Workshop on Ambient Energy for Buildings: Beyond Energy Efficiency

DOE HQ 12-13 July 2023

37 architects, engineers, builders, realtors, social scientists

https://sites.google.com/view/2023-aeb-workshop/home

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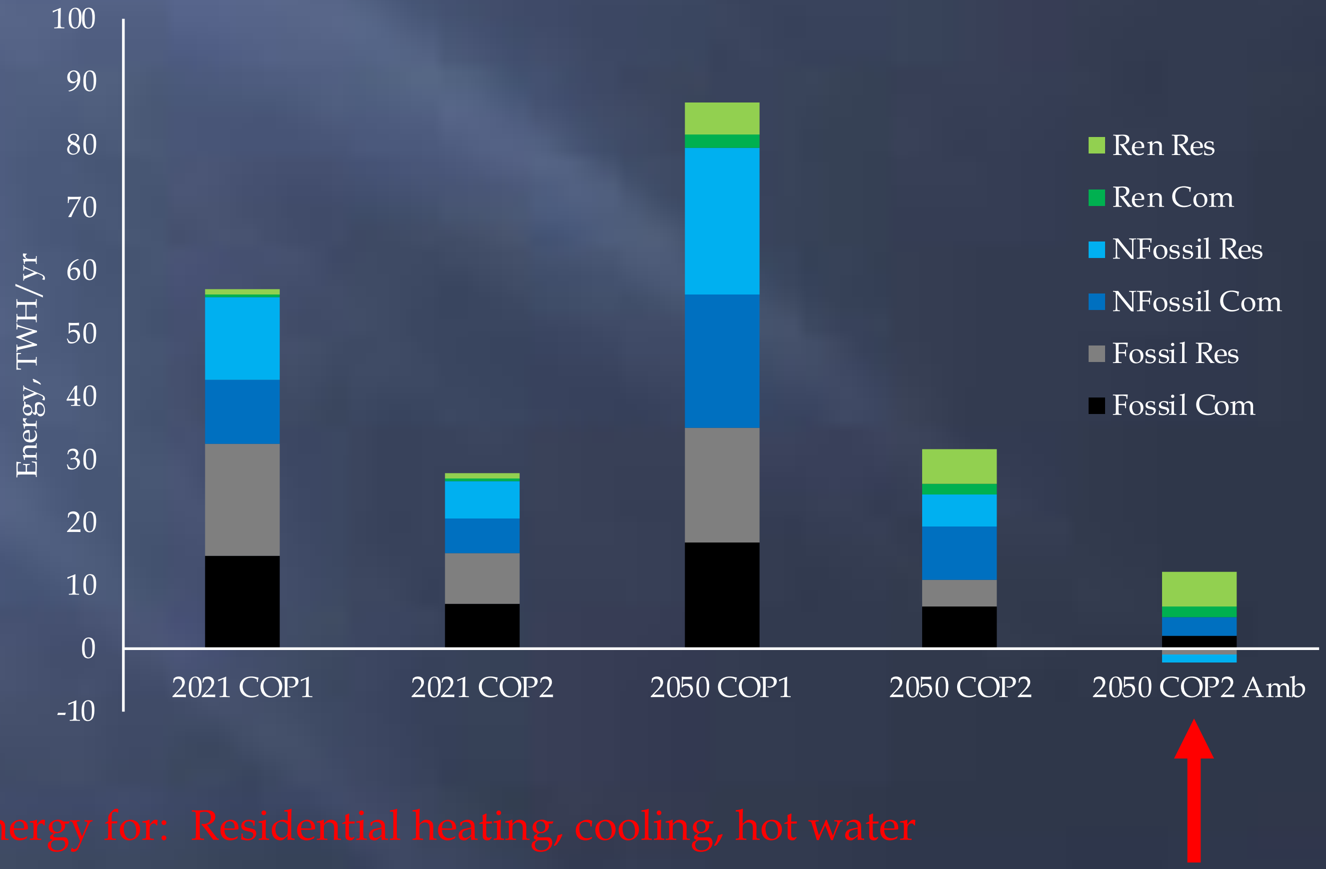
Projection from Current Trends

Assumptions: Fossil-derived electricity decreases from 60% (2021) to 44% (2050) [EIA]

Built floor area doubles by 2060

On-site PV increases linearly at 2019-2021 rate (22%)



