BERKELEY LAB

LAWRENCE BERKELEY NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY

A Tale of Three Cities: Reducing Emissions with Building Performance Standards

Background: Reducing emissions with BPS

- Several jurisdictions are planning and implementing policies to help reduce GHG emissions from buildings (e.g., benchmarking, audits, tune-ups, BPS)

- Building Performance Standards (BPS) require performance improvement to meet specified targets

- BPS policy design and impacts depend on many factors
  - Building stock (type, size, age, energy use, fuels, equipment)
  - Data availability (tax assessor, benchmarking, audit)
  - BPS targets (EUI, GHGI, electrification)
  - Policy goals (energy and/or emissions reductions, electrification)
  - Resources available (technical expertise, time, effort)

BERKELEY LAB

Overview: Analysis results from three cities

- Seattle, WA: Impacts of a building tune-ups program
  - What are the expected savings?
  - Do particular buildings (sizes, types, systems) save more?
  - Are some buildings more likely to have certain issues?

- Aspen, CO: Selecting EUI and GHGI targets for BPS
  - What should the BPS metrics and targets be?
  - Can buildings meet targets by electrifying?
  - How do grid emissions factors affect BPS?

- Berkeley, CA: Electrification of equipment upon replacement
  - What are the emissions savings from electrifying space and water heating?
  - How does age of replacement affect savings?
  - How does efficiency of the new system affect savings?

BERKELEY LAB

Seattle: Building Tune-Ups Program

- Seattle is designing BPS policies for meeting GHG targets
  - How to help building owners comply with BPS?
  - Are tune-ups a good tool for compliance?
  - What are expected savings?
  - Are tune-ups best suited to particular building types, etc.?
  - Which measures are most effective?

- Seattle implemented a building tune-ups program
  - Assessors identified measures during inspection
  - Building implemented measures (either during inspection, or later)
  - Energy use measured before and after tune-up

BERKELEY LAB

Seattle: Tune-ups data

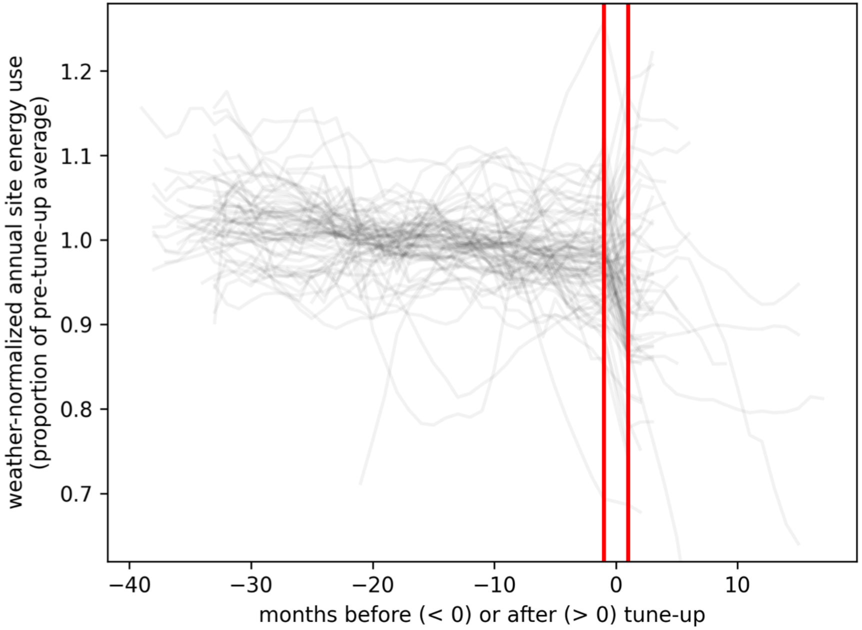
- Building characteristics (type, size, vintage, % occupied, etc.)
- Systems (type, condition, age for lighting, heating, cooling, etc.)
- Energy use (pre- and post- weather-normalized site energy)
- Measures
  - HVAC operations (review schedules, setpoints, etc.)
  - HVAC maintenance (check filters, motors, fans, etc.)
  - Lighting (check sensors, schedules, etc.)
  - Domestic hot water
  - Envelope

