ASSOCIATION FOR ENERGY AFFORDABILITY INC.

Energy Efficiency Upgrades & Lifecycle Carbon

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November 27, 2018

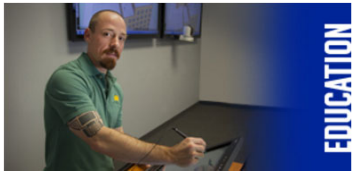
ASSOCIATION FOR ENERGY AFFORDABILITY INC.

Energy Efficiency is our Specialty, Affordable Housing is our Priority

The Association for Energy Affordability, Inc. is dedicated to achieving energy efficiency in new and existing buildings in order to foster and maintain affordable and healthy housing and communities, especially those of low-income.

With locations in NY, CA, and IL, AEA representatives engage in a broad range of educational, technical and construction management activities and services to promote this mission and develop the industry that advances and sustains it.

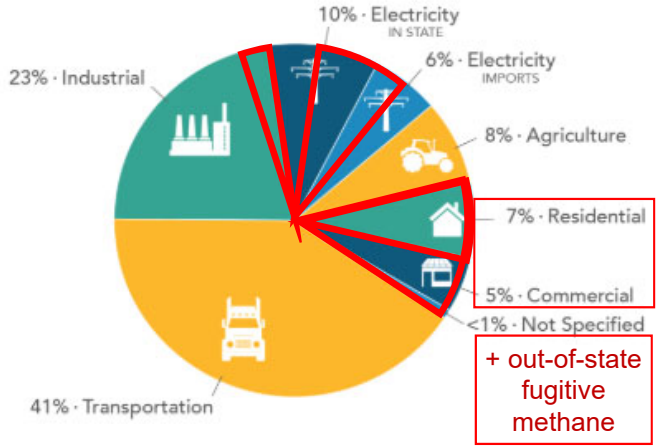
- Energy Efficiency Program Design and Implementation
- Energy Research & Demonstration Projects
- Energy Audits and Green Building Design for New Construction and Existing Buildings
- Provider of Weatherization Assistance Program Services
- National Weatherization Training Center



Tackling the Biggest Carbon Sources in Existing Buildings

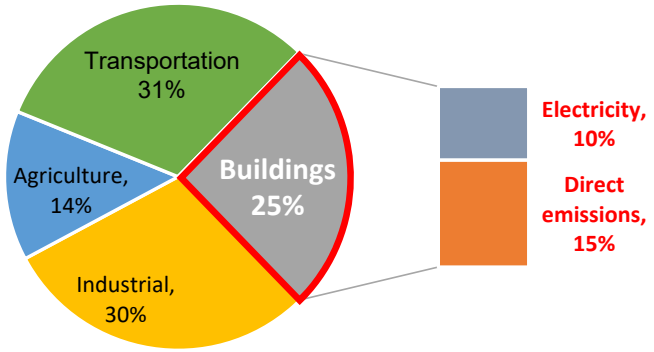
Building emissions in California

CARB 2016 GHG Inventory



- Fragmented view of building sector emissions:
  - Residential
  - Commercial
  - Electricity
  - Industry
- Ignores out-of-state methane leakage

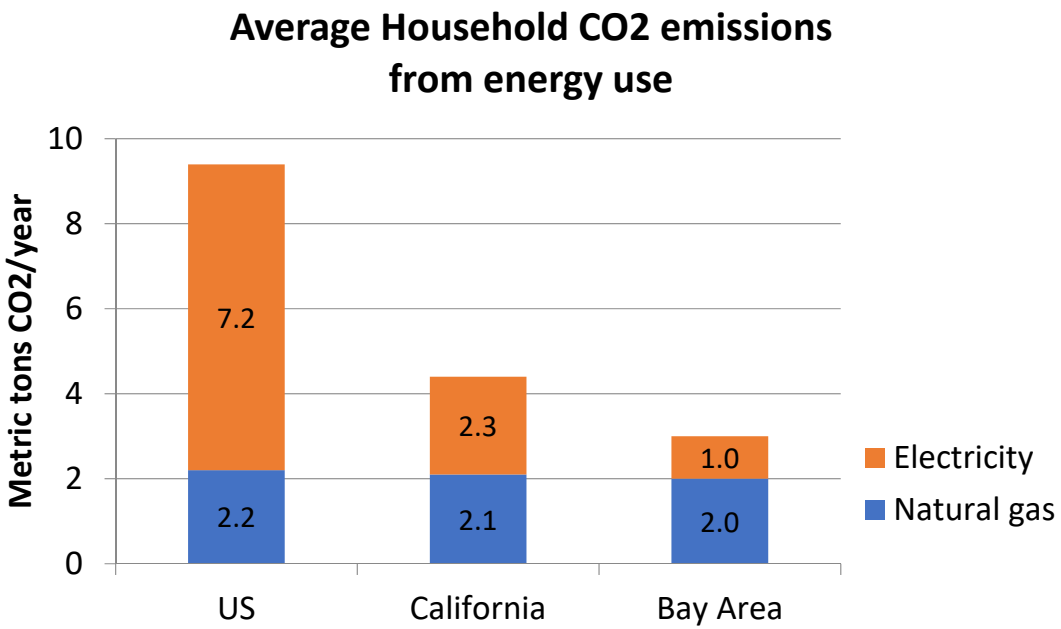
Demand View



- Demand view of building emissions, including:
  - ☑ Direct onsite emissions
  - ☑ Emissions from electricity generation
  - ☑ Fugitive methane from extraction, distribution, use