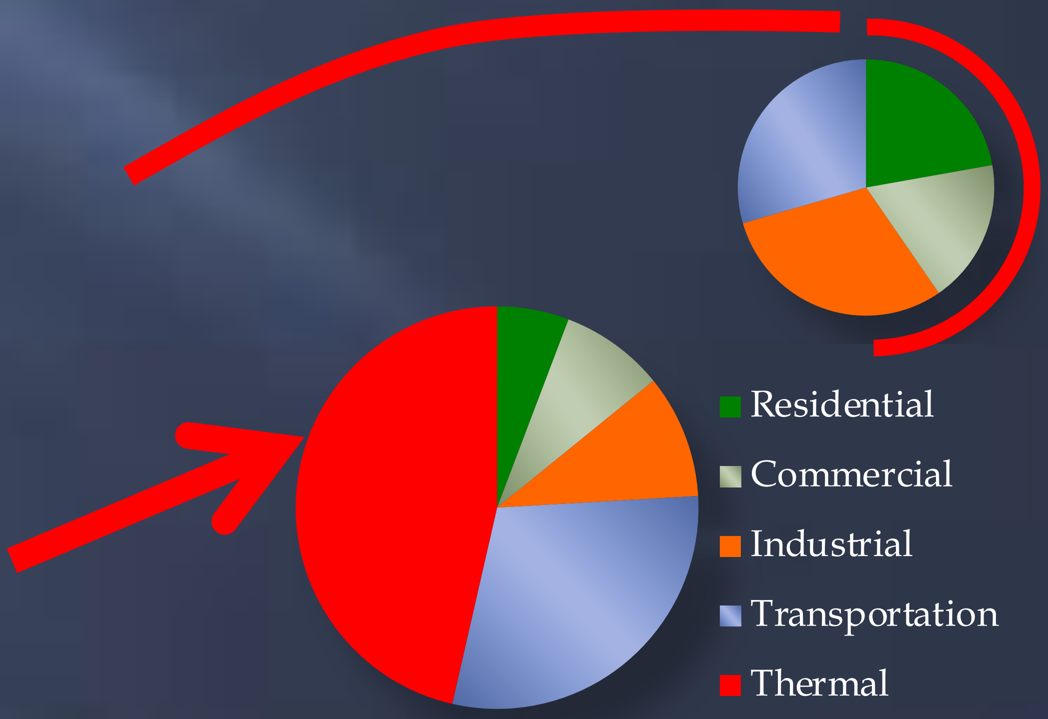
Ambient energy for: Residential heating, cooling, hot water