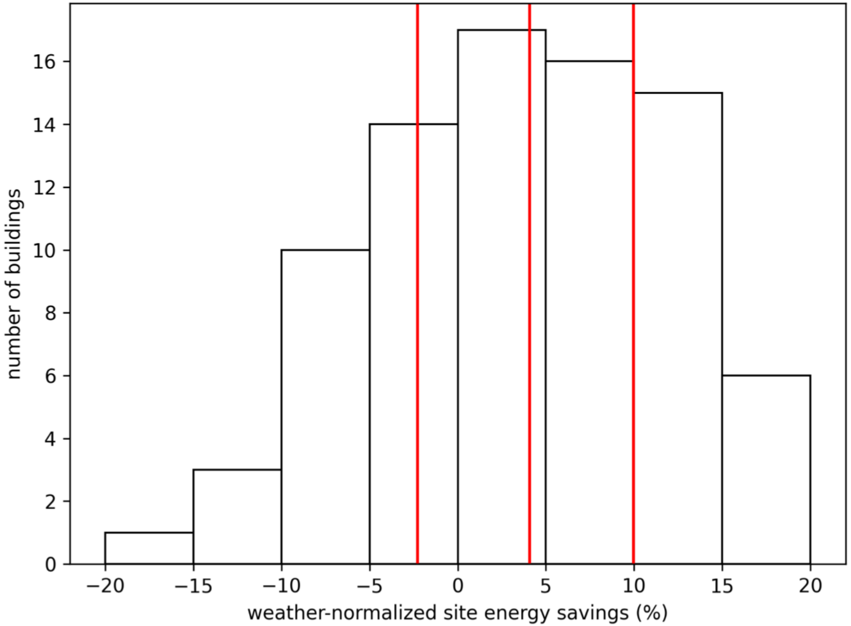
- Characteristics, systems, and measures data for 420 buildings
- Only 82 buildings with 1 year of post- energy data (due to pandemic)

BERKELEY LAB

Seattle: Energy savings

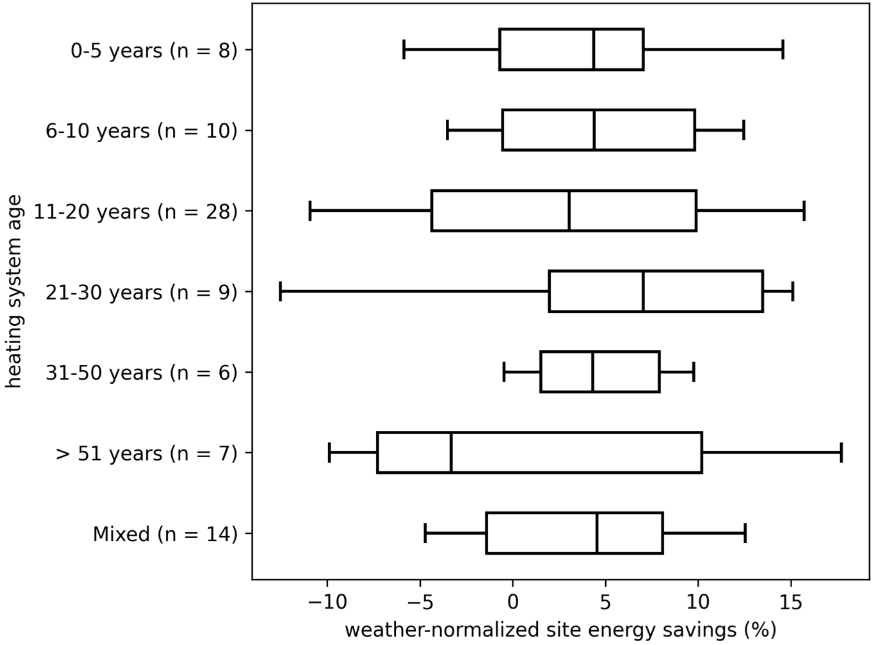
- Energy use highly variable before and after tune-ups
- 4.1% median site energy savings
- 34% of buildings increased energy use (equip fixed? operational changes?)