Source: Vukovich, Delforge, NRDC blog, The Real Climate Impact of California's Buildings, 9/18/2018

As electricity is getting cleaner, emissions from burning natural gas are becoming the majority of energy-related emissions from buildings



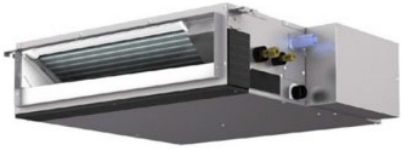
- Jones C., Kammen D., "Bay Area Consumption-Based Greenhouse Gas Emissions Inventory", Jan. 2016, http://www.baaqmd.gov/research-and-data/emission-inventory/consumption-based-ghg-emissions-inventory
- Note including emissions from methane and other high global warming potential gases

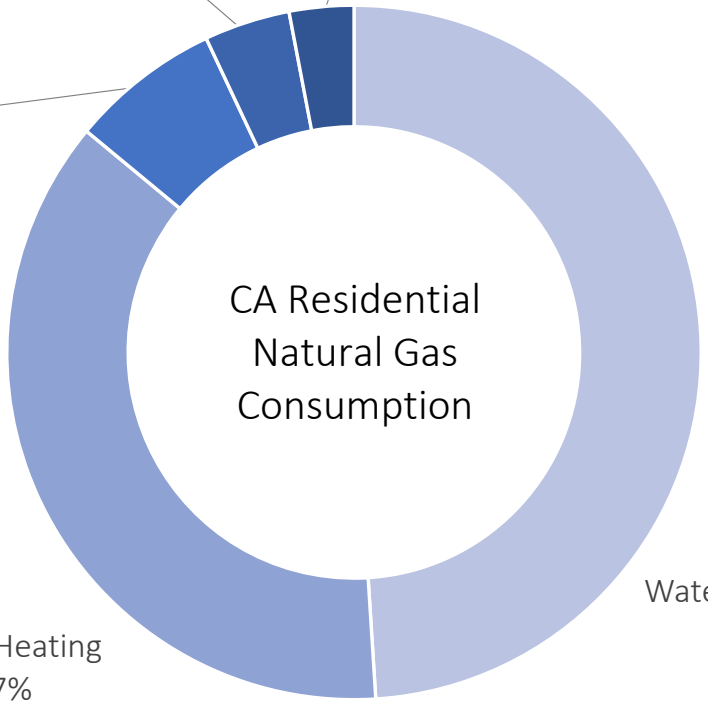
Heat Pumps Can Mostly Do It

Pool/Spa/Misc
4%

Dryer
3%

Cooking
7%





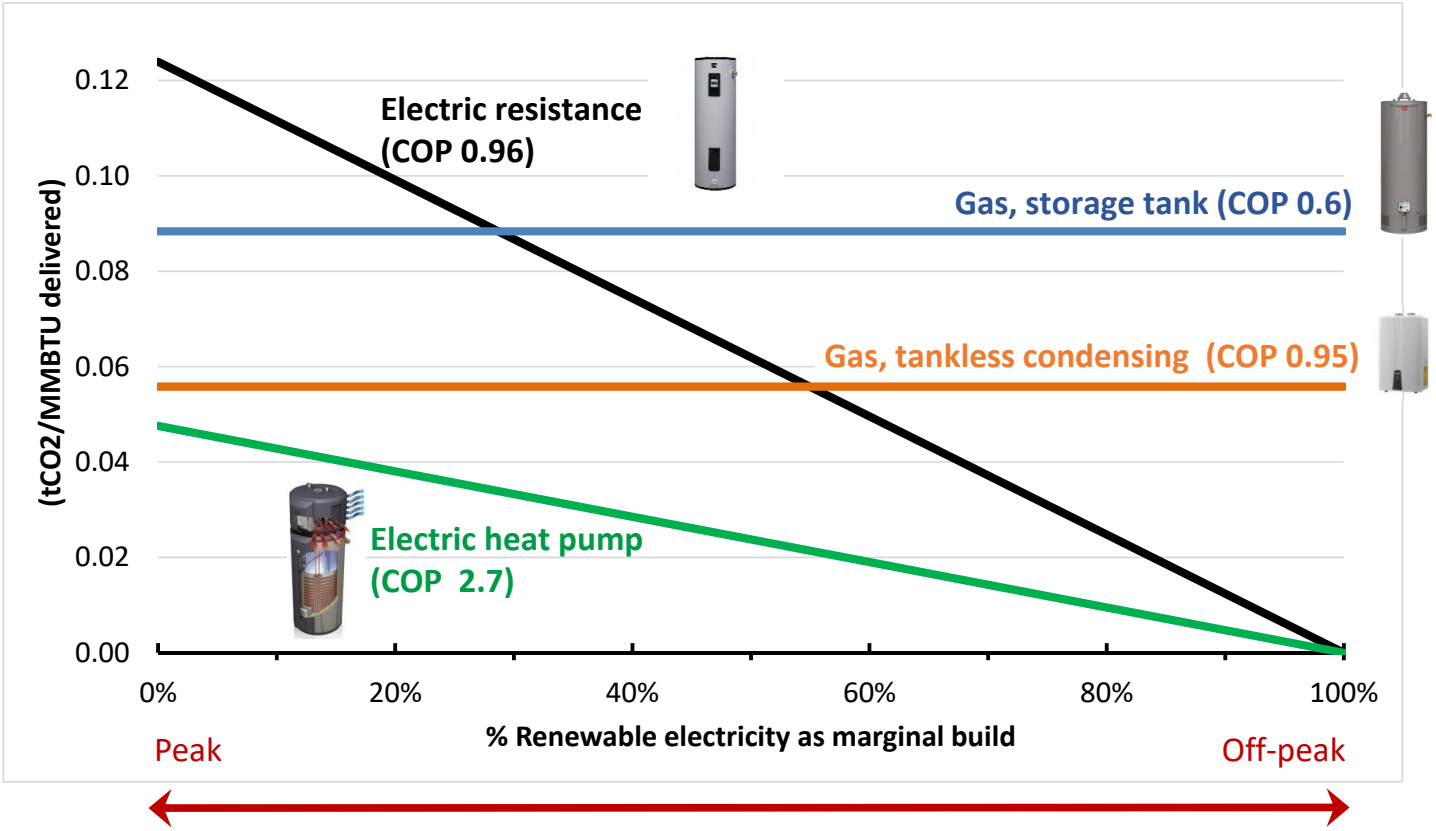
Space Heating
37%

Water Heating
49%

Data: 2010 California Residential Appliance Saturation Survey. Images: Mitsubishi, Frigidaire, Hayward, Electrolux, Sanden