Commercial heating, cooling, ventilation, lighting

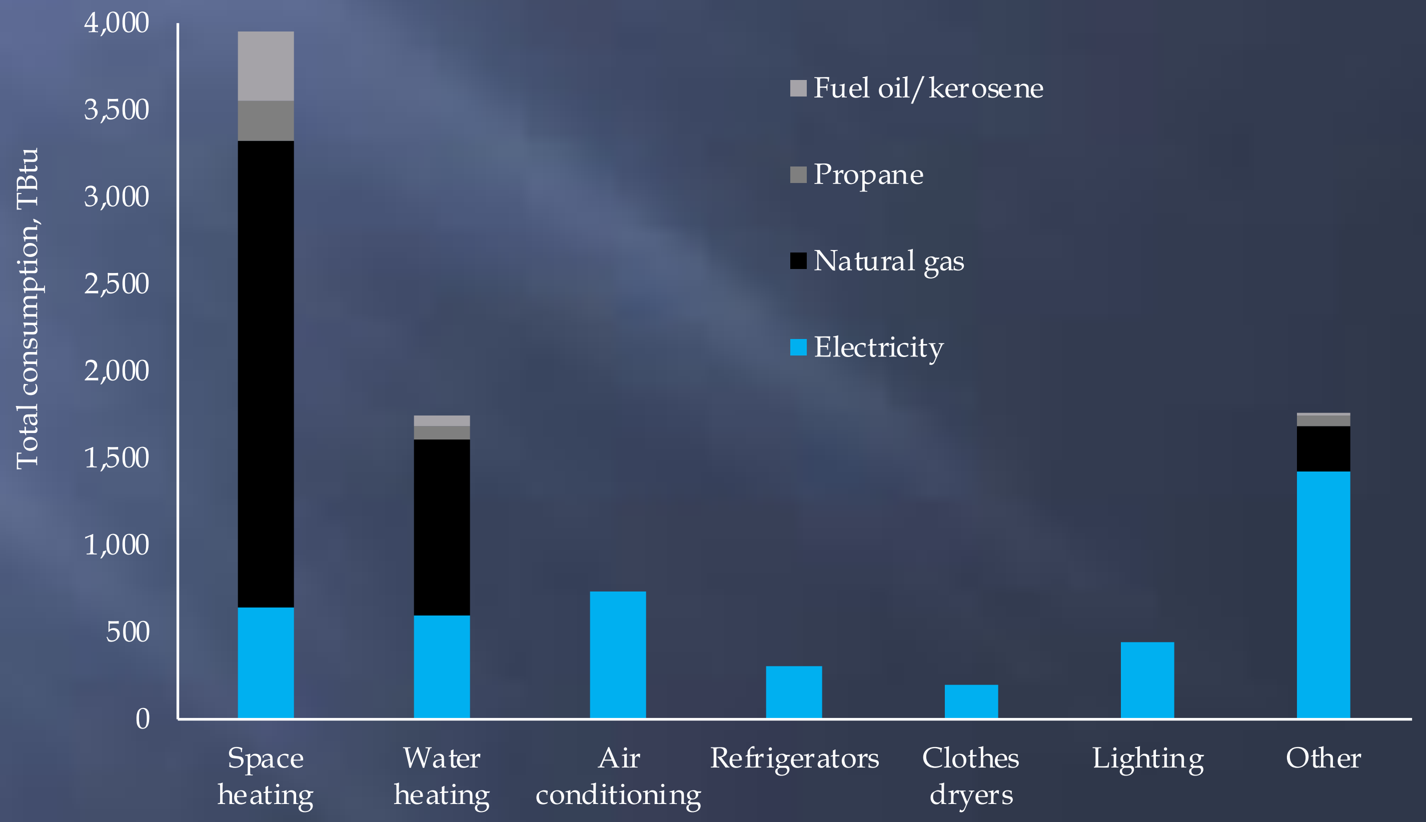
US Energy Use

- 49% of US energy used by buildings,
- → **Buildings must be addressed to meet long-term sustainability goals**

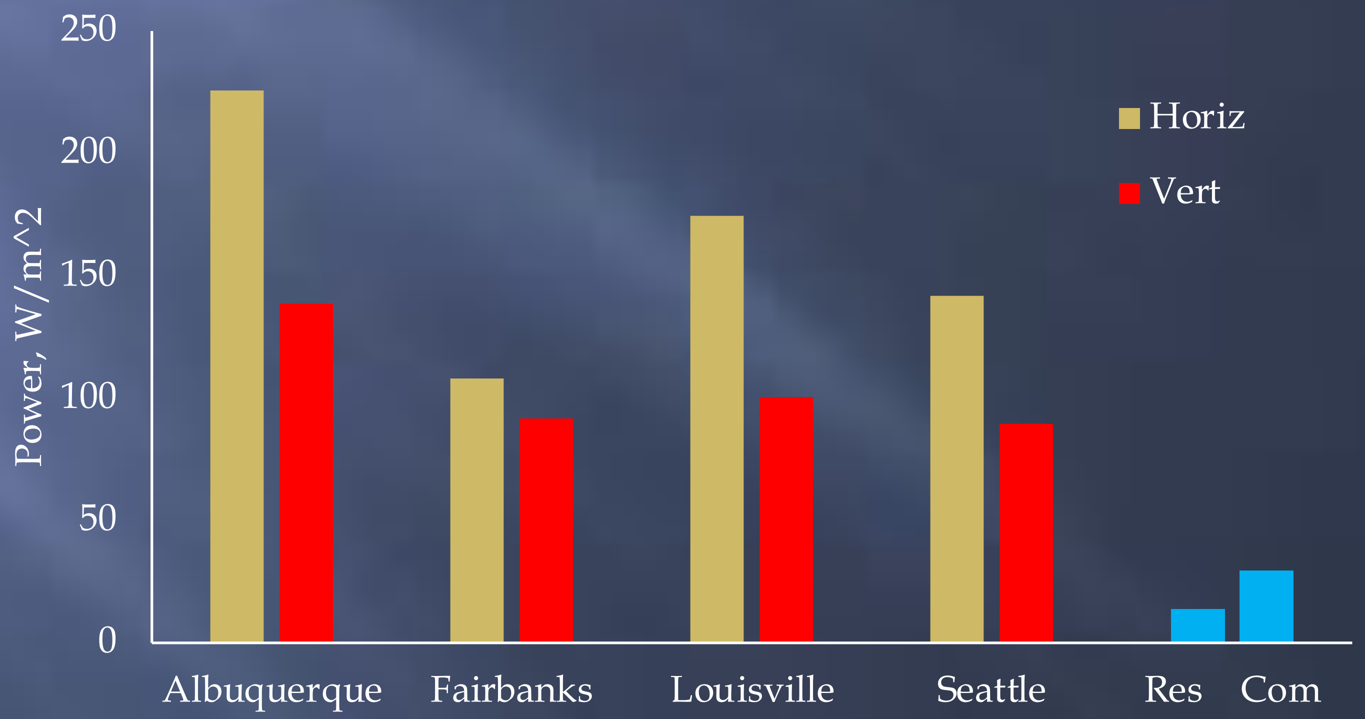
- Nearly half of all energy is used in thermal form
- → **Alternative sources of thermal energy are key**