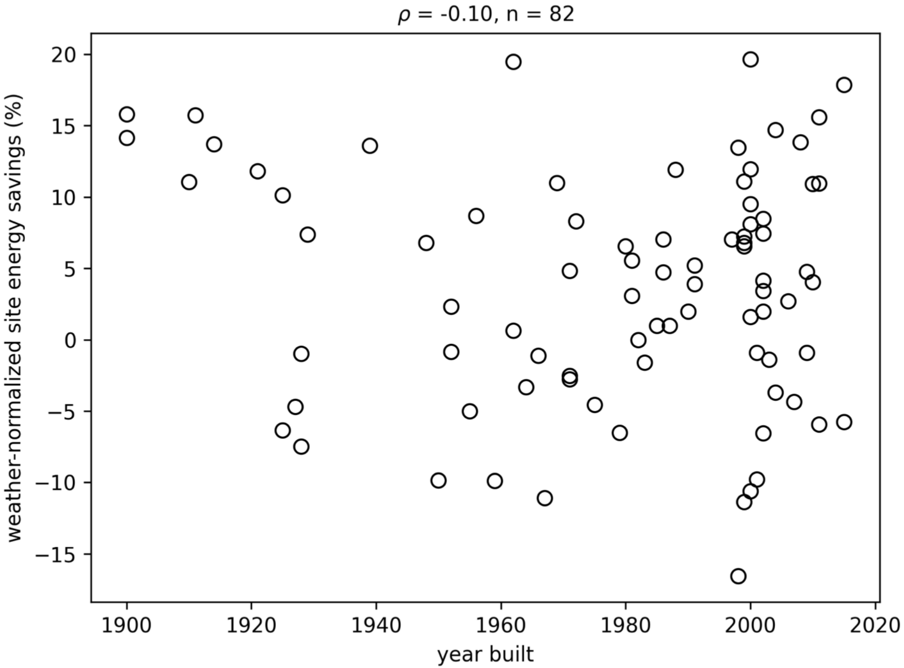




Seattle: Relationships between savings, measures, etc.?

- We fit hundreds of regression models, looking for trends





BERKELEY LAB

Seattle: Relationships between savings, measures, etc.?

- Do some buildings have more savings? (bldg and system chars, num issues)
  - No significant relationships

- Do some buildings have more issues? (bldg and system chars, assessor)
  - Some relationships, most intuitive (e.g., more issues with old equip, or equip in bad condition)
  - Effect is small (~2 more/less issues)

- Are some buildings more likely to have particular issues?
  - Most results indicate issue it not likely, only a few indicate issue is likely
  - Issues most likely to be found depend on assessor (expertise with certain systems?)

BERKELEY LAB

Seattle: Lessons learned

- Energy savings
  - Stock-level savings ~4%, but individual buildings with more/less savings
  - Tune-ups alone likely won’t reach BPS targets
- Don't bother targeting tune-ups towards specific buildings, systems, etc.
  - More assessor training for better consistency?
- More data and further analysis needed
  - Only 82 buildings with energy data
  - Clearly enumerated measures helped analysis

Aspen: Emissions reductions using BPS

- Aspen is planning to implement BPS legislation
  - Emissions goals: 55% by 2030, zero by 2050

- Policy design questions
  - What should BPS targets be? EUI or GHGI?
  - Can buildings meet targets by electrifying?
  - How do grid emissions factors affect BPS?
  - Should some building types be exempt?

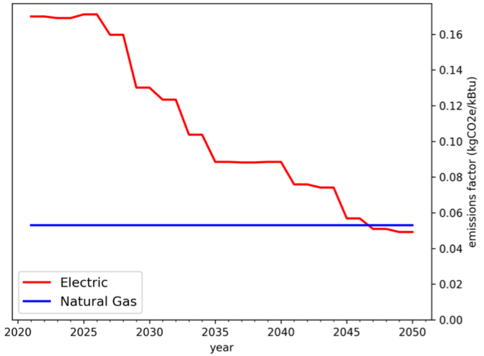
- Limited data availability
  - Tax assessor data (floor area, a few building types)
  - No energy use data (sampled from CBECS/RECS)