Water heater CO2 emissions*

As CA grid gets cleaner, HPWH offer pathway to very low-GHG hot water



1) Not including fugitive methane emissions
2) 45%-efficient combined cycle gas plant (build margin)

But what about the high-GWP refrigerants?

- Many heat pumps, air conditioners, and refrigerators use refrigerants with high GWP.
- Regulations and technical advances should bring these lower
- Reducing system size and complexity based on energy efficient load reductions reduces volume of refrigerant

Refrigerant	GWP
R404a	3,922
R410a	2,088
R22	1,810
R407c	1,774
R134a	1,430
R32	675
R290 (propane)	3
R744 (carbon dioxide)	1

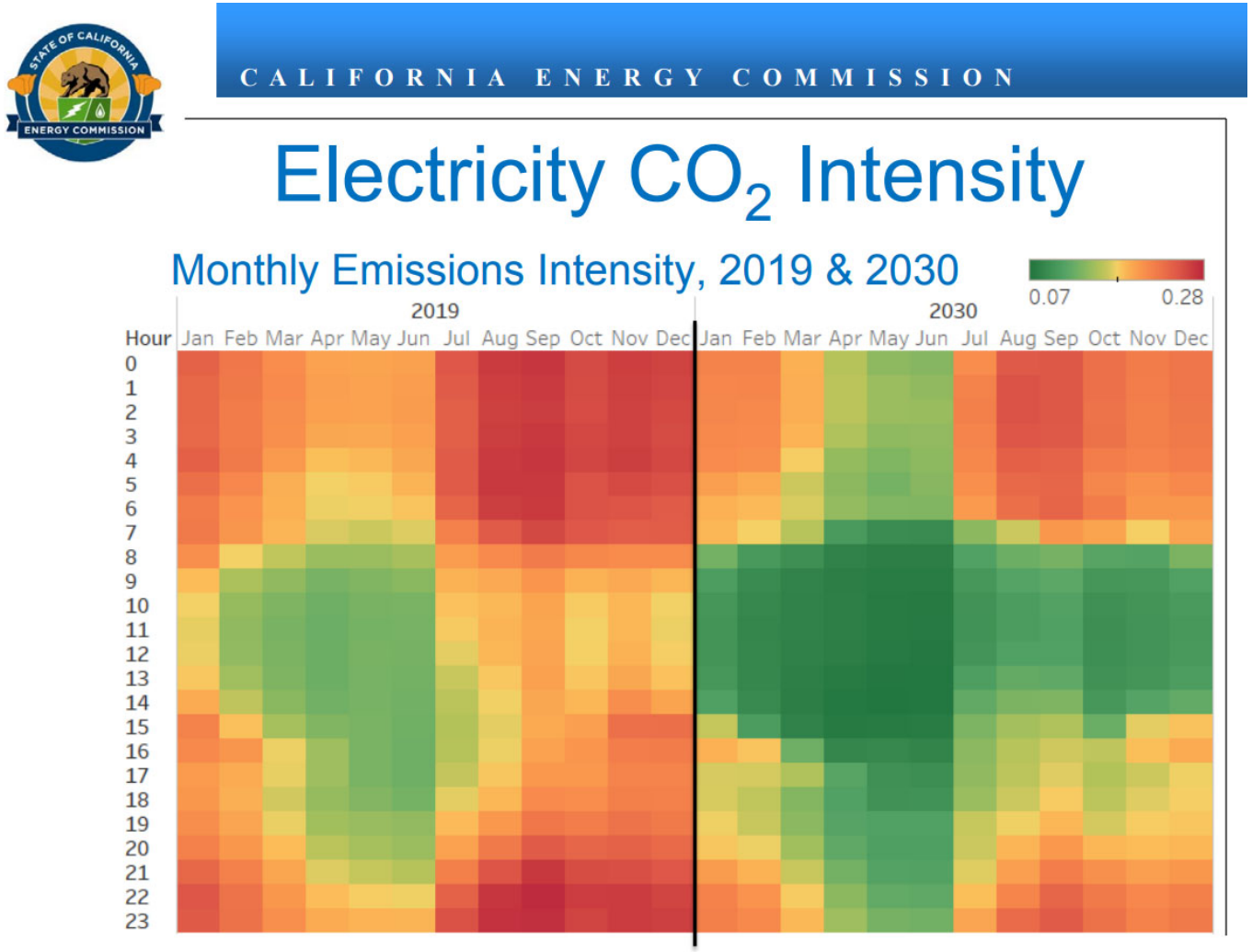
Typical Space Heating Heat Pump (reversible)

Typical Heat Pump Water Heater

750: CARB's Proposed2023 regulations for A/C

CO2 based heat pumps (ex. Sanden)

Is All Efficiency Equal through the Lens of Carbon?



