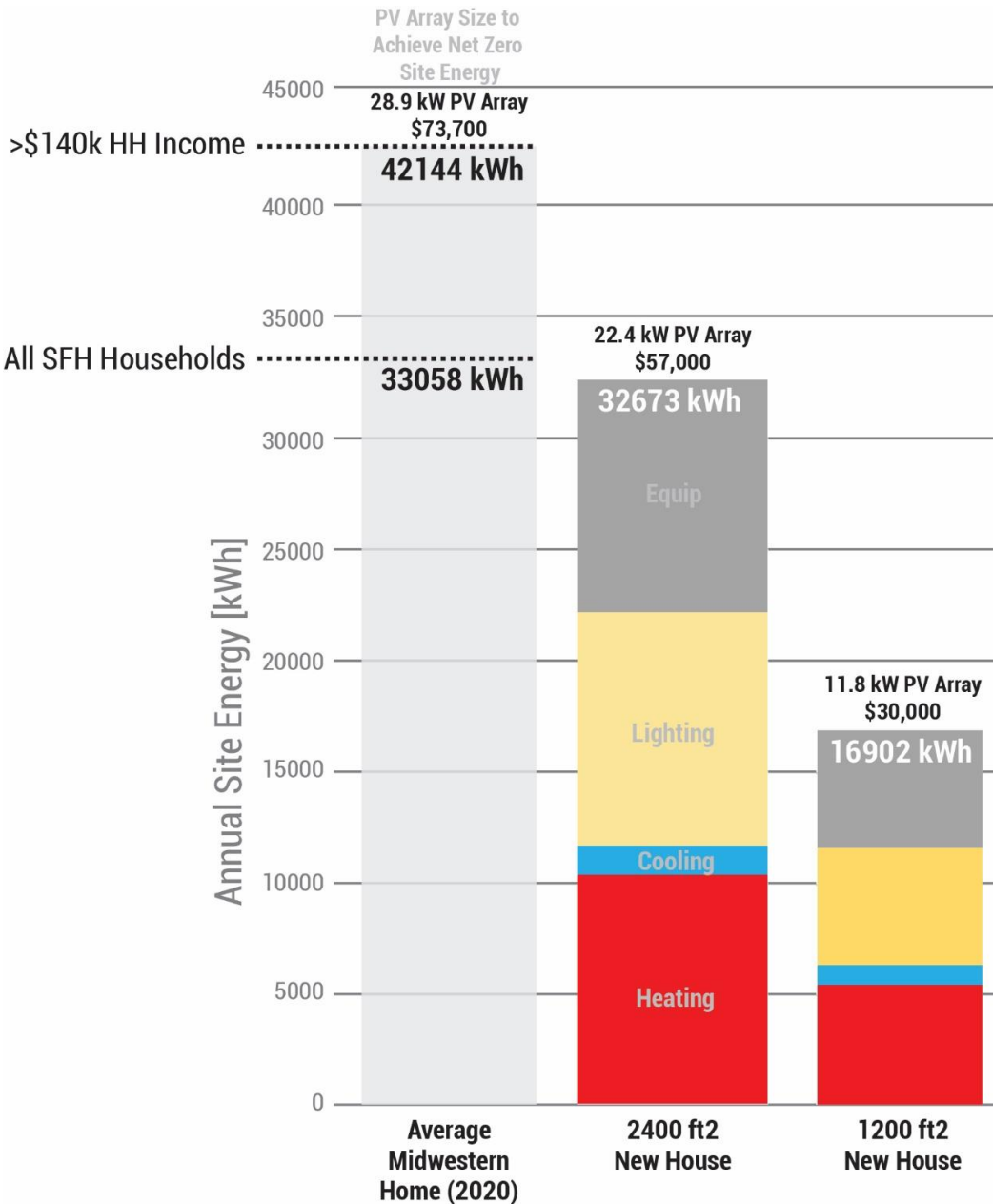


New 2400 ft2 House



- IRC 2018 envelope minimums:
 - R-20 walls | R-49 clg | U-0.32 glazing | slab on grade, perim. insul. only
- 0.35 ACHnat Infiltration (equiv. to blower door test of 7 ACH50)
- 80 AFUE, 14 SEER HVAC
- 72F Heating, 75F Cooling Setpoints

New 1200 ft² House



Same parameters:

- IRC 2018 envelope minimums:
 - R-20 walls | R-49 clg | U-0.32 glazing | slab on grade, perim. insul. only
- 0.35 ACHnat Infiltration
- 80 AFUE, 14 SEER HVAC
- 72F Heating, 75F Cooling Setpoints

How Does Society Perceive Sustainable Technology?

Technology must be:

- **Expensive**
- **Futuristic**
- **Hyperreal**
- **Exclusive**
- **Automated**
- **App Based & Connected**



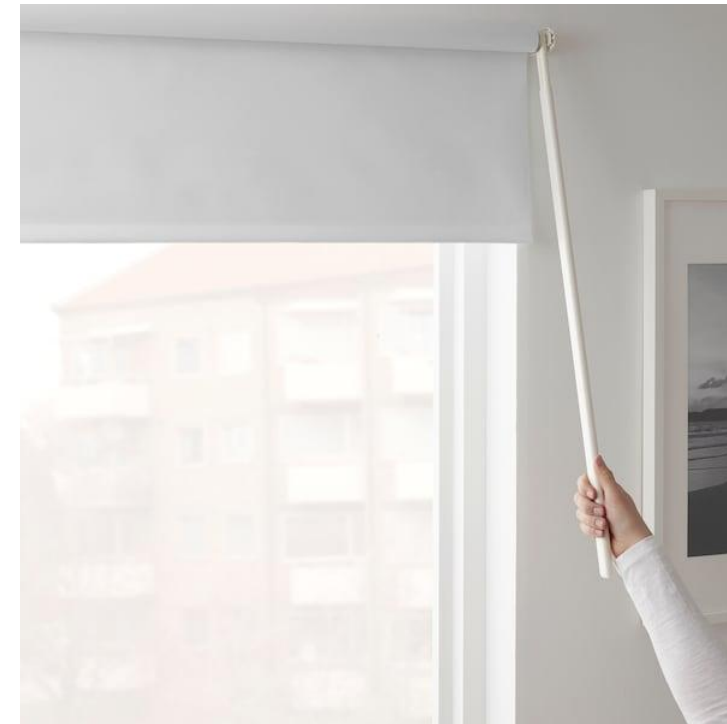
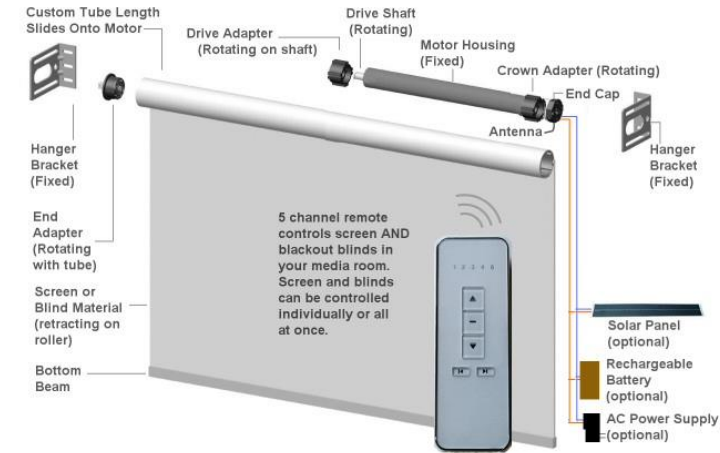
Various DOE Solar Decathlon
Demonstration Homes,
Pre-Local Build Program



Defining Lean Technology

Lean Tech is...

- **Simple**
- **Functional**
- **Accessible and Inexpensive**
- **Resilient**
- **Serviceable**
- **User- and Occupant-Focused**
- **Compatible w/ Daily Life**
- **Builds Awareness, Understanding, and Knowledge**
- **Nature-revealing (vs. nature-rejecting)**



Economics of Sustainable Technology

High Cost

Affordable

Slow/Boring

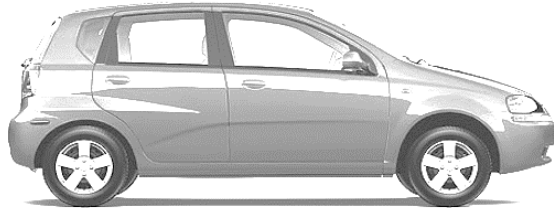
**Low Performance,
High Cost**

**REALLY
BAD**



1985 Cimarron
The Cadillac of smaller cars
Best of all...it's a Cadillac.

**Low Performance,
Affordable**



Fast/Fun

**High Performance,
High Cost**



**High Performance,
Affordable**



DIFFICULT BUT POSSIBLE

Design challenge: making something affordable and great.