US annual energy consumption in residential buildings



Solar Potential



Annual average insolation on horizontal and south-facing vertical surfaces compared to mean residential and commercial building energy use rates

Conventional House:

T = *constant* with auxiliary energy

Ambient House:

$T_l \leq T \leq T_h$ with 100% Ambient Energy

Validated ~100% Ambient Conditioning


Telkes 1948 Dover, MA.


Hay 1973 Atascadero, CA.


Shippee 1978 Longmont, CO.


Warren/Saunders 1986 Boxborough, MA.


Riggins/Coleman 2011 Monument, CO.

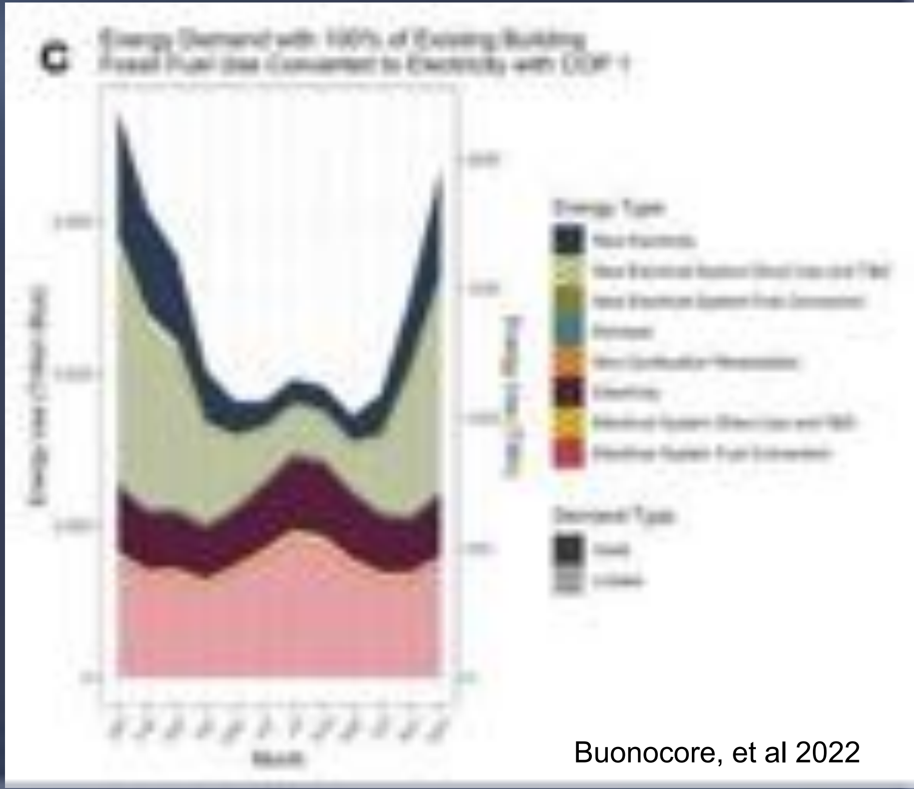

Sharp 2021 Pagosa Springs, CO.