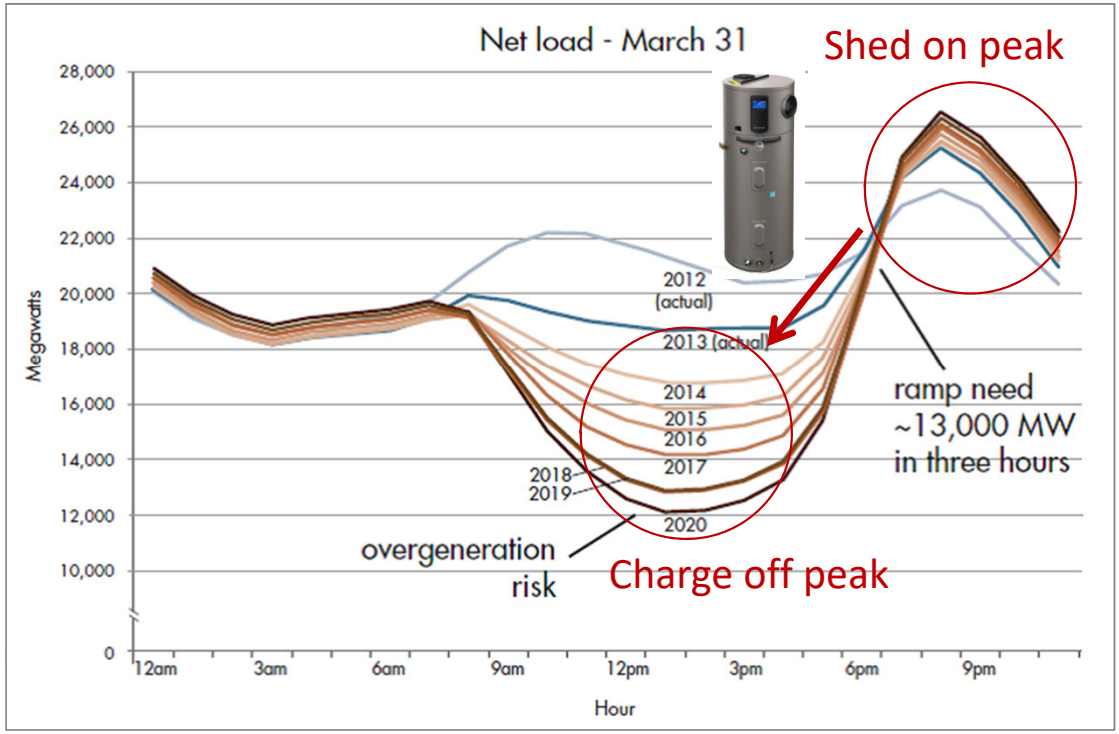
Source: Martha Brook, California Energy Commission Building Decarbonization Presentation 2018 Update Integrated Energy Policy Report, June 14, 2018

Not all electricity usage is equal

Therefore, not all EE is equal

Emissions intensity will change over time

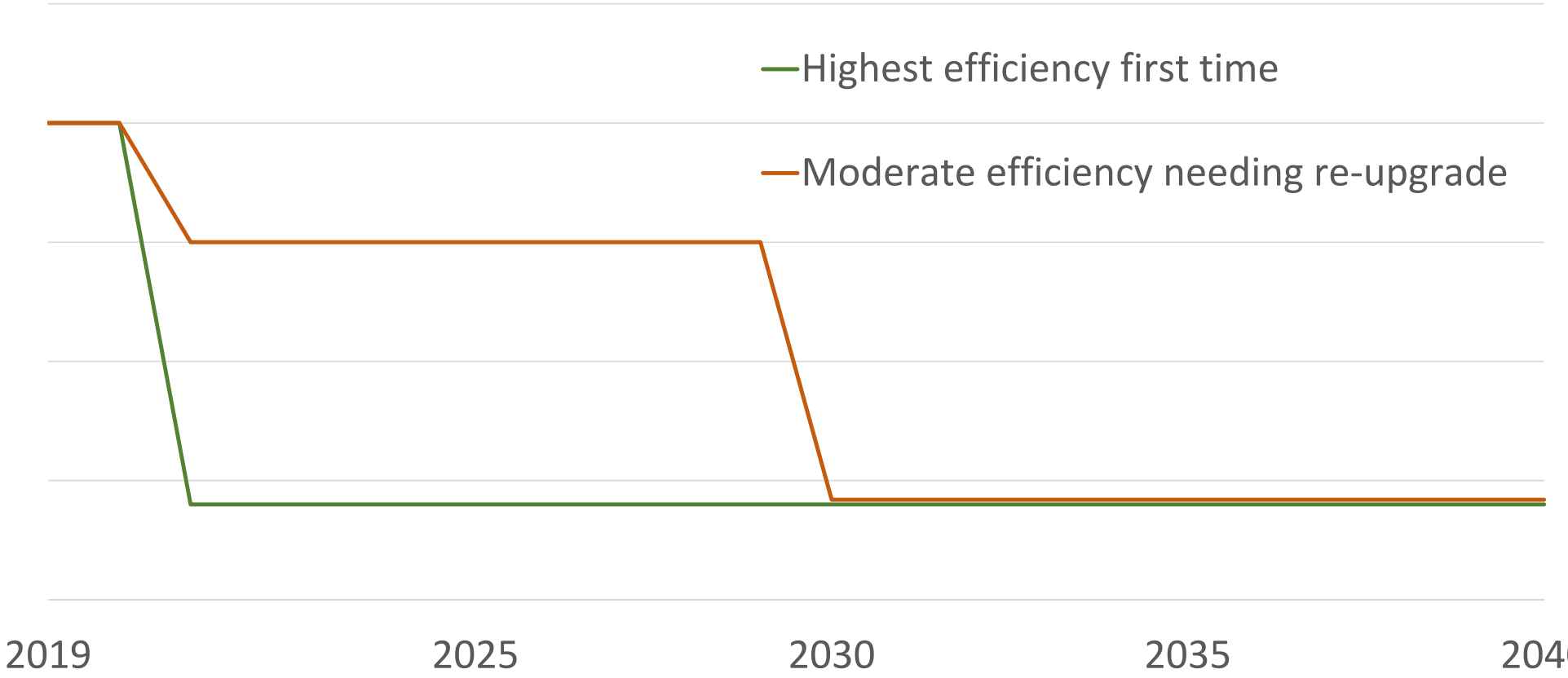
Grid-interactive heat pump water heaters can help integrate renewable energy