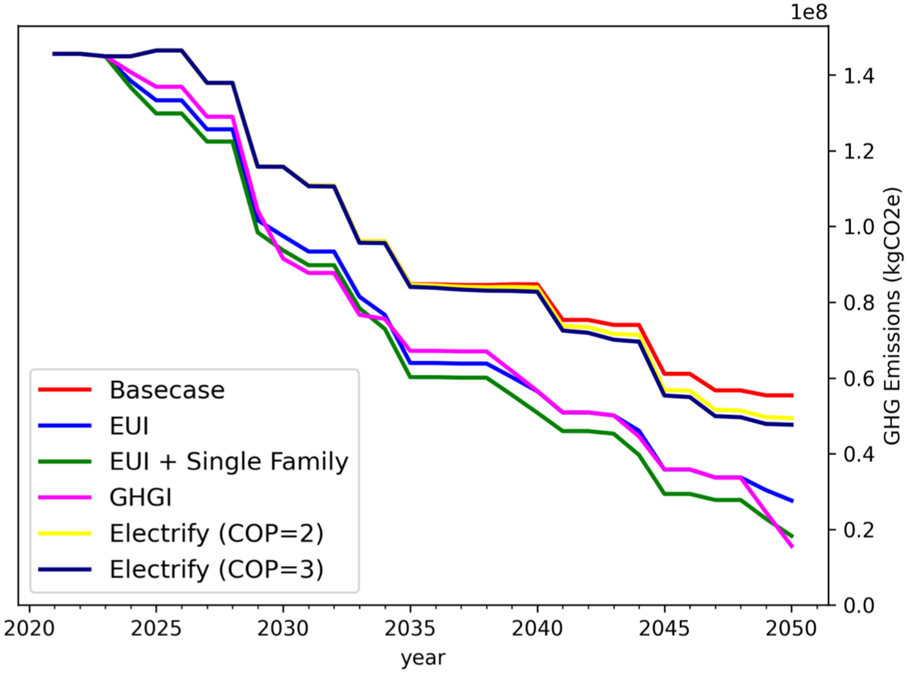
Aspen: BPS policy modeling

- We predicted each building's electric and gas from 2020-2050
  - Targets are specific values of either EUI or GHGI
  - Buildings meet targets with efficiency or electrification
- We modeled several different policy scenarios
  - Basecase: Buildings don't reduce energy use. Emissions only reduce due to grid.
  - Buildings reduce elec and gas to meet EUI targets (with and without single family exempt)
  - Buildings reduce elec and gas to meet GHGI targets (single family exempt)
  - Buildings electrify (with COP=2 and COP=3) to meet GHGI targets (single family exempt)

Aspen: Modeling results

- EUI and GHGI targets chosen for realistically-achievable reductions
  - City-wide goals not met, even when single family included
  - EUI and GHG targets have similar effect
- Electrification barely better than basecase
  - Aspen's electric is carbon intensive
  - Electrifying doesn't reduce emissions until ~2033





BERKELEY LAB

Aspen: Lesons learned

- Electrification alone won't meet goals
  - Significant savings due to grid getting cleaner, only small additional savings from electrifying
  - Electrifying doesn't reduce emissions until ~2033

- Efficiency alone won't (quite) meet goals

- Should policy start with efficiency, then include electrification later?
  - Start with efficiency (to reduce cumulative emissions)
  - Later, when grid is clean enough, include electrification too

- City-specific data will improve confidence in results
  - Measured energy data for city buildings (e.g., benchmarking ordinance)
  - More specific building types

BERKELEY LAB

Berkeley: Electrification upon replacement

- Berkeley's goal is to reduce emissions to zero by 2045
  - Electricity is already essentially zero emissions, so just need to electrify
  - Policy would require electrifying equipment at end-of-life

- Policy design questions
  - What are the emissions savings from electrifying space and water heating?
  - How does age of replacement affect savings?
  - How does efficiency of the new system affect savings?

- How to predict effects of electrification with limited systems data?
  - Audit data from Berkeley and nearby city (San Francisco)
  - End Use Load Profile data (from ComStock and ResStock)