Ambient Conditioning of Buildings is Cheaper

- All-Renewable Electric Cost $3.3T – 7.8T
  - some estimates neglect increase in buildings and expanded transmission, underestimate storage costs (Chu, Gates)
  - Seasonal variability doubles peak demand

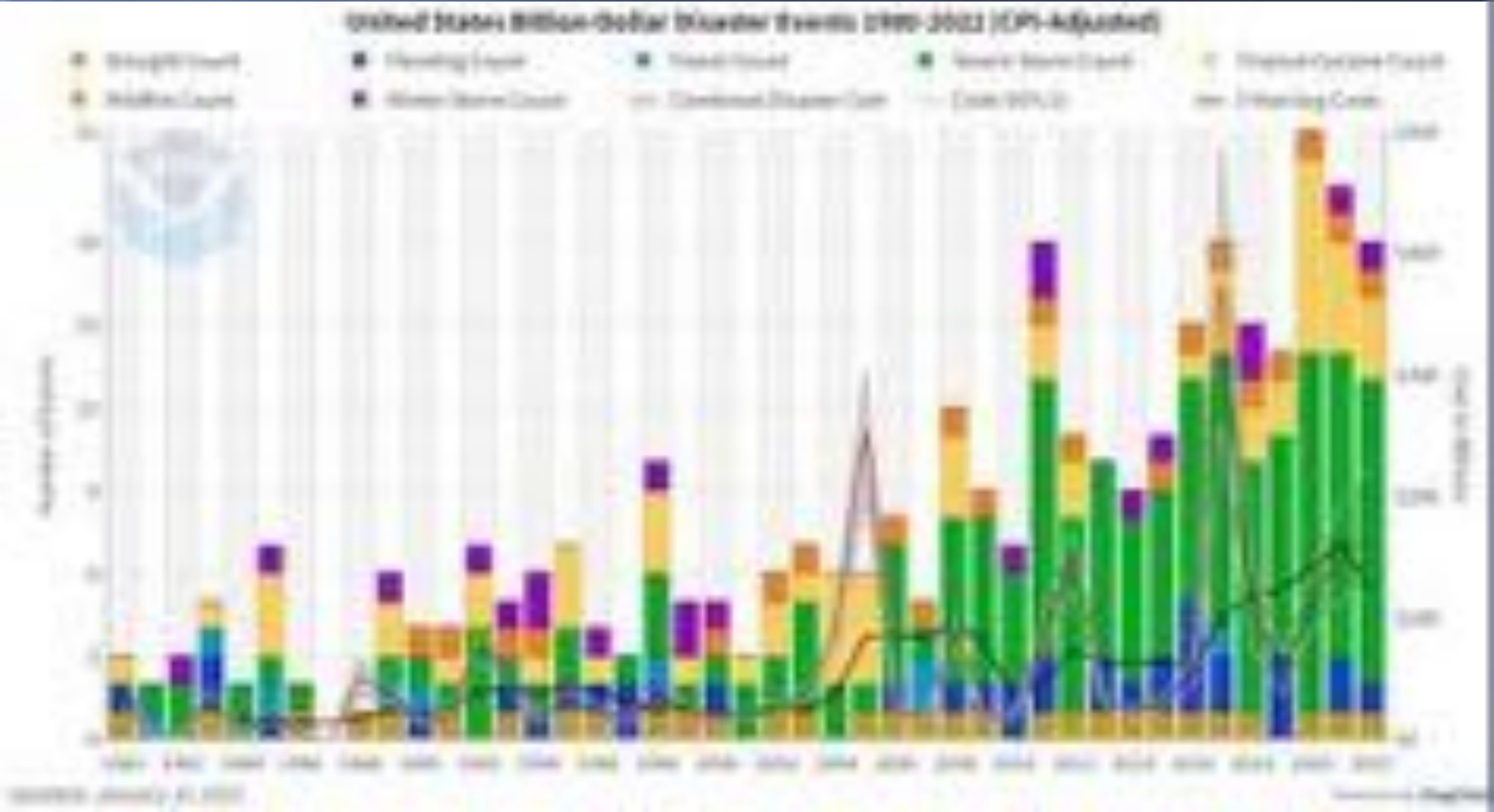
- Heating and cooling of buildings (25% of total)
  - $8T*0.25/140M buildings = $14k/building