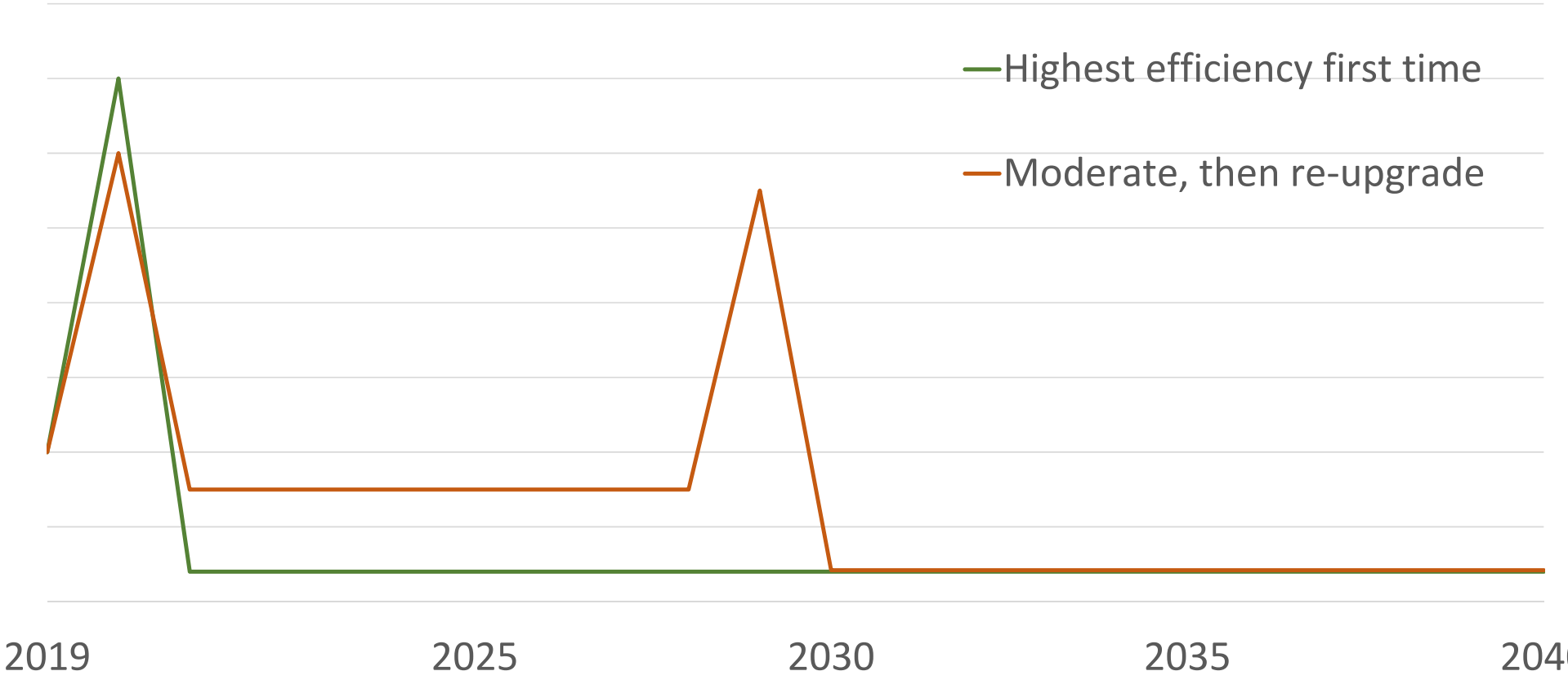
NRDC and Ecotope study, ACEEE Aug. 2018

Lifecycle Carbon of Existing Building Upgrades

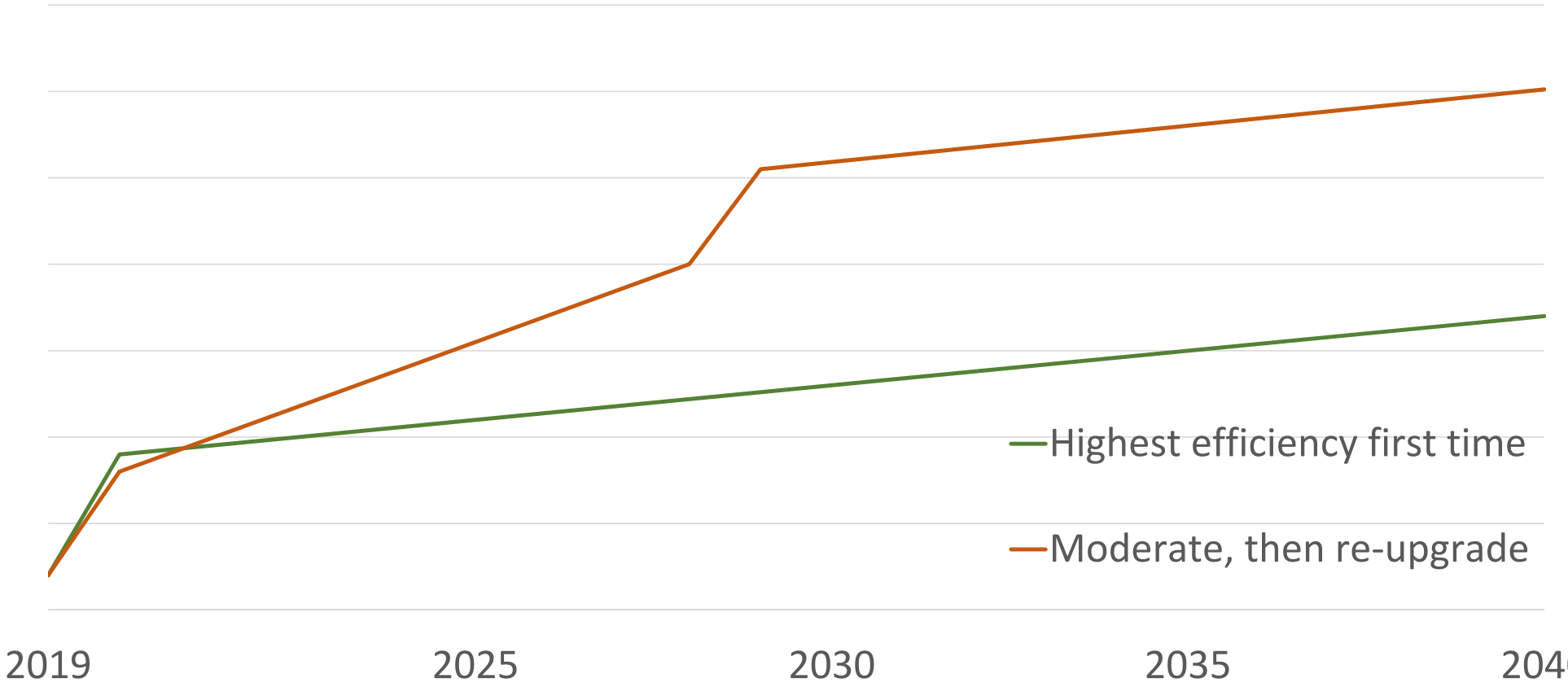