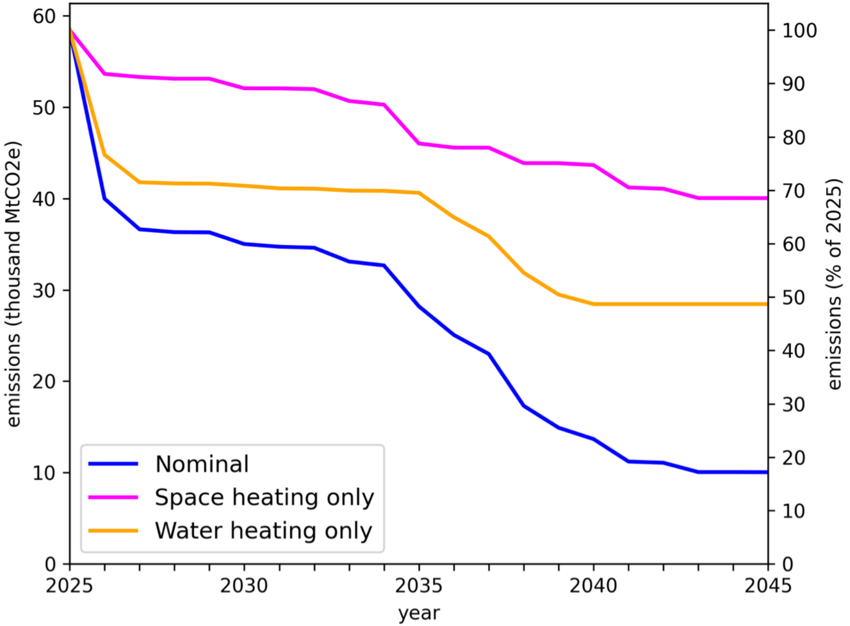
Berkeley: Modeling policy scenarios

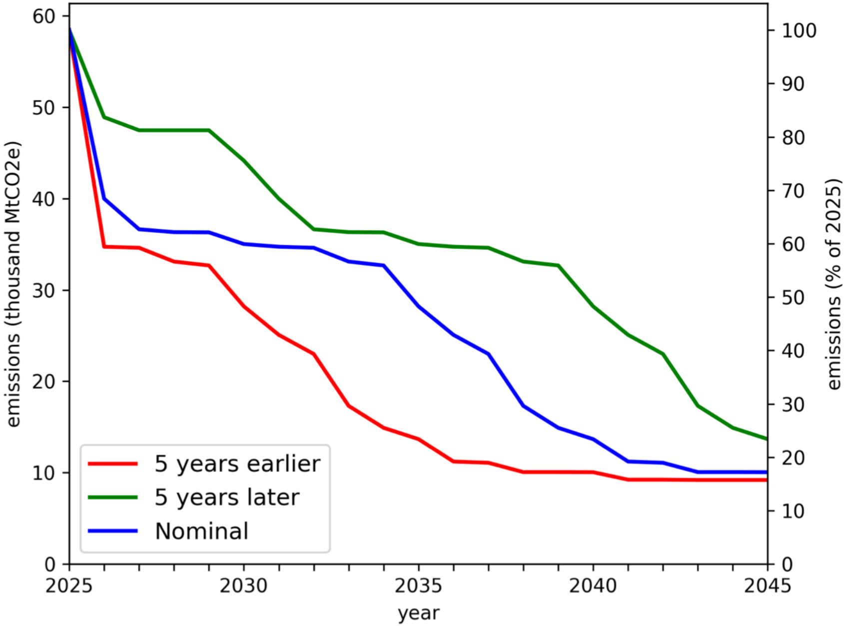
- We modeled each buidling's electric and gas use from 2025-2045
  - Equipment replacement age depends on end use and system type
  - New equipment efficiency depends on current year (COP starts at 2.0, then 3.0, then 4.0)

- Policy scenarios
  - Nominal policy: Space and water heating equip replaced after ~25 years
  - All equipment replaced after ~20 years
  - All equipment replaced after ~30 years
  - Only space heating equipment replaced
  - Only water heating equipment replaced
  - Comparison policy: Instead of replacing equipment, must reduce gas use 25% every 5 years