Economics of Sustainable Technology

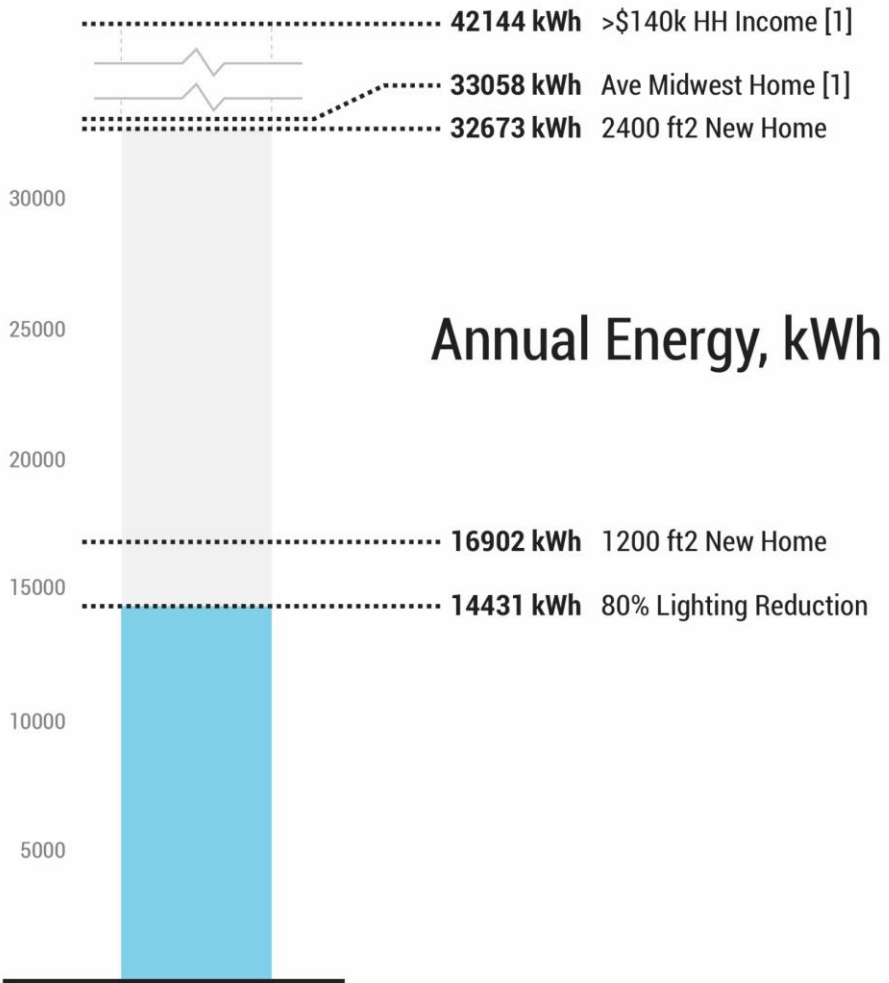
	High Cost	Affordable
Low Performance	<p>Low Performance, High Cost</p> <p>REALLY BAD</p> 	<p>Low Performance, Affordable</p> 
H-P, Net Zero	<p>High Performance, High Cost</p>  <p>High Tech</p>	<p>High Performance, Affordable</p>  <p>DIFFICULT BUT POSSIBLE</p> <p>Lean Tech</p>

Design challenge: making something affordable and great.

Can we do this with high-performance homes? YES WE CAN!

Getting to Net Zero with Lean Tech

80% Lighting Energy Reduction

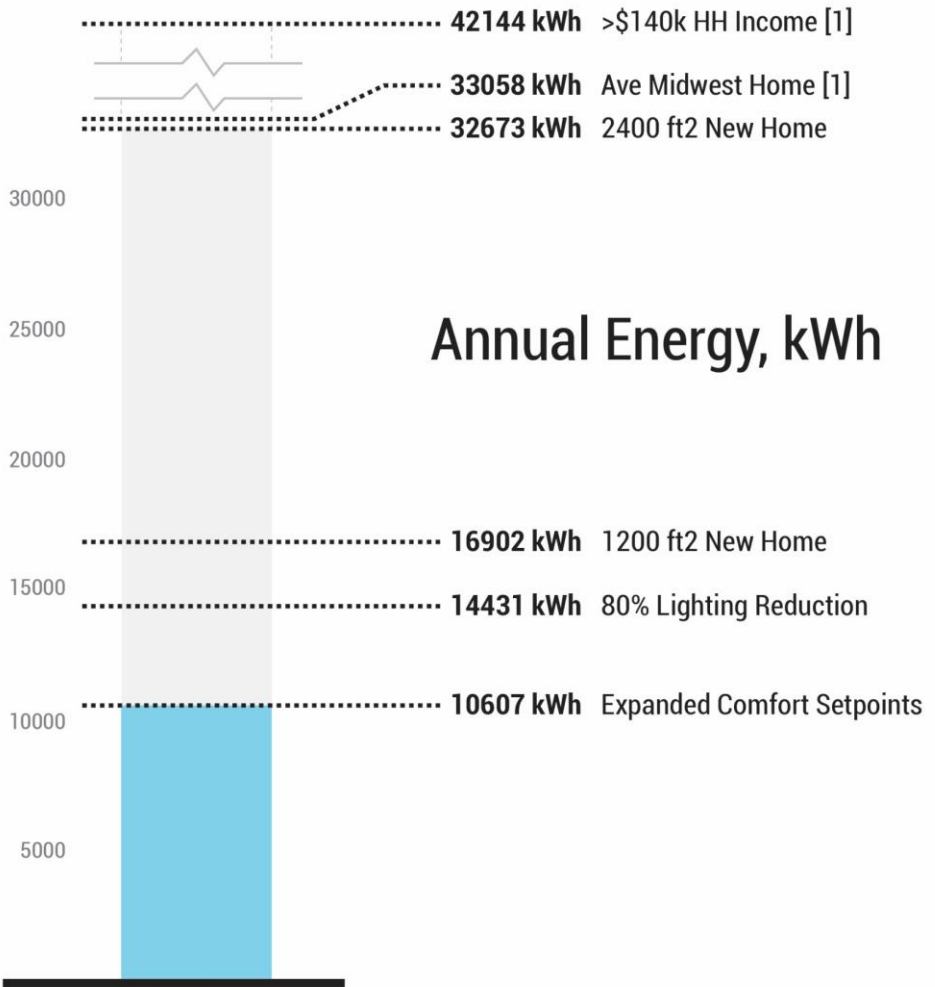


- Implement **Daylighting**
- Appropriate **Solar Control**
- Switch to **all-LED Lighting**
- Use **Low Ambient and Task Lighting Strategies**
- Design with task and contrast in mind
- Reconsider Landscape Lighting and other “**accent lighting**” unless solar powered or necessary for safety

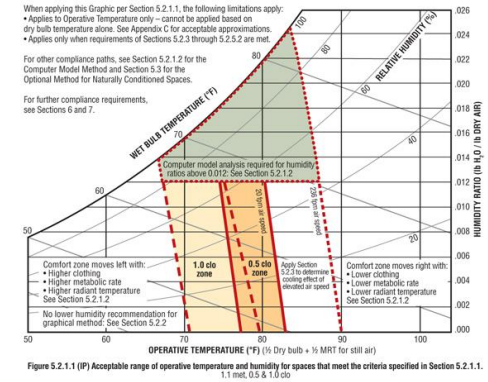


Getting to Net Zero with Lean Tech

Expanded Comfort Setpoints



- **68F winter setpoint w/ 66F setback**
- **80F summer setpoint**
- **Wear climate-adapted clothing**
- **Acclimate:** spend time outside
- **Elevate air speed w/ NV and fans in summer**
- **Climate Consultant:** excellent tool to review comfort model
- **Bigger comfort zone = less HVAC energy**



75°F
 The 'traditional' all-season thermostat setting. Very inefficient.

68°F
 Most people are comfortable at this temp in winter if they wear appropriate clothing and are healthy.

66°F
 People feel comfortable sleeping at this temperature.