Annual Emission: Operational Only



Annual Emission: Operational + Embodied Carbon



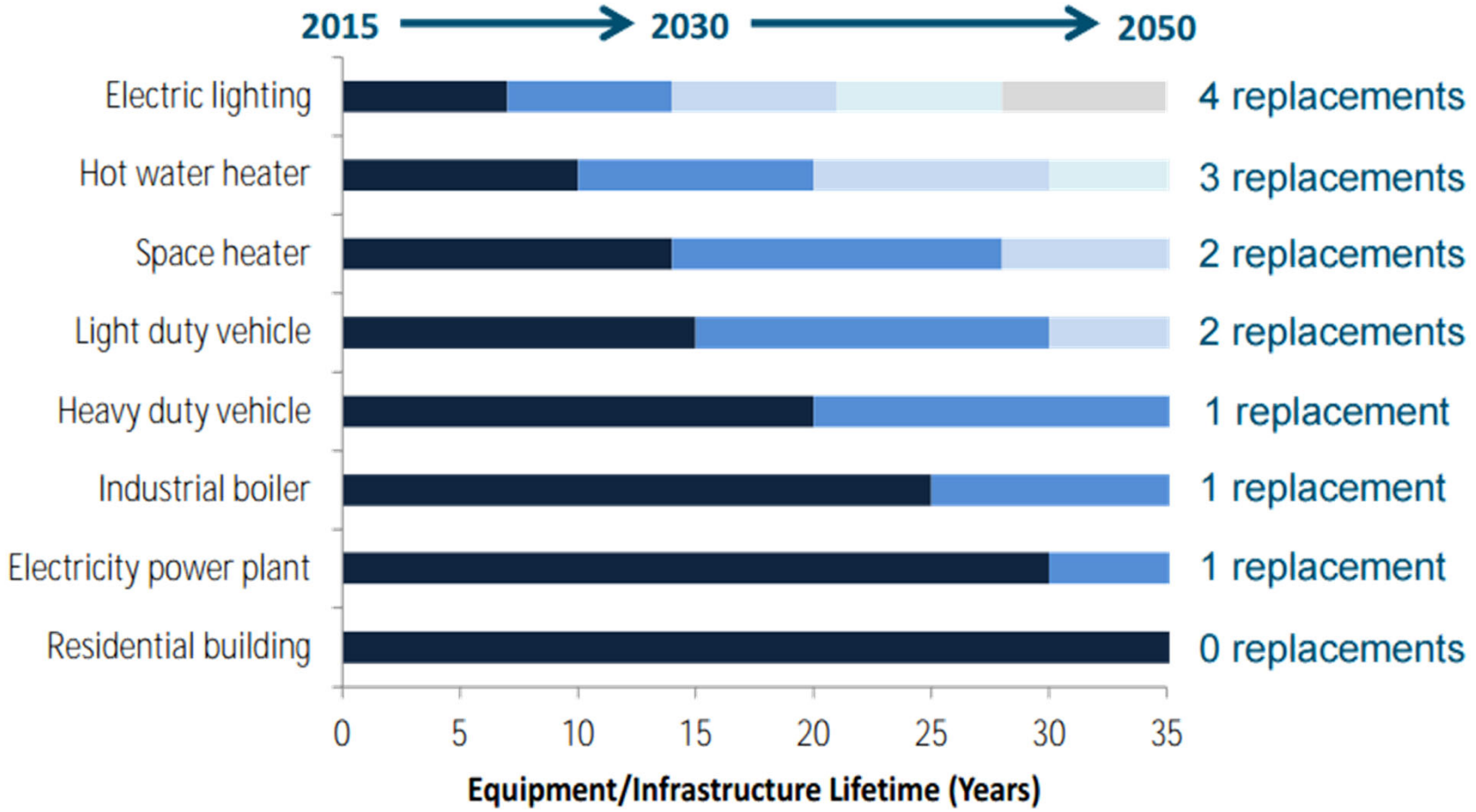
Cumulative Emission: Operational + Embodied Carbon



