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LAWRENCE BERKELEY NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY

Building Performance Standards for Decarbonization

Agenda

- Background + Context
- Case Studies on BPS-related Policy Crafting
  - Impacts of Tune-Up program on proposed BPS requirements in Seattle, WA
  - Crafting a BPS for Aspen, CO
  - Electrification in Berkeley, CA

Background: Decarbonizing Buildings

- Cities + States WANT to decarbonize buildings, and have several policy tools to do so for existing buildings

- Building Performance Standards are the most recent, and most aggressive, of these tools

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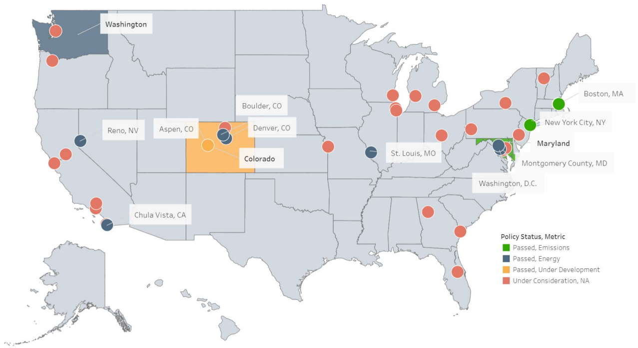
Background: Reducing emissions with BPS

- 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)



Background: Existing BPS Implementations

Jurisdiction	Building Type Scope	Initial Compliance Period	Performance Metric(s)
Boston, Massachusetts	Municipal buildings of any size. Commercial and multifamily buildings ≥ 20,000 square feet (sf), or 15 units for multifamily.	2025 for buildings ≥ 35,000 sf[a]	Carbon dioxide equivalent (CO_2e) GHG intensity (GHGI)
Chula Vista, California	Municipal, commercial, institutional, and multifamily buildings ≥ 20,000 sf	2023 for buildings ≥ 50,000 sf[a]	Site energy use intensity (EUI) reduction target (%) or ENERGY STAR score
Denver, Colorado	All commercial and multifamily ≥ 25,000 sf	2024 for buildings ≥ 25,000 sf	Site EUI[b]
Montgomery County, Maryland	Public, commercial, institutional, and multifamily buildings starting at ≥ 50,000 sf and decreasing to ≥ 25,000 sf over time	2024 for public buildings ≥ 50,000 sf[c]	Site EUI
New York, New York	All commercial and multifamily buildings ≥ 25,000 sf	2024	CO_2e GHGI
Reno, Nevada	Municipal buildings ≥ 10,000 sf. Commercial and multifamily starting at ≥ 100,000 sf and decreasing to ≥ 30,000 sf over time	2026	ENERGY STAR score or site EUI
St. Louis, Missouri	Municipal, institutional, commercial, and multifamily buildings ≥ 50,000 sf	2025	Site EUI
State of Colorado	Public, institutional, commercial, and multifamily buildings ≥ 50,000 sf	2026	Under development
State of Maryland	Public, institutional, commercial, and multifamily buildings ≥ 35,000 sf	2030	Onsite GHG emissions[d]
Vancouver, Canada	Commercial buildings ≥ 100,000 sf	2026	CO_2e GHGI and Heating (space and hot water) Energy Intensity
State of Washington	Commercial buildings ≥ 50,000 sf[e]	2026	Site EUI
Washington, District of Columbia (D.C.)	Municipal buildings ≥ 10,000 sf. Commercial and multifamily buildings starting at ≥ 50,000 sf and decreasing to ≥ 10,000 sf over time	2026	ENERGY STAR score or source EUI

Overview: Analysis results from three cities

- Seattle, WA: Impacts of a building tune-ups program
    - What are the expected savings?
    - Are tune-ups a good tool for BPS compliance?
    - 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?

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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

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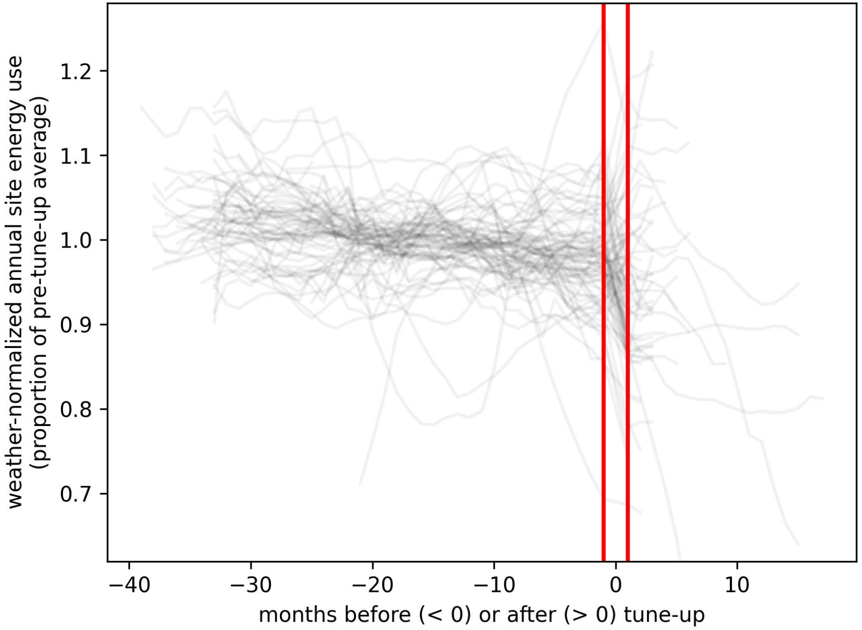
Seattle: Tune-ups data

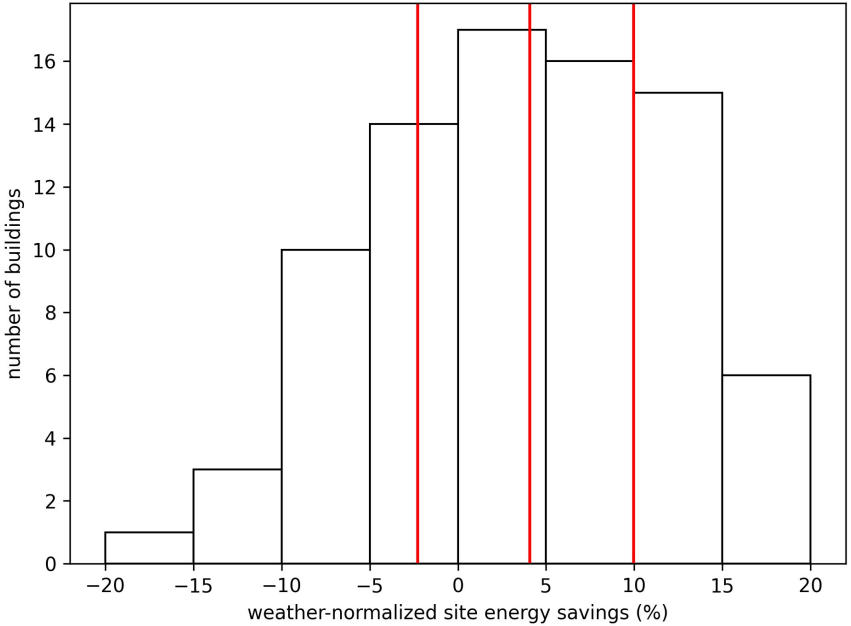
- Building characteristics (type, size, vintage, % occupied, etc.)
- Systems (type, condition, age for lighting, heating, cooling, etc.)
- Energy use (pre- and post- weather-normalized site energy)
- Measures
  - HVAC operations (review schedules, setpoints, etc.)
  - HVAC maintenance (check filters,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

Seattle: Energy savings

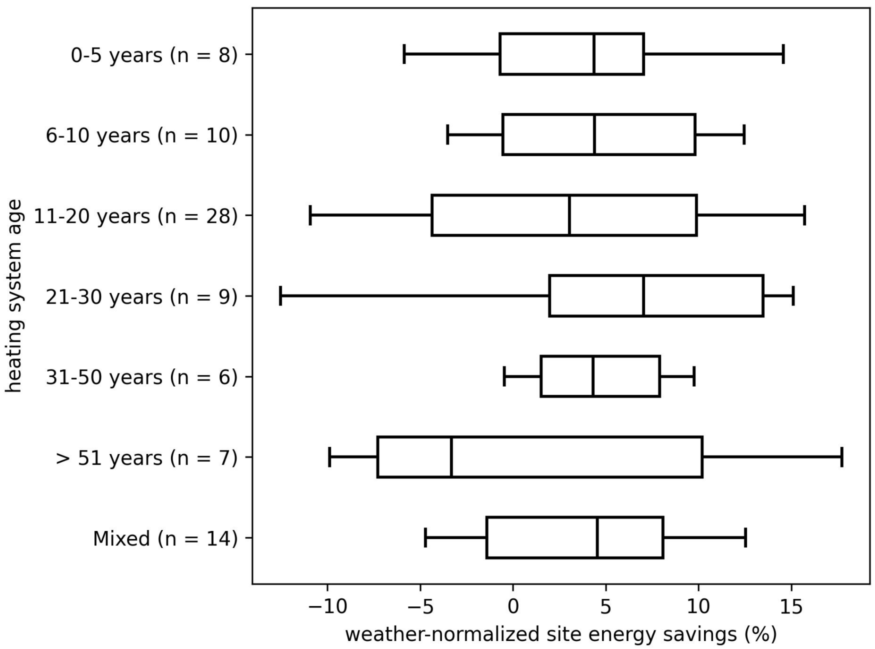
- Energy use highly variable before and after tune-ups
- 4.1% median site energy savings
- 34% of buildings increased energy use (equip fixed? operational changes?)

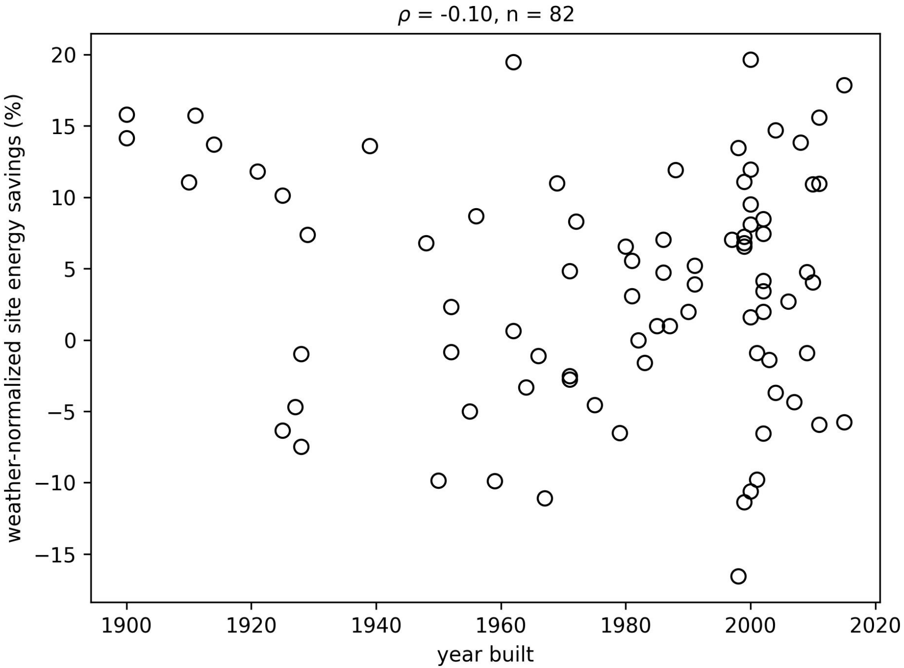




Seattle: Relationships between savings, measures, etc.?

- We fit hundreds of regression models, looking for trends





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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?)

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)

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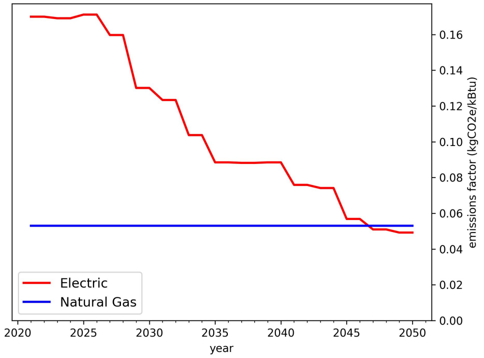
Aspen: BPS policy modeling

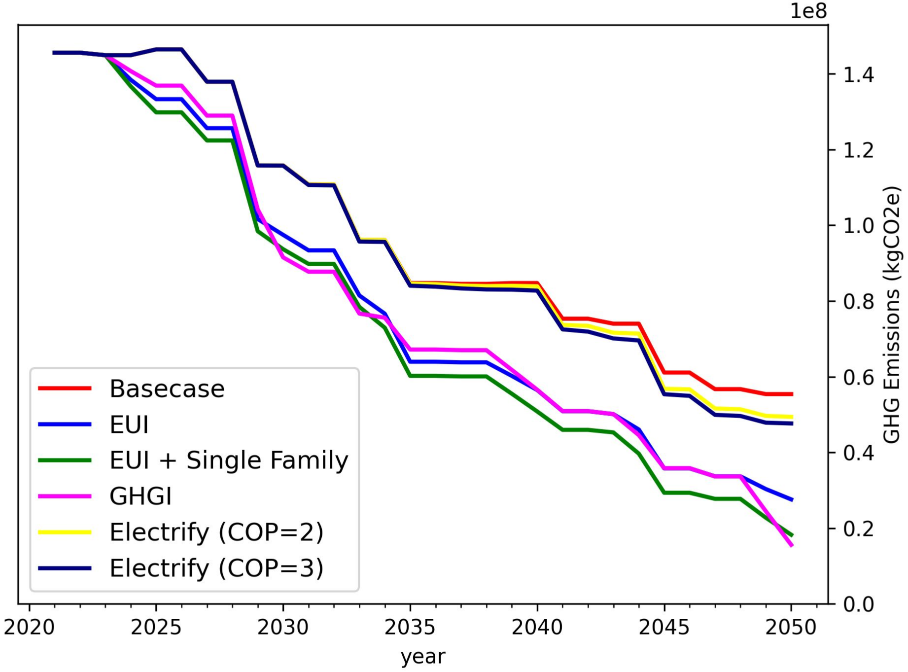
- We predicted each building's electric and gas from 2020-2050
  - Targets are specific values of either EUI or GHGI
  - Buildings meet targets with efficiency or electrification

- 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





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Aspen: Lessons 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

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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)

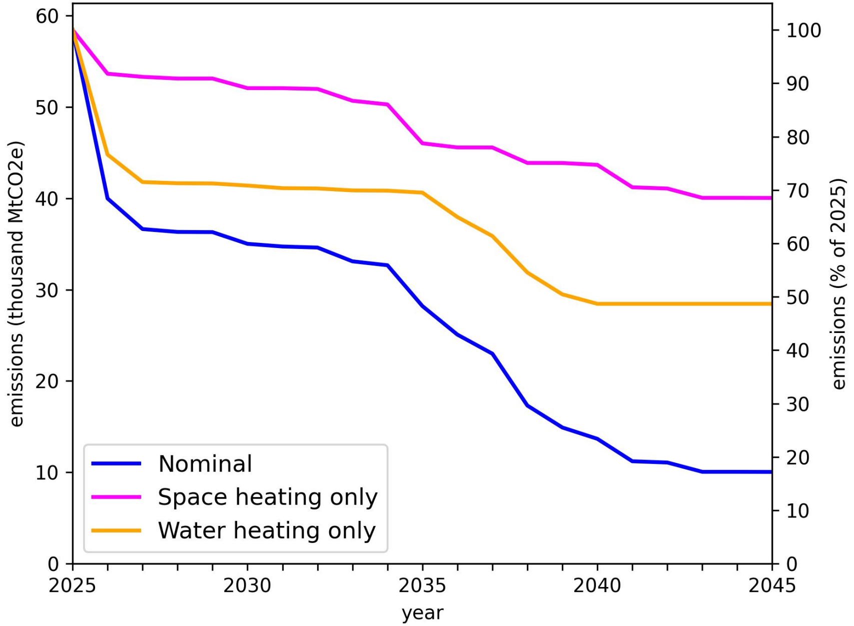
Berkeley: Modeling policy scenarios

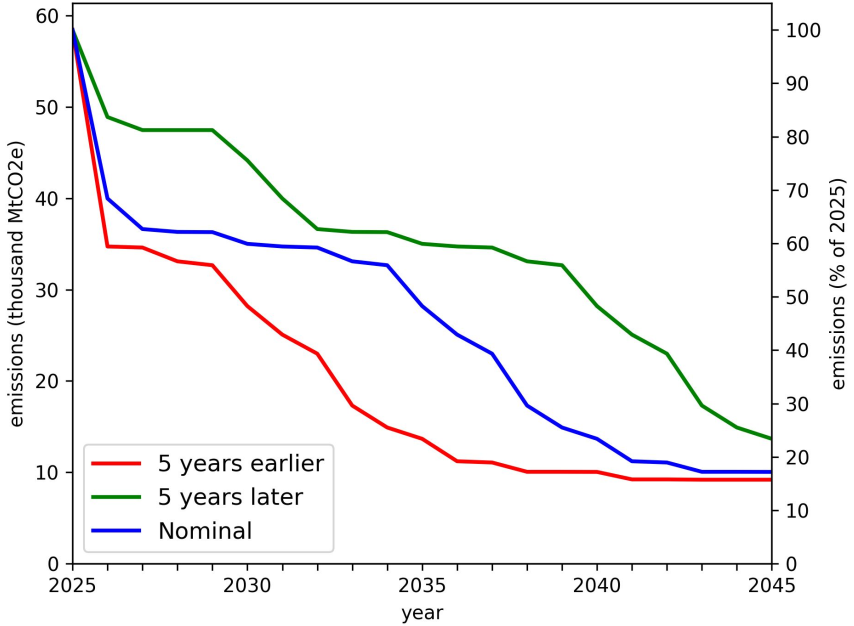
- We modeled each buidling's electric and gas use from 2025-2045
  - Equipment replacement age depends on end use and system type
  - New equipment efficiency depends on current year (COP starts at 2.0, then 3.0, then 4.0)

- 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

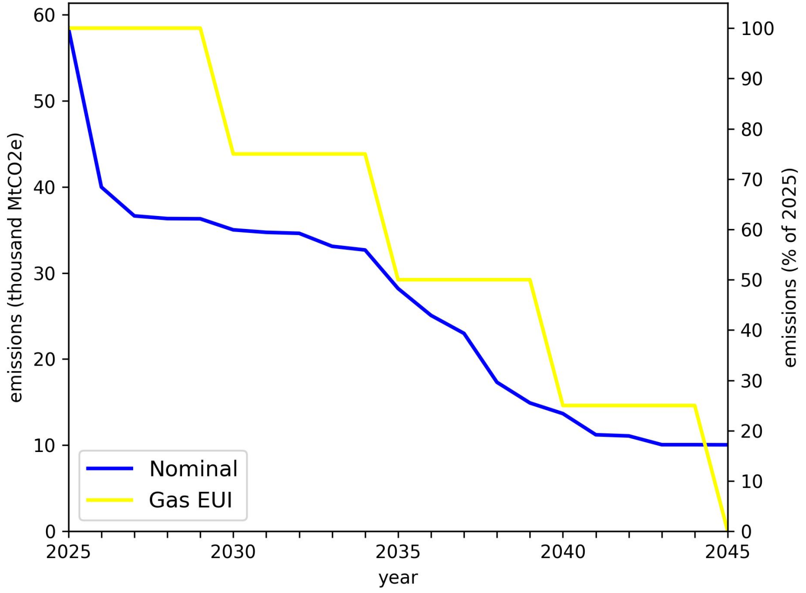
- Nominal emissions savings: 82% (31% from space heating, 51% from water)
- Replacing 5 years earlier/later: final savings barely change, but cumulative savings change significantly

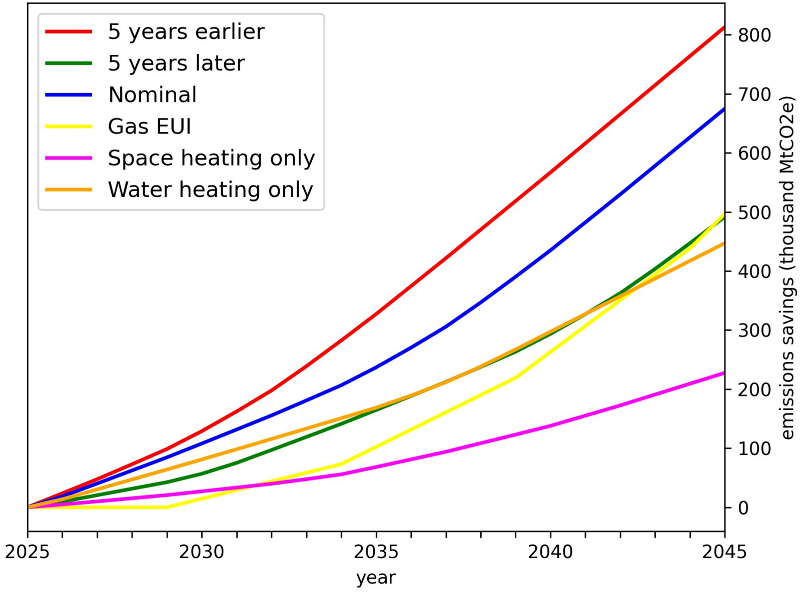




Berkeley: Electrification vs. gas reduction

- 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

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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

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Appendix

Abstract

- A key component of accelerating decarbonization of the built environment is municipal & state policy making requiring consistent ongoing performance / carbon reduction in buildings. Careful crafting of these requirements, called Building Performance Standards (BPS), is critical to their long-term success. This presentation will dive into the structures and frameworks that exist for this type of policy making, compliance pathways, and some examples from cities across the US.

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‘Cool Climate’ Office Monthly Electricity Profile

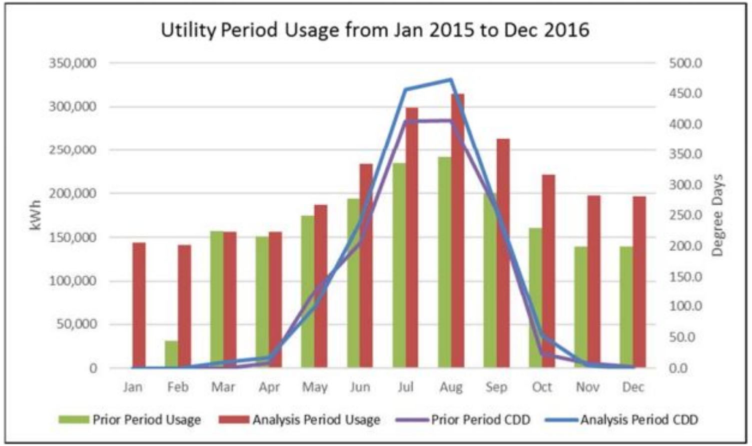

Figure 14, Electricity Consumption Comparison

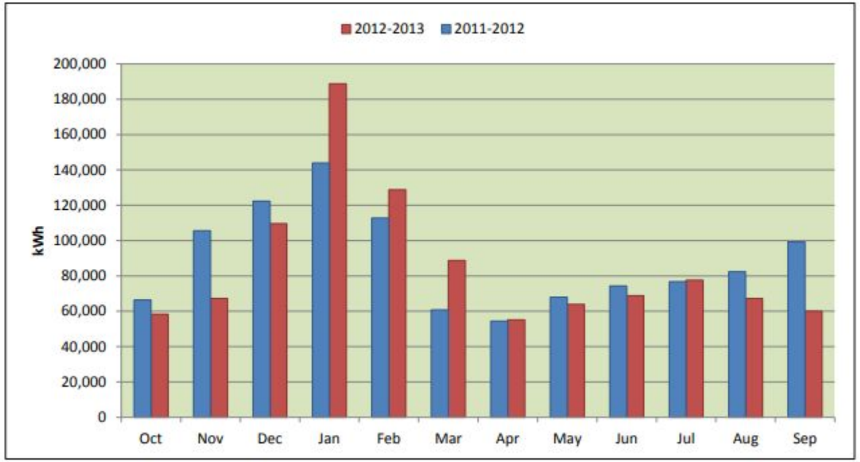

Figure 15, Electricity Consumption Comparison (2012 – 2013)

Natural Gas for Heat

Electric Resistance Heat

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