Berkeley: Timing and end uses

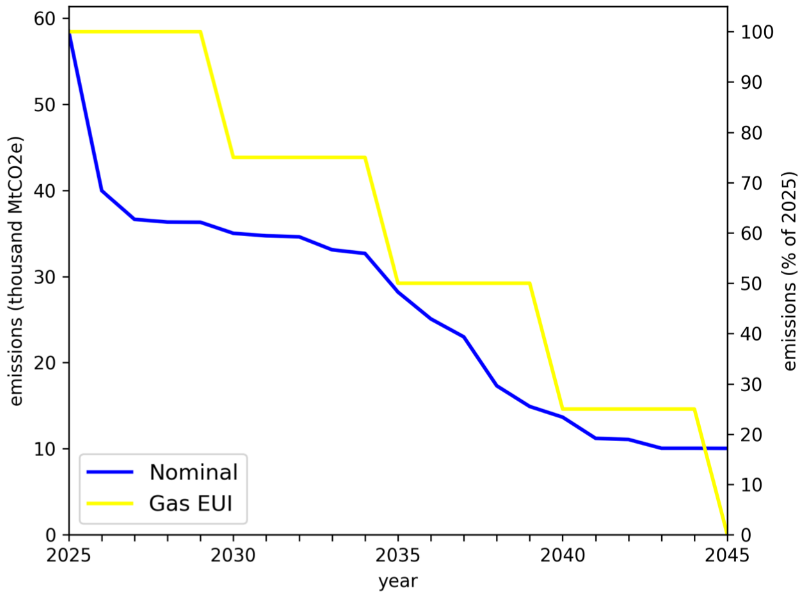
- Nominal emissions savings: 82% (31% from space heating, 51% from water)
- Replacing 5 years earlier/later: final savings barely change, but cumulative savings change significantly

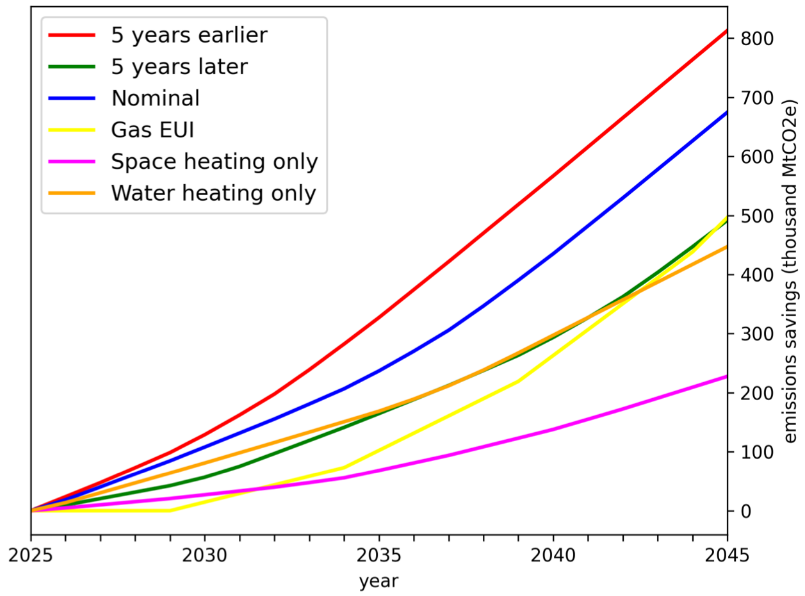




Berkeley: Electrification vs. gas reduction

- Comparison policy: reduce gas use by 25% every 5 years
- Gas reduction gets emissions to zero, but not replacement (some gas use isn't for space or water heating)
- Replacement has less cumulative emissions (starts in 2025)





Berkeley: Lessons learned

- Replacing equipment reduces emissions drastically (82%)
- Need to include non-space and water heating to reach zero emissions
- Space and water heating cause roughly equal emissions
  - Shouldn't focus on just one end use
- Earlier end-of-life reduces cumulative emissions significantly
  - Replacing 5 years earlier: 20% more savings
  - Replacing 5 years later: 25% less savings
- For cumulative emissions, implementing policies sooner is important

BERKELEY LAB

Conclusions and Future Work

- Stock-level analysis can help compare alternate policy implementations
  - Use empirical data to quantify impacts of policy design decisions (e.g., exemptions, timing)
  - Relatively modest level of expertise and effort needed
  - Reasonably accurate at stock-level (even if not at building level)
- City-specific data greatly improves confidence in results
  - Especially for detailed electrification analysis of individual systems
- Many cities seeking data-driven technical assistance for BPS design
  - How to design policies with reasonable levels of effort and expertise for data collection and analysis?
  - Forthcoming ASHRAE guidance (targets, analysis approaches, equity, etc.)
  - More work needed on estimating costs to building owners for compliance
- Get started now, refine policies later

Contacts

Travis Walter
twalter@lbl.gov

Paul Mathew
pamathew@lbl.gov

Harry Bergmann
harry.bergmann@ee.doe.gov