Stranded Assets of Gas Equipment

- **Gas Lines**
  - Meter to Equipment
  - For New Construction, utility hookups to meter
  - Both can be $$$
- **Combustion Venting Equipment**
  - Metal, PVC, or stainless steel venting to remove combustion gasses from equipment
- **Envelope Penetrations**
  - For venting (roof or wall) and gas lines (walls or floors)

Figure ES 2. Stock Lifetimes and Replacement Opportunities



Pathways to Deep Decarbonization in the United States, 2015

Carbon Perspective on Energy Loading Order:

- **Reduce loads as small as possible, to make equipment smaller, easier and cheaper**

- **High Performance Envelopes and Ventilation systems can mean**
  - Smaller Heat Pumps for Space Heating
  - Possibly Low-Cost Electric resistance for heating (no refrigerant GHGs)

- **Efficient Plumbing Fixtures and Distribution Systems**
  - Smaller, simpler heat pump water heaters

- **Smaller Renewable Energy Systems to offset overall energy use**

Empire State Building Case Study

Cost-Effective Greenhouse Gas Reductions via Whole-Building Retrofits: *Process, Outcomes, and What is Needed Next*

For more information, please visit www.esbsustainability.com

Jones Lang LaSalle
Real value in a changing world

Clinton Foundation | Clinton Climate Initiative

Rocky Mountain Institute

Johnson Controls

I. MOTIVATION

1) Prove or disprove the economic viability of whole-building energy efficiency retrofits.

Prior to 2008, the Empire State Building's performance was average compared to most U.S. office buildings.

Annual utility costs:

- $11 million ($4/sq. ft.)

Annual CO2 emissions:

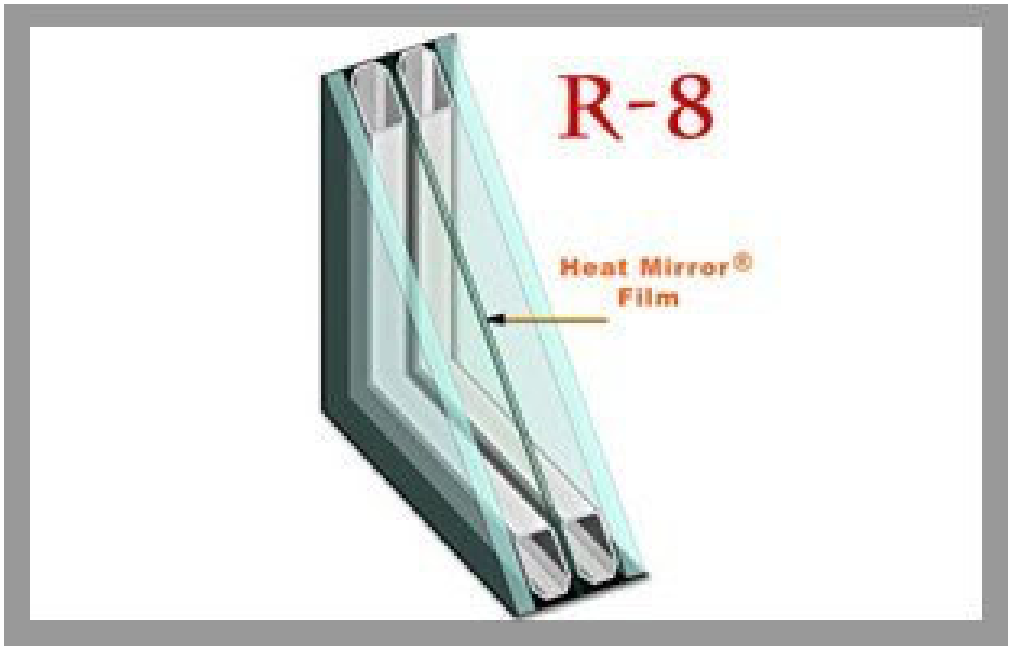
- 25,000 metric tons (22 lbs/sq. ft.)

Annual energy use:

- 88 kBtu/sq. ft.