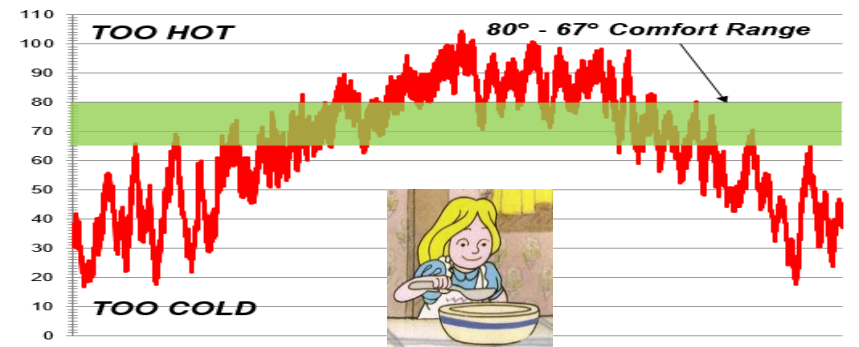
78°F
 A more efficient summer setting that still keeps people comfortable even with humidity.

80°F
 With low humidity (<50RH) and appropriate summer clothes, most people are comfortable at this temp.

85°F +
 With air circulation (fans) people can remain comfortable.

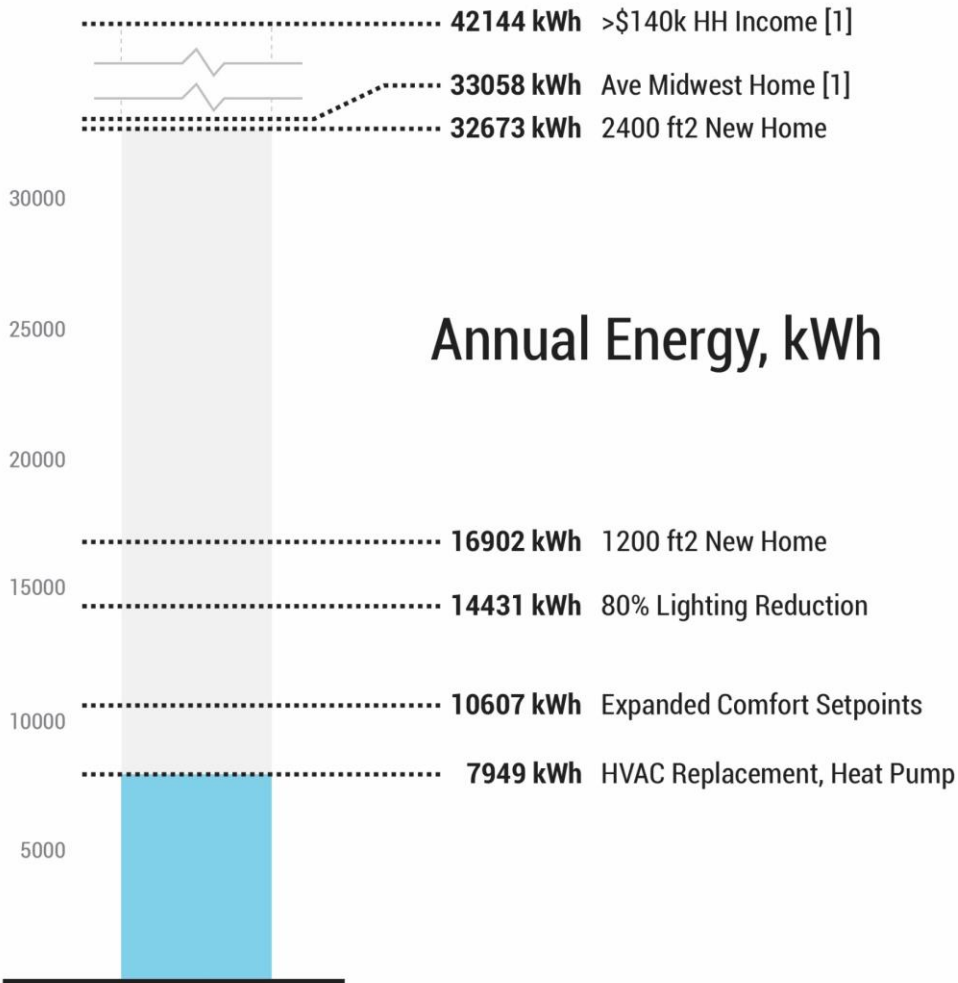
Rule of thumb for small buildings in mixed-climate U.S. a 1F change in thermostat is about 3% change in heating or cooling costs.

In between 68 and 78 most people feel comfortable

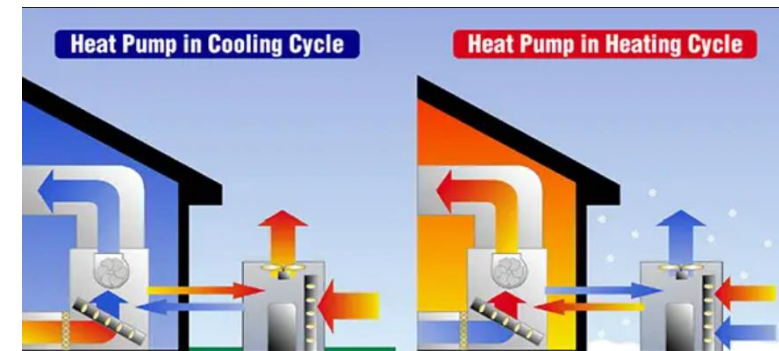


Getting to Net Zero with Lean Tech

HVAC Replacement with Air Source Heat Pump

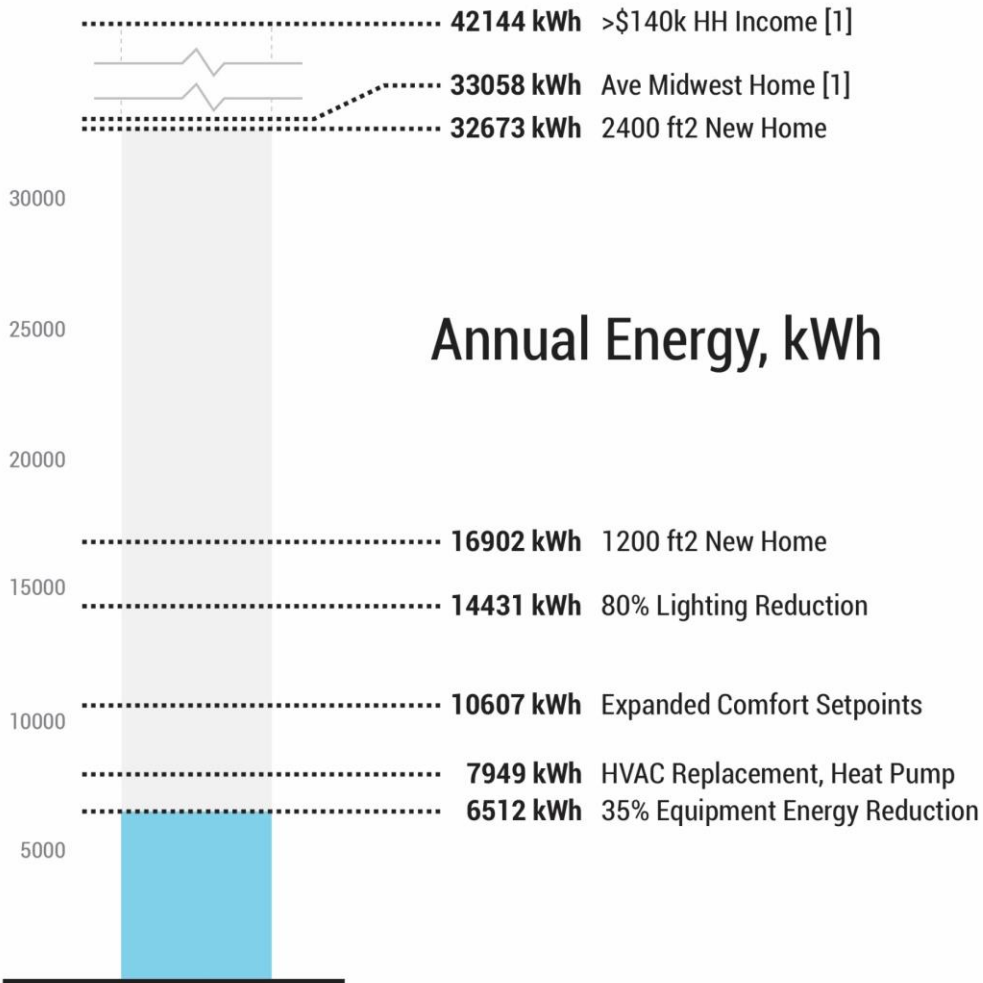


- Air source **heat pump**: functionally similar to conventional AC
- Great fit for **low-load** home
- **Useful heating capacity down to 0F**, backup heat is inexpensive safety net
- **New tech**: variable refrigerant, variable speed to respond to load.
- **Reverse cycling** for frost-prevention.
- Modeled efficiencies: 13.6 HSPF derated to 7.5, 18 SEER



Getting to Net Zero with Lean Tech

35% Equipment Energy Reduction



- **Equipment energy** is unavoidable in a home...often the largest energy user in an efficient home.
- **EnergyStar appliances** and **improved water heating** can make a reasonable impact on equipment energy.
- Users must be open to **changing expectations & habits**
- Beware of **“energy hogs”**
- **Vampire loads** typically 10% of household electricity.
- **Water is energy too!**

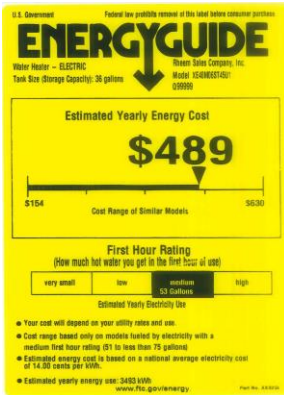


Getting to Net Zero with Lean Tech

Water Heating Sidebar

**Electric 40 Gal. Water Heater:
3493 kWh est. annual E usage!**

Rheem
Performance 40 Gal. Medium 6 Year 4500/4500-Watt Elements
Electric Tank Water Heater



\$400 (equip)

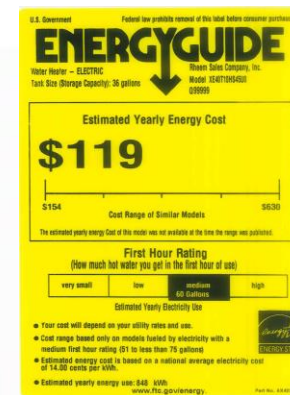
**Hybrid (Heat Pump) 40 Gal. Water Heater:
848 kWh est. annual E usage, but with
some special installation criteria**

Rheem
ProTerra 40 Gal. 10-Year Hybrid High Efficiency Smart Tank
Electric Water Heater with Leak Detection & Auto Shutoff

★★★★☆ (2529) Questions & Answers (1202)



\$2000+ (equip)



**18kW Tankless Electric Water Heater:
1095 kWh est. annual E usage.
1 gpm shower heads w/ whole house
pressure regulation @ 60 psi,
20 min/day utilization assumed.**

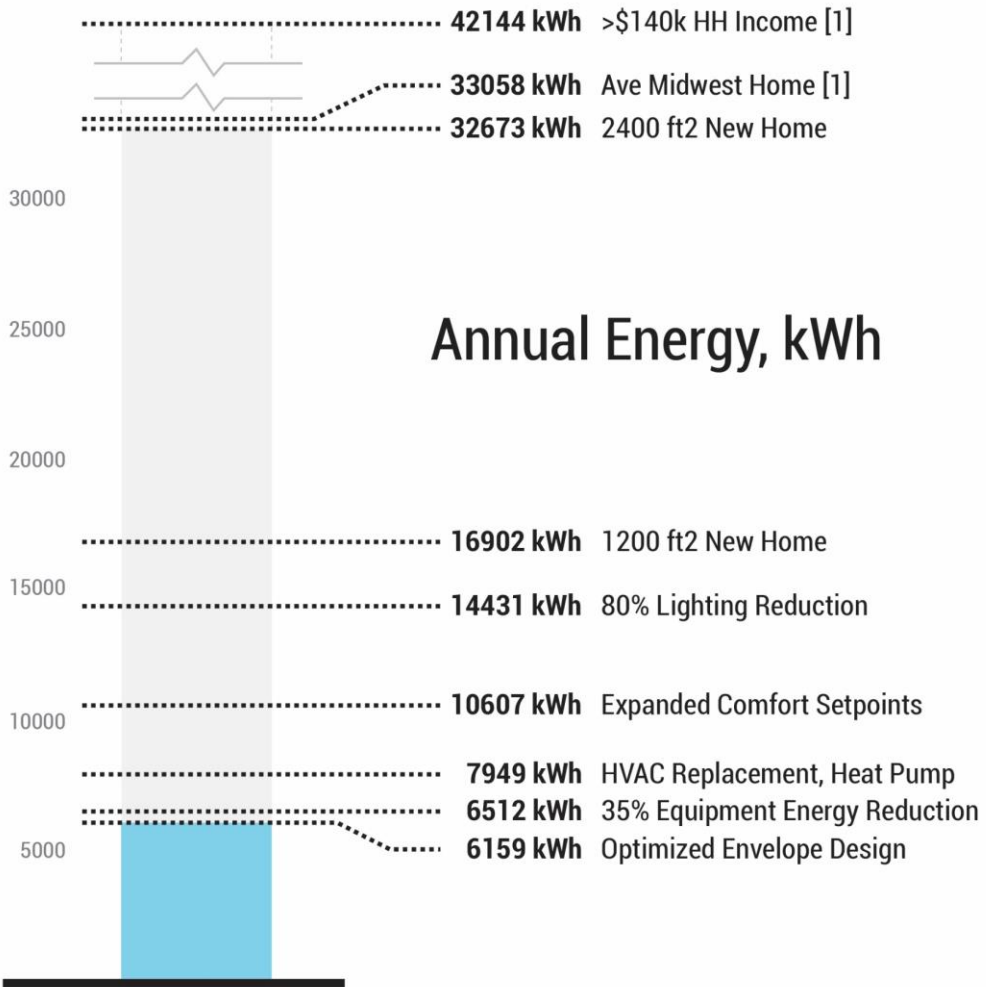
EcoSmart
ECO 18 Tankless Electric Water Heater 18 kW 240 V



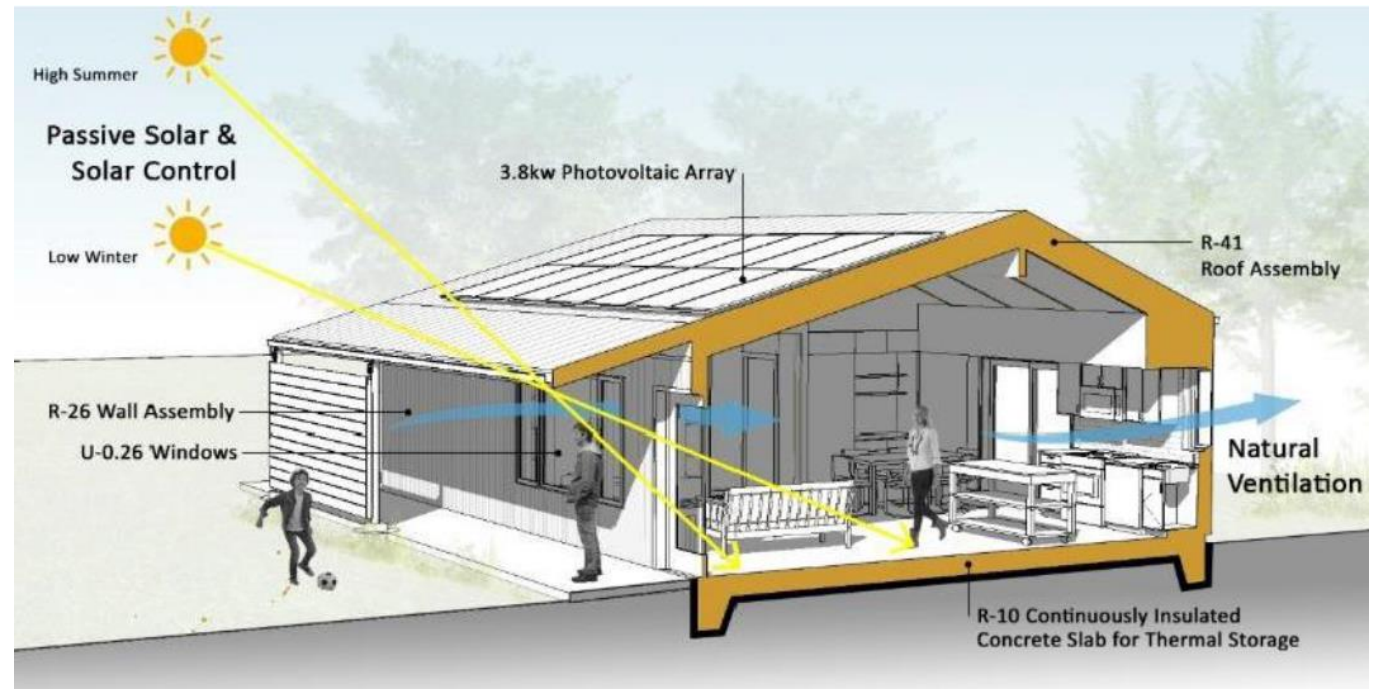
\$440 (equip)

Getting to Net Zero with Lean Tech

Optimized Envelope Design

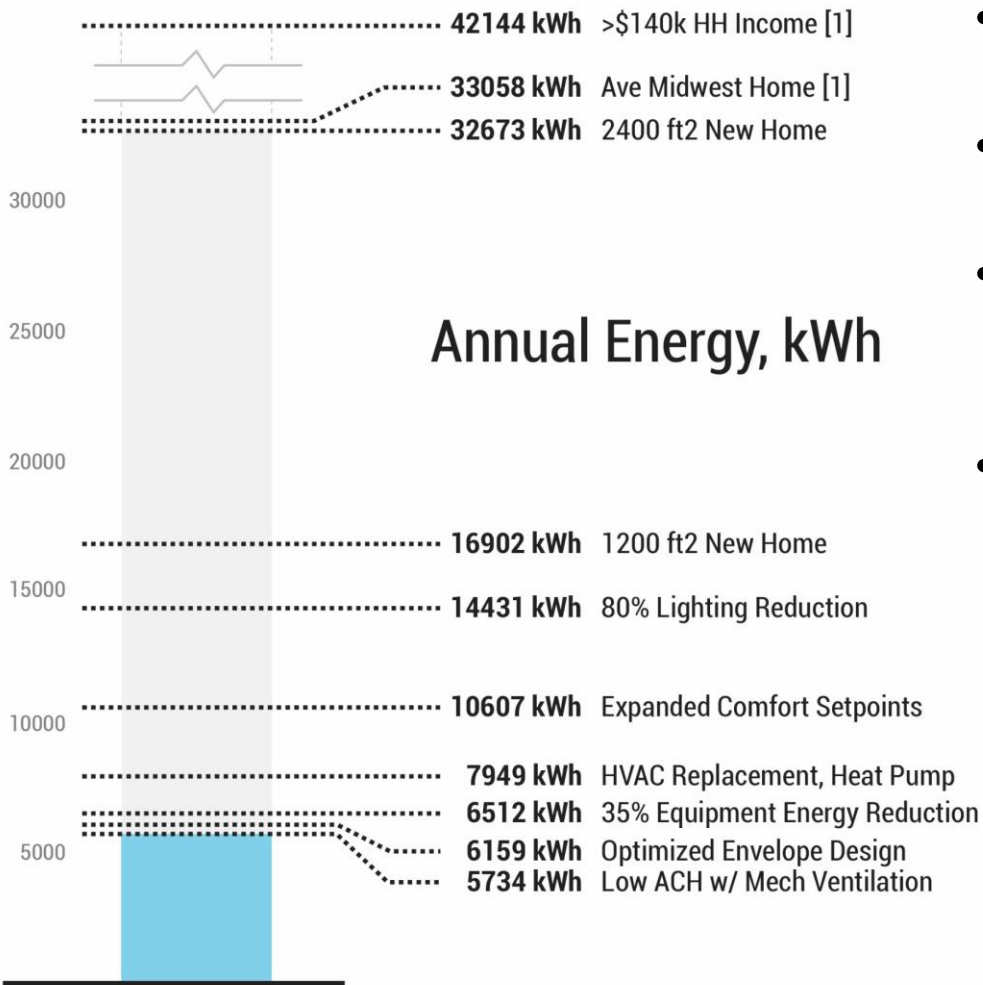


- Continuous R-10 slab insulation
- R-14 + R-13 c.i. walls | R-32 + R-15 c.i. roof/clg | U-0.269 double glazing w/ low-E and Argon
- Modest passive solar heating strategy
- Sun shading in overheated months
- Sensible daylight and natural ventilation improvements



Getting to Net Zero with Lean Tech

Low Infiltration w/ Mechanical Ventilation

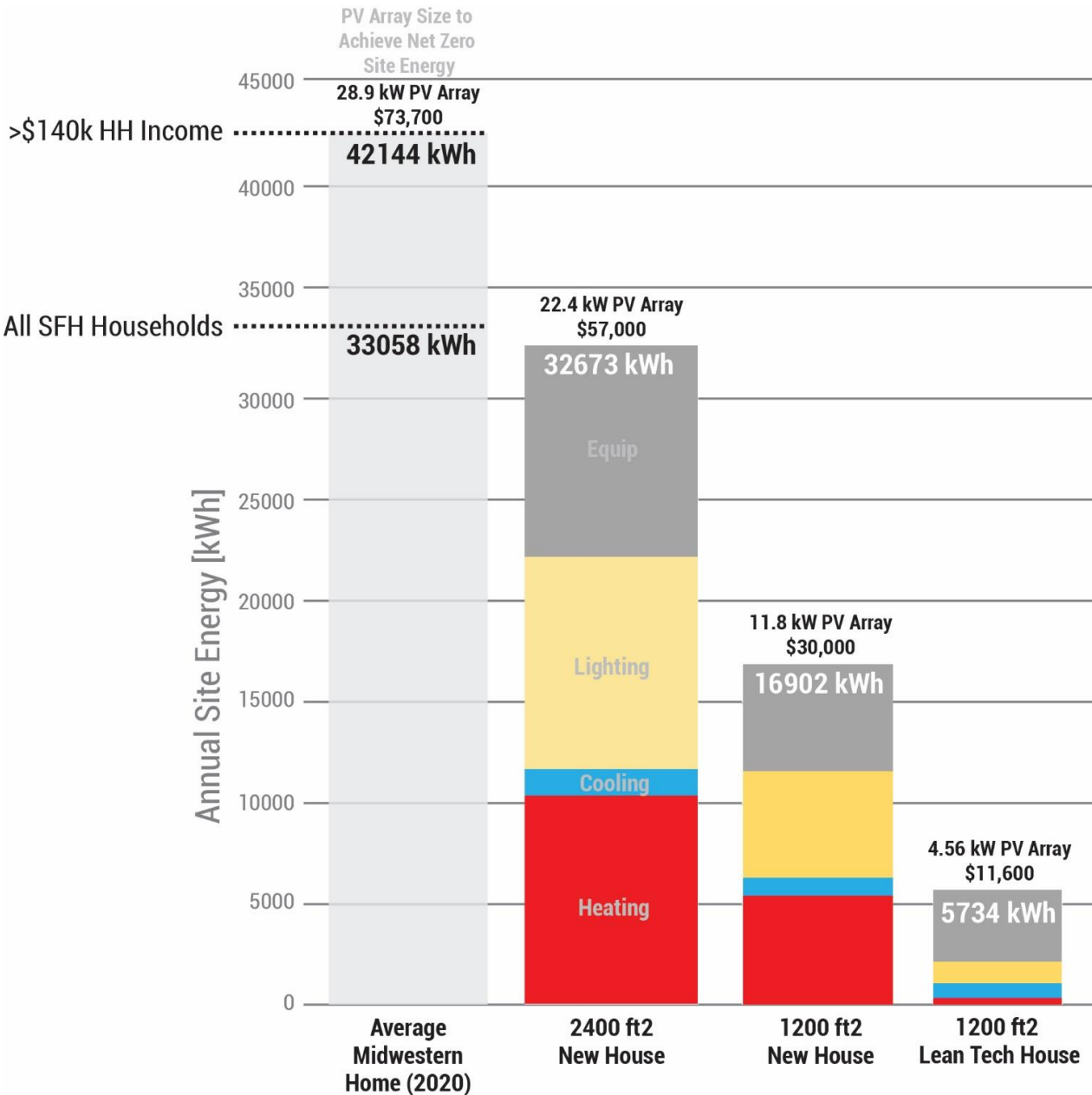


- Achieving low infiltration is a “system” that takes planning, not an afterthought
- Model assumes ACH50 of 1.25, or ACHnat of 0.0625
- Ventilation gains/losses from full-time ERV added for an average infiltration rate of 0.17 ACHnat
- Most chances for success:
 - Rigid, continuous air barrier systems
 - Reasonable taping & sealing strategy
 - Minimize penetrations
 - Blower door testing during construction to find leaks



A Lean Tech House:

St. John Net Zero Prototype
KSU Net Positive Studio (2021)



A Lean Tech House:

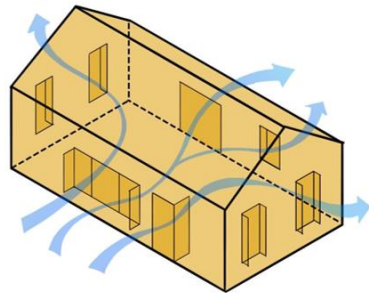
St. John Net Zero Prototype
KSU Net Positive Studio (2021)



A Lean Tech House:

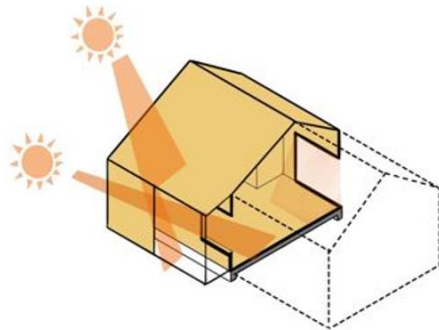
St. John Net Zero Prototype KSU Net Positive Studio (2021)

Passive Design Strategies



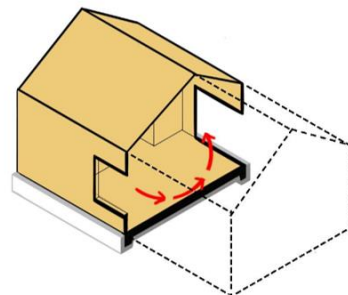
Passive Cooling: Cross Ventilation

Using plentiful local wind reduces need for A/C



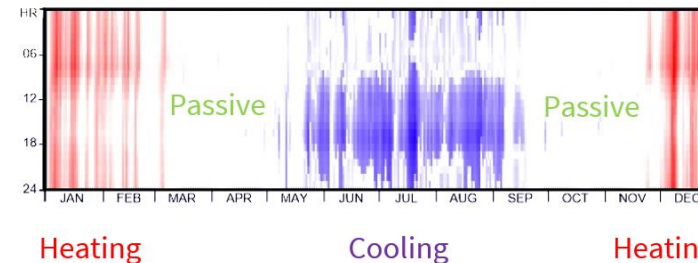
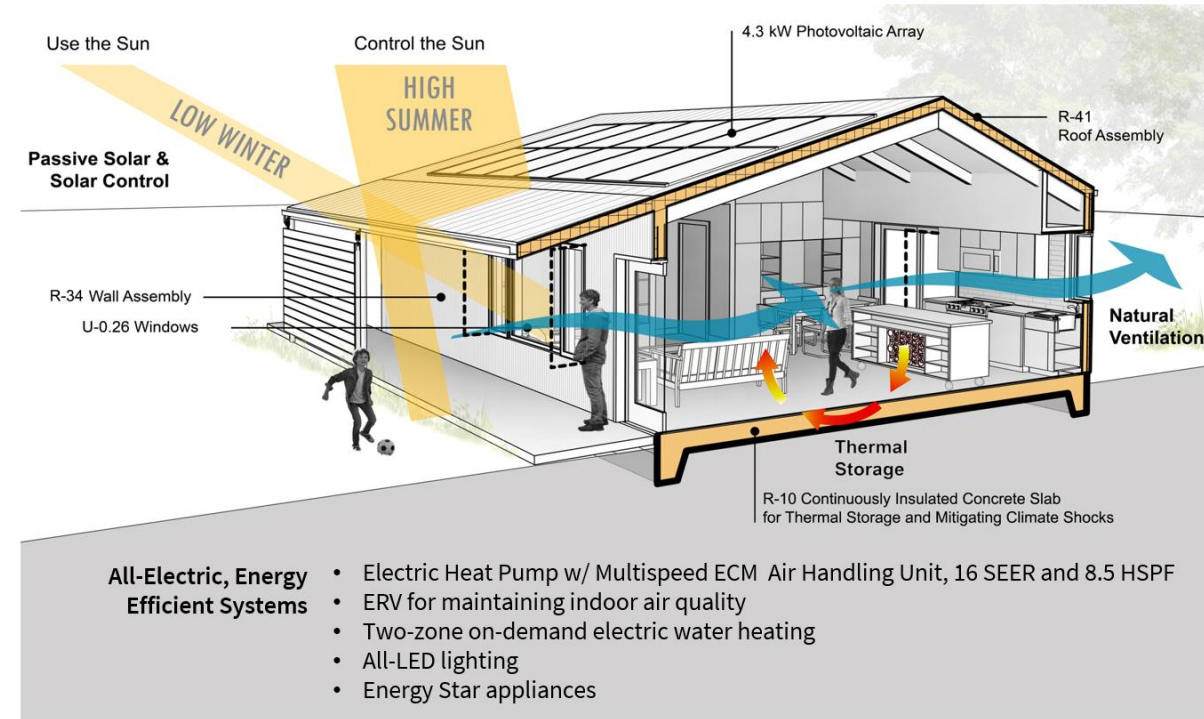
Daylighting, Shading, & Passive Solar Heating

Blocking high summer sun and bringing in low winter sun reduces heat and cooling loads, while daylight reduces electric lighting dependence and cooling demand.



Thermal Mass

Insulated mass in the floor tempers thermal extremes in summer and winter.



Energy Performance

EUI: 17.9 kBtu/SF per year
Annual Energy: 5,625 kWh*
** 78% less than typical new construction*
Passive Hours: 56% annually
HVAC not required for comfort



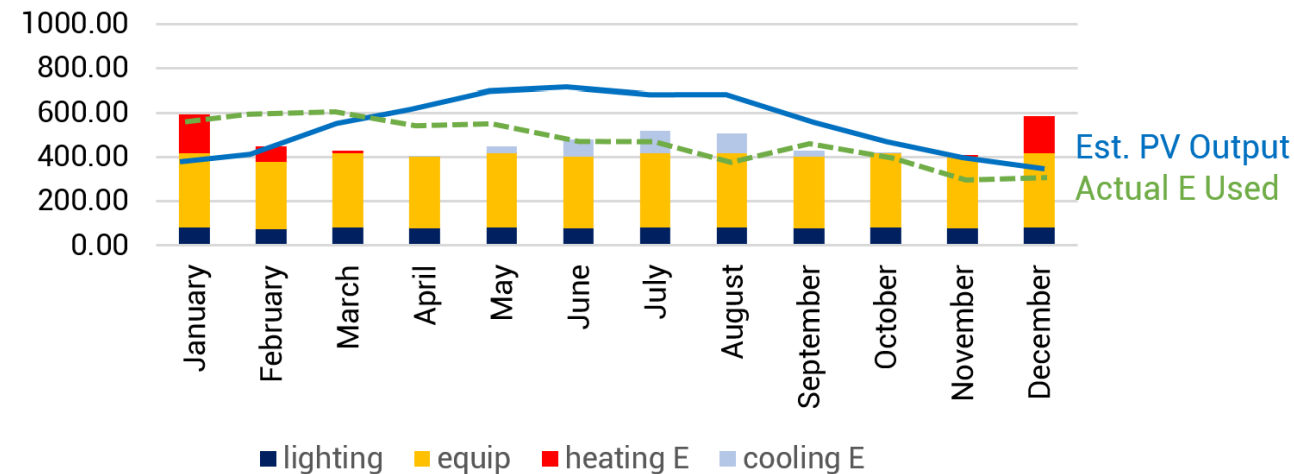
A Lean Tech House:

St. John Net Zero Prototype
KSU Net Positive Studio (2021)



Estimated Energy, Actual Energy, and PV Production

A 4.3 kW PV array produces an estimated 6621 kWh of electricity per year with a retail value of \$881: **more than enough energy to offset the home's annual energy use, including energy for heating and cooling.**



Lean Tech Summary

Thermal Comfort

Efficient, climate-adapted setpoints save energy while robust envelope prevents comfort issues.

Efficient Lighting & Equipment

80% reduction in lighting w/ LEDs and daylighting; 35% reduction in equipment energy with efficient appliances and water heating.

Affordable PV Array

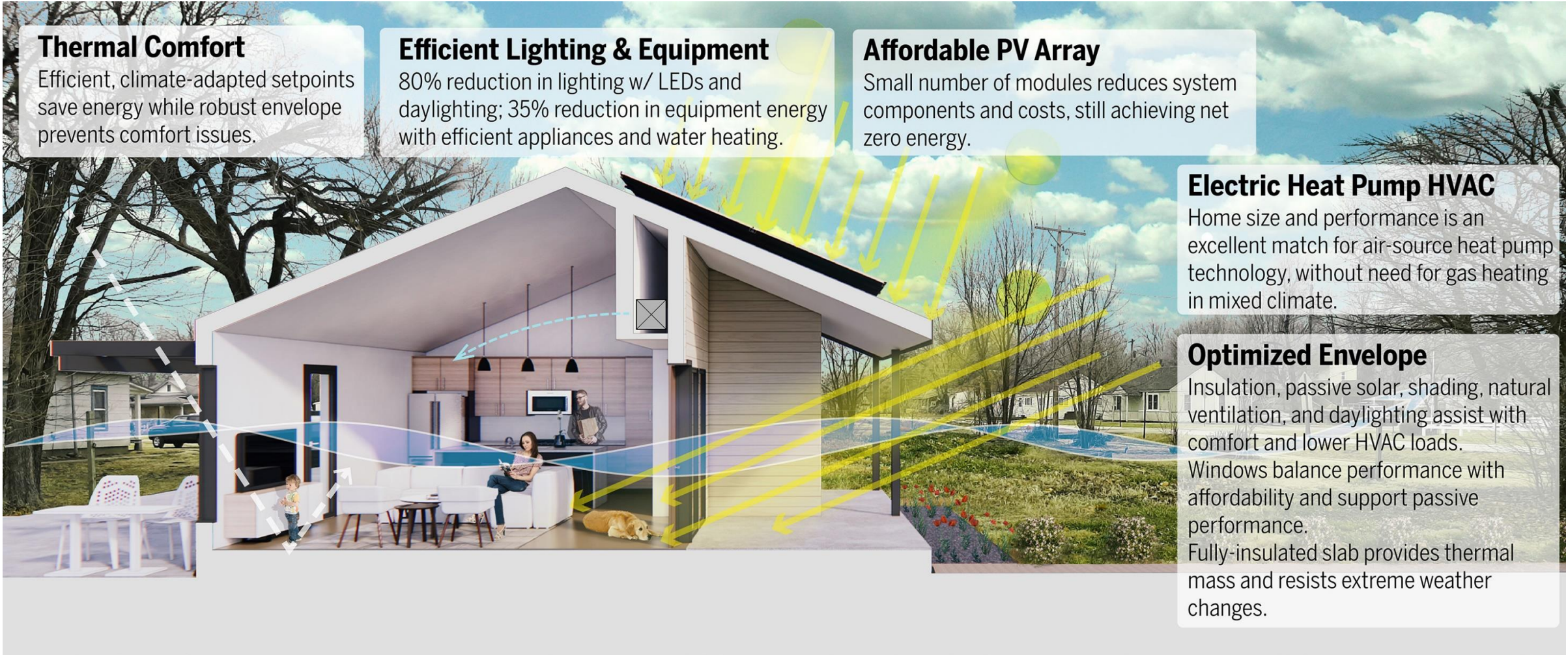
Small number of modules reduces system components and costs, still achieving net zero energy.

Electric Heat Pump HVAC

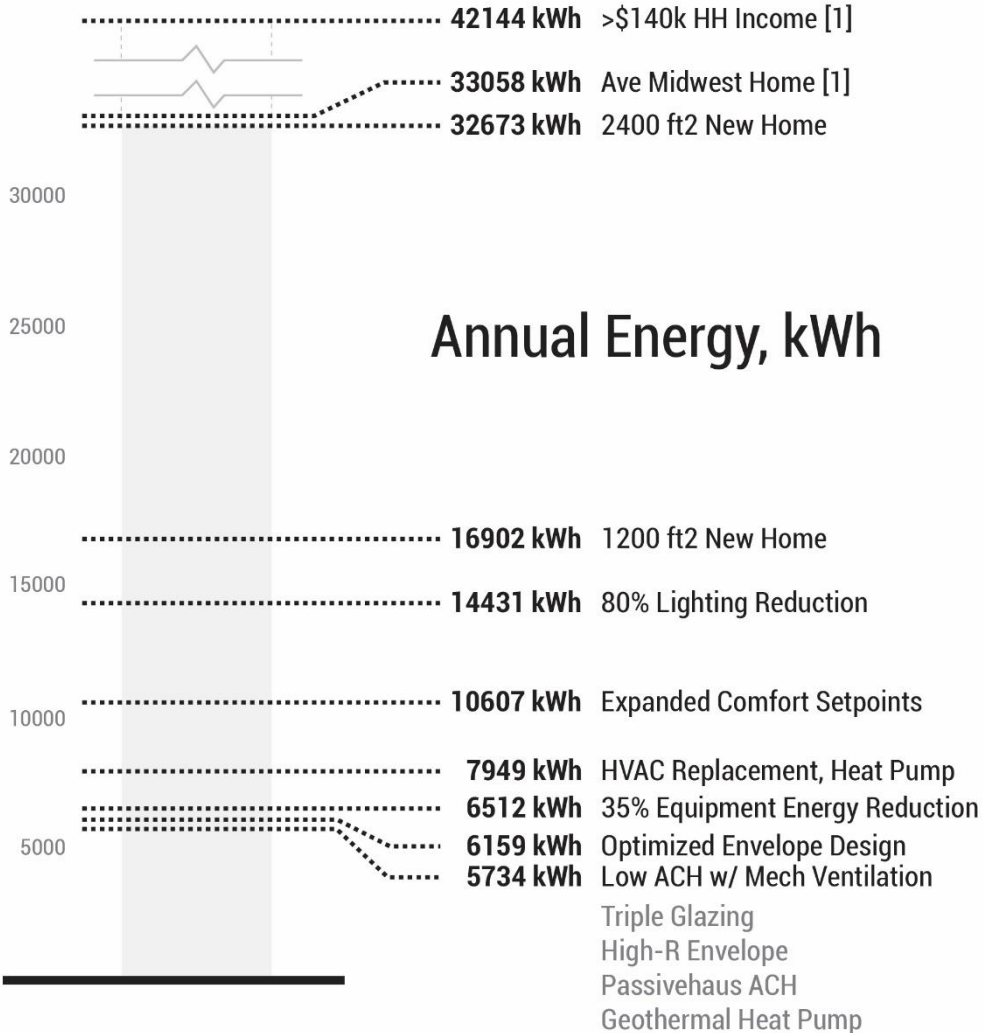
Home size and performance is an excellent match for air-source heat pump technology, without need for gas heating in mixed climate.

Optimized Envelope

Insulation, passive solar, shading, natural ventilation, and daylighting assist with comfort and lower HVAC loads. Windows balance performance with affordability and support passive performance. Fully-insulated slab provides thermal mass and resists extreme weather changes.



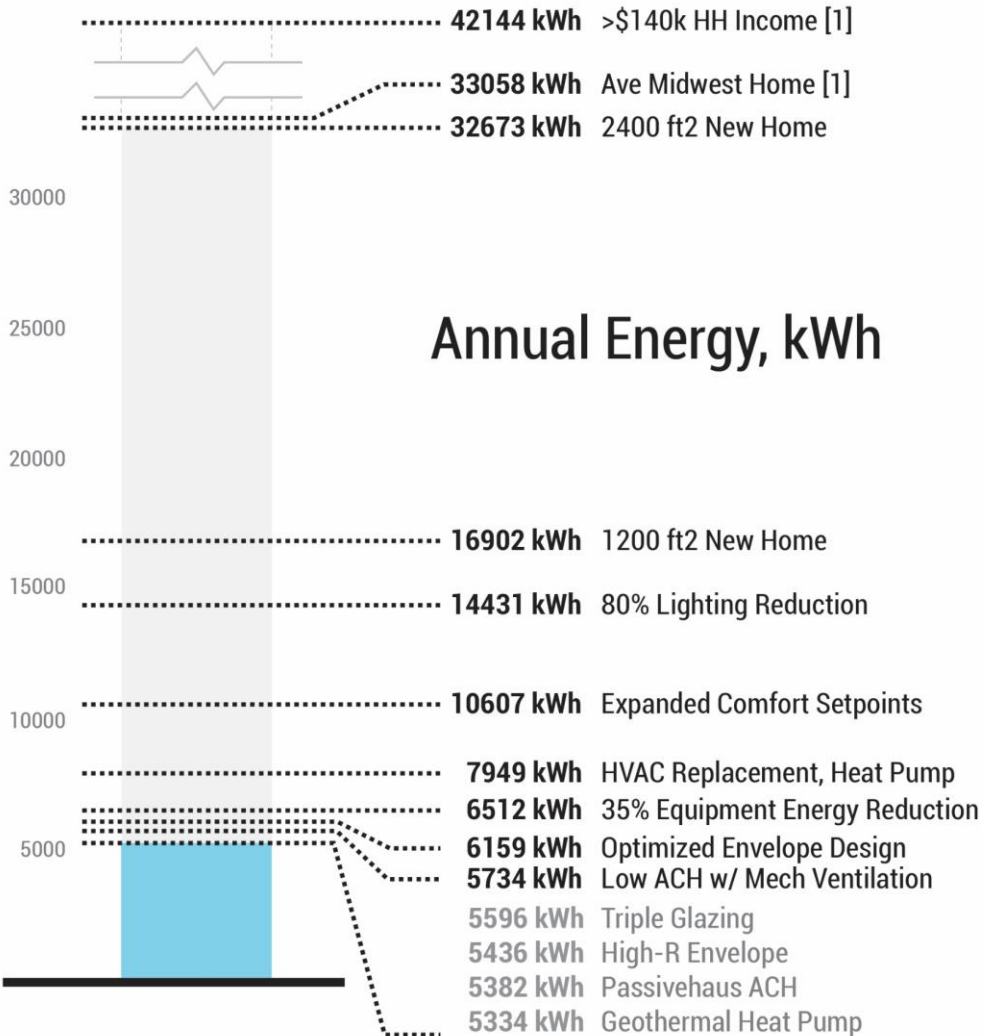
Bring on the (Expensive) Tech



- **Triple Glazing:** U-0.144, state-of-the art windows
- **Very thick insulation:** R-40 walls | R-70 ceiling
- **Passivehaus airtightness** of 0.06 ACH50, equivalent to 0.11 ACHnat w/ ERV
- HVAC system replaced with **ground source heat pump**, with a COP of 4.0

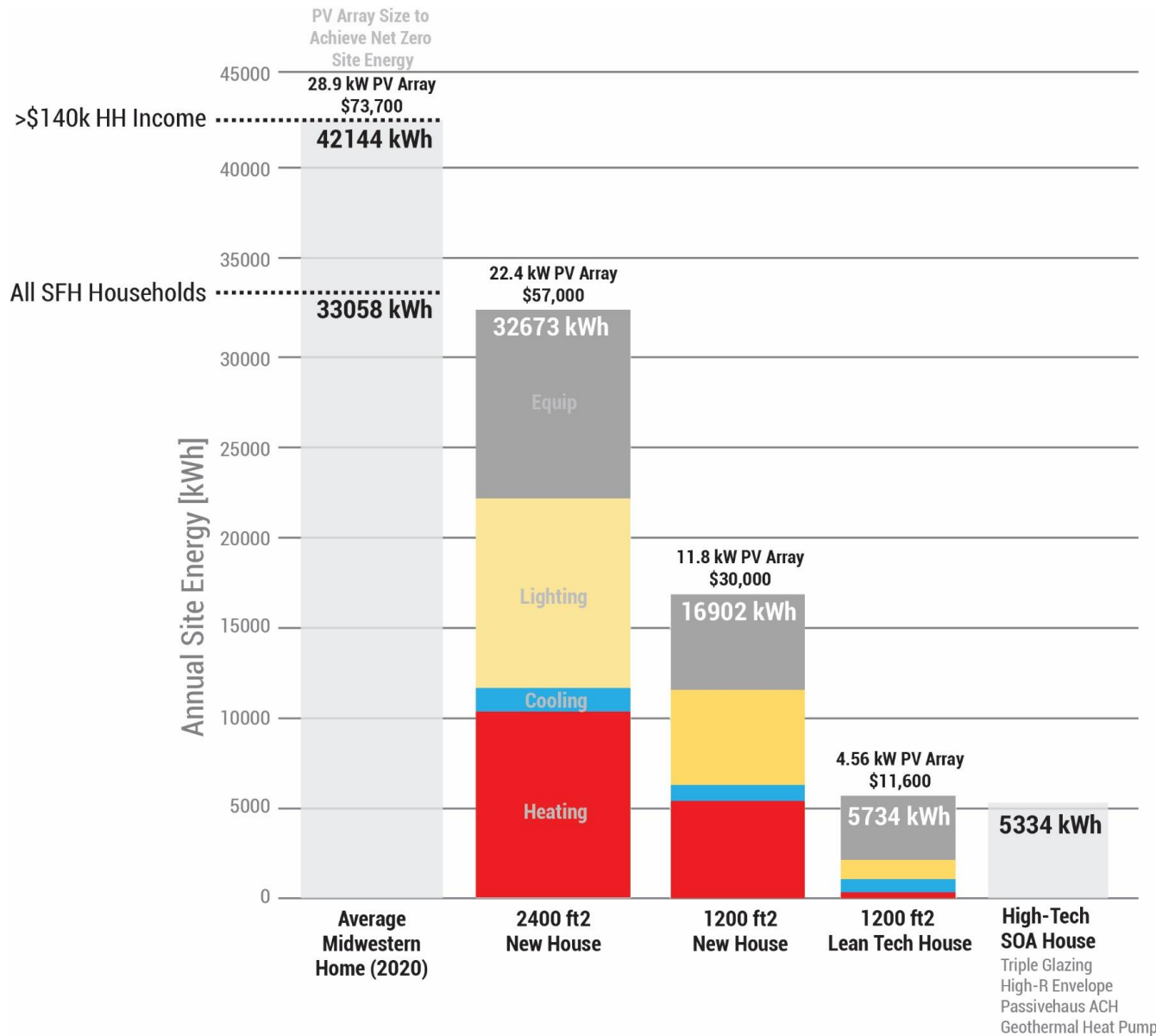


Bring on the (Expensive) Tech



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A High-Tech, State of the Art House is only about 5% more energy efficient than the Lean Tech house...



...and would achieve net zero energy with the same PV system.

Conclusions

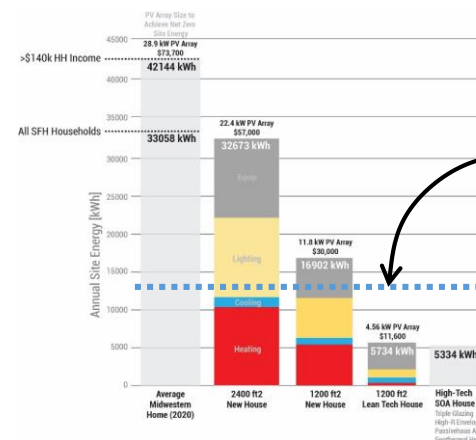
- To build most (all) new homes net zero, accessibility to net zero must be increased while using good design, engineering, and building methods to get there in a sensible way.
- Say “yes” to net zero: it isn't necessarily easy, but it shouldn't be hard or out of reach either.
- Societal impact must be valued over exclusive innovation: 1000s of Mini Coopers vs. a few Ferraris.
- People and our behavior are important! Not just technology!



How to Do Better at Home...

Occupant Factors: YOU! And also FREE!

- Connect w/ Outdoors: acclimate, expand sensory experience
- Use Daylight
- Natural Ventilation
- Climate Adaptive Thermal Control
- Plug Load Reduction
- Conserve Hot Water Utilization
- Adaptation + Positive Habits



Gibson Household:
13,628 kWh Annual E (2021)

How to Do Better at Home...

Invest in systems (stuff that costs \$\$\$)

- Water Pressure Reduction: 50 psi @ shutoff, 1.5 GPM @ showers
- LED Electric Lighting
- Energy Efficient Appliances + Water Heating
- Envelope Improvements: insulation, airtightness, better windows
- Improved HVAC and Ventilation