- Riggins house
  - ~100% heating and cooling for ~$5k



Buonocore, et al 2022

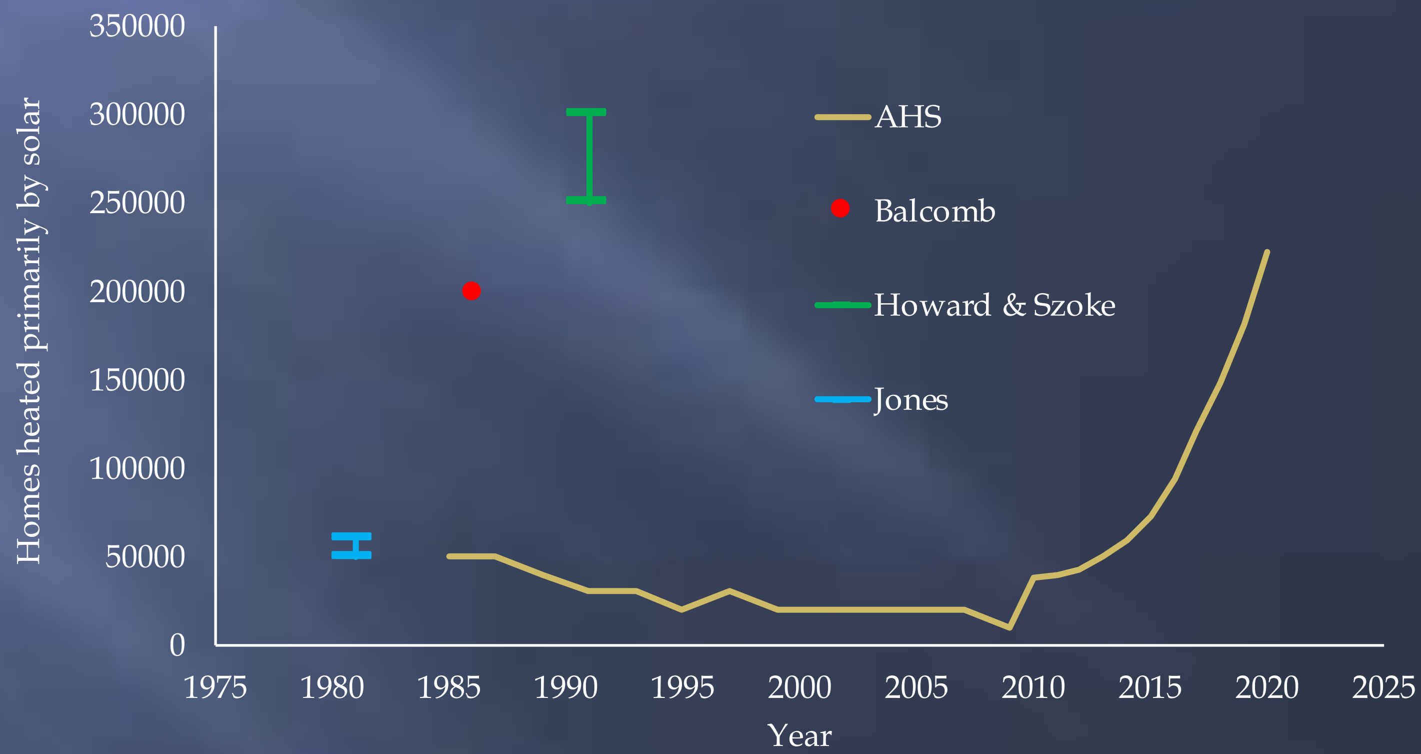
Ambient-conditioned buildings are more resilient




BEYOND ENERGY EFFICIENCY:
AMBIENT ENERGY IS UBIQUITOUS, ABUNDANT AND FREE!

Backup slides

Number of Solar Buildings



Homes for which solar is the "fuel used most for heating" (American Housing Survey (AHS) [US Census 2020]) and number of passive solar buildings [Jones, et al. 1981, Balcomb 1987, Howard & Szoke 1991].

Current total buildings: 140m residential, 6m commercial

Codes and Standards

- IECC 2021 - Passive solar is illegal in zones 0-5 (Max SHGC = 0.4)
  - REScheck, COMcheck follow IECC
- USGBC LEED – 3 points for passive solar building orientation (certified 40, platinum 80)
  - Passive solar course by Coleman & Stitt (750 trained)
- Building America Program
  - Solution Center Home » Building Components » Passive Solar Design » "No results found"
- Energy Star
  - Solar water heaters, but no passive solar

NSRDB Linked Performance Prediction Resources

- PVWatts – used 100m times per year
- System Advisor Model
  - Photovoltaic systems
  - Battery storage
  - Concentrating Solar Power
  - Industrial process heat
  - Wind power
  - Marine energy wave and tidal systems
  - Solar water heating
  - Fuel cells
  - Geothermal power generation
  - Biomass combustion for power generation
  - High concentration photovoltaic systems

NO SOLAR HEATING AND COOLING OF BUILDINGS

A Modern Ambient House Design Tool

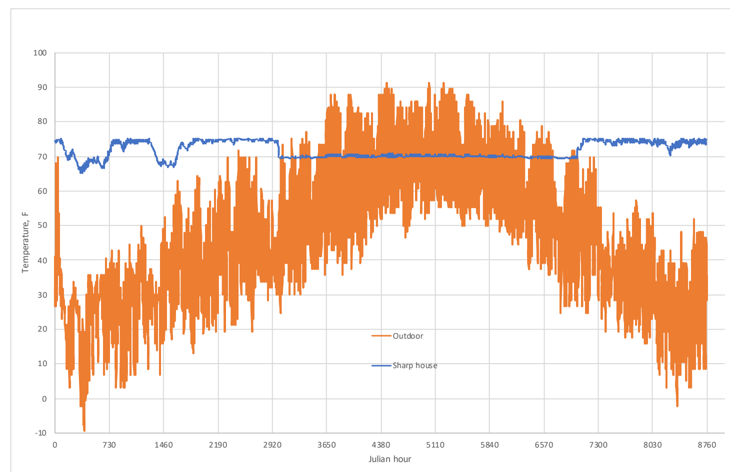
Solar Load Ratio

"AmbientWatts"

INPUTS			
Variable	From Envelope Loss sheet	Value	Notes
Loss/floor area, Btu/hr ft^2 F	0.046		Envelope loss (UA value) per floor area
Heat Gen/floor area, G/A (W/ft^2)	0.191		Internal heat generation per floor area
Solar aperture/floor area, A_c/A	0.062		Solar aperture per floor area
Variable	From Thermal Mass sheet	Value	Notes
Mass/floor area, mc_p/A (Btu/ft^2 F)	15.89	17.2	Thermal mass x specific heat per floor area
Variable	Default	Value	Notes
(hA_v+UA)/UA	10		Ventilation cooling multiplier relative to envelope loss rate

OPTIONAL INPUTS			
Variable	Default	Value	Notes
Solar aperture slope, degrees	90		Vertical = 90
Solar aperture azimuth, degrees	0		South = 0, West positive
Transmittance absorptance product	0.5		Transmittance absorptance product of solar aperture
Cooling start Julian hr	3000		Beginning Julian hour of the cooling season
Heating start Julian hr	7000		Beginning Julian hour of the heating season
Cooling setpoint (F)	69.8		Set this temp a bit higher (e.g., one degree) than the desired annual min indoor temp.
Heating setpoint (F)	75.2		Set this temp a bit lower (e.g., one degree) than the desired annual max indoor temp.

INITIAL CONDITION			
Variable	Default	Value	Notes
Initial indoor temp (F)	75.2	74.6	For the first run, enter a guess for the initial indoor temp.
Final indoor temp (F)		74.6	For the final run, type the value from C27 into C26.
			(Or Copy and "Paste Special" to enter just the value.)



Passive House

120,000 worldwide
1000 US

Saunders' 100% rules:

1. Super-insulation
2. Solar gain
3. ~~Thermal mass~~

Overheating is allowed for 10% of the year

Education

- Survey of 50 state university curriculae
  - 13 have courses on solar thermal technology
    - 5 include passive solar or passive design
- ABET environmental sustainability
- Solar Decathlon
  - Old rules discouraged thermal mass
  - New permanent installations make thermal mass feasible

DOE Program Offices

1. Office of Electricity
2. Office of Indian Energy Policy and Programs
3. Advanced Research Projects Agency – Energy
4. Office of Energy Efficiency and Renewable Energy
5. Ofice of Environmental Management
6. Office of Fossil Energy and Carbon Management
7. Office of Legacy Management
8. Loan Programs Office
9. Office of Nuclear Energy
10. Office of Science
11. Federal Energy Management Program
12. Office of State and Community Energy Programs
13. Office of Cybersecurity, Energy Security and Emergency Response
14. Artificial Intelligence and Technology Office
15. Office of Clean Energy Demonstrations
16. Office of Manufacturing and Energy Supply Chains
17. Grid Deployment Office

Electric power

Building Technology Office