Peak electric demand:

- 9.5 MW (3.8 W/sq. ft. inc. HVAC)



WINDOWS
Remanufacture 6,500 existing dual glazed windows
Add suspended film between panes, fill with argon gas
R-2 to R-8

RADIANT BARRIERS
Install more than 6,000radiant barriers behind existing radiators at perimeter of building

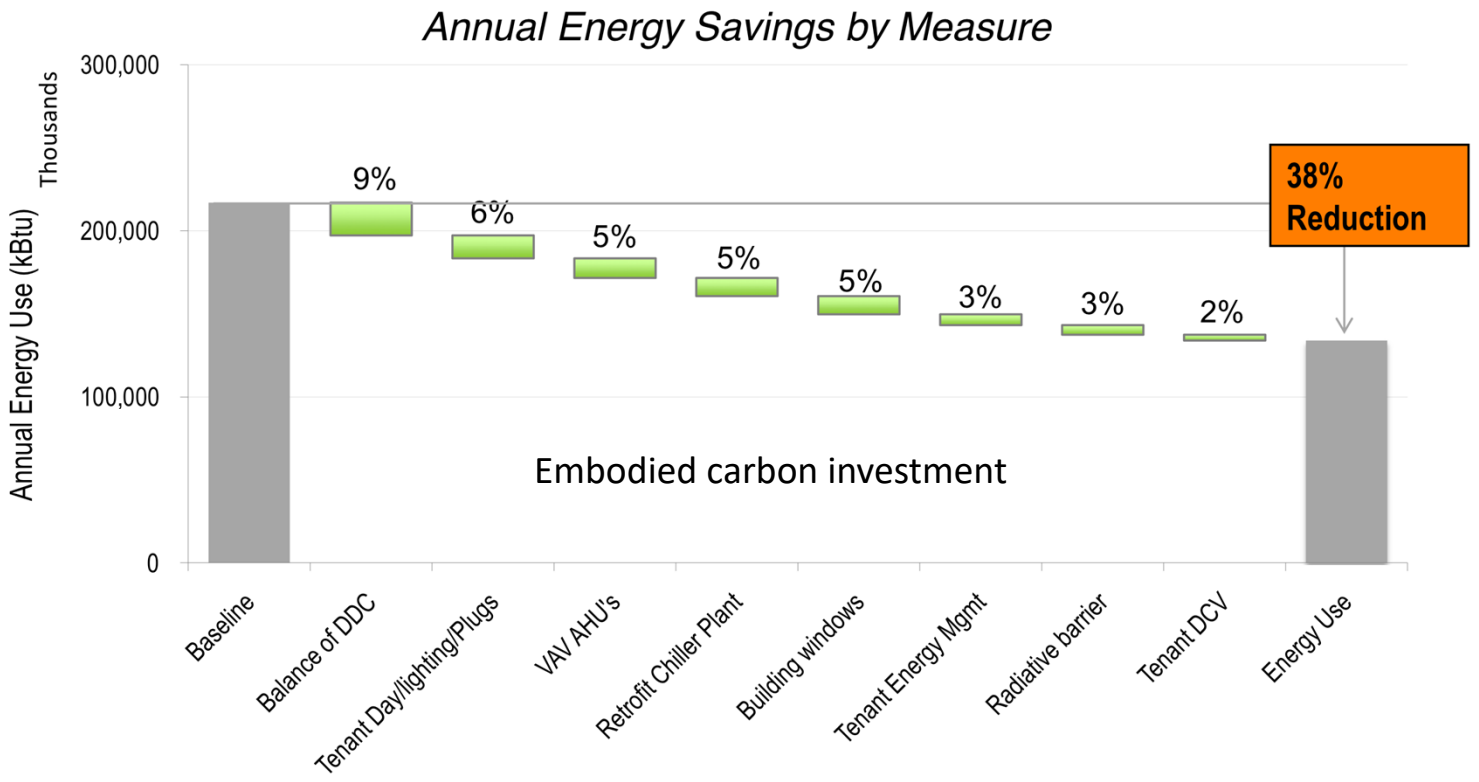
CHILLER PLANT RETROFIT
Retrofit + controls, variable speed drives and primary loop bypass

VAV AIR HANDLING UNITS
Replace existing constant volume units with Variable Air Volume units using 2 floor mounted instead of 4 ceiling mounted

III. KEY FINDINGS

1) Eight interactive levers ranging from base building measures to tenant engagement deliver these results.

Energy and CO2 savings in the optimal package result from 8 key projects.



= **8.3 metric Tons/year**

III. KEY FINDINGS

1) Eight interactive levers ranging from base building measures to tenant engagement deliver these results.

Though it is more informative to look at financials for the package of measures, capital costs and energy savings were determined for each individual measure.

Project Description	*Projected Capital Cost*	*2008 Capital Budget*	*Incremental Cost*	*EstimatedAnnual Energy Savings**
Windows	$4.5m	$455k	$4m	$410k
Radiative Barrier	$2.7m	$0	$2.7m	$190k
DDC Controls	$7.6m	$2m	$5.6m	$741k
Demand Control Vent	Inc. above	$0	Inc. above	$117k
Chiller Plant Retrofit	$5.1m	$22.4m	-$17.3m	$675k
VAV AHUs	$47.2m	$44.8m	$2.4m	$702k
Tenant Day/Lighting/Plugs	$24.5m	$16.1m	$8.4m	$941k
Tenant Energy Mgmt.	$365k	$0	$365k	$396k
Power Generation (optional)	$15m	$7.8m	$7m	$320k

***Note that energy savings are also incremental to the original capital budget.**

Consider Carbon Payback

Embodied carbon “investment”

Reduced operational carbon “savings” or “return”

Energy efficiency measures can have
short or long “payback”
high or low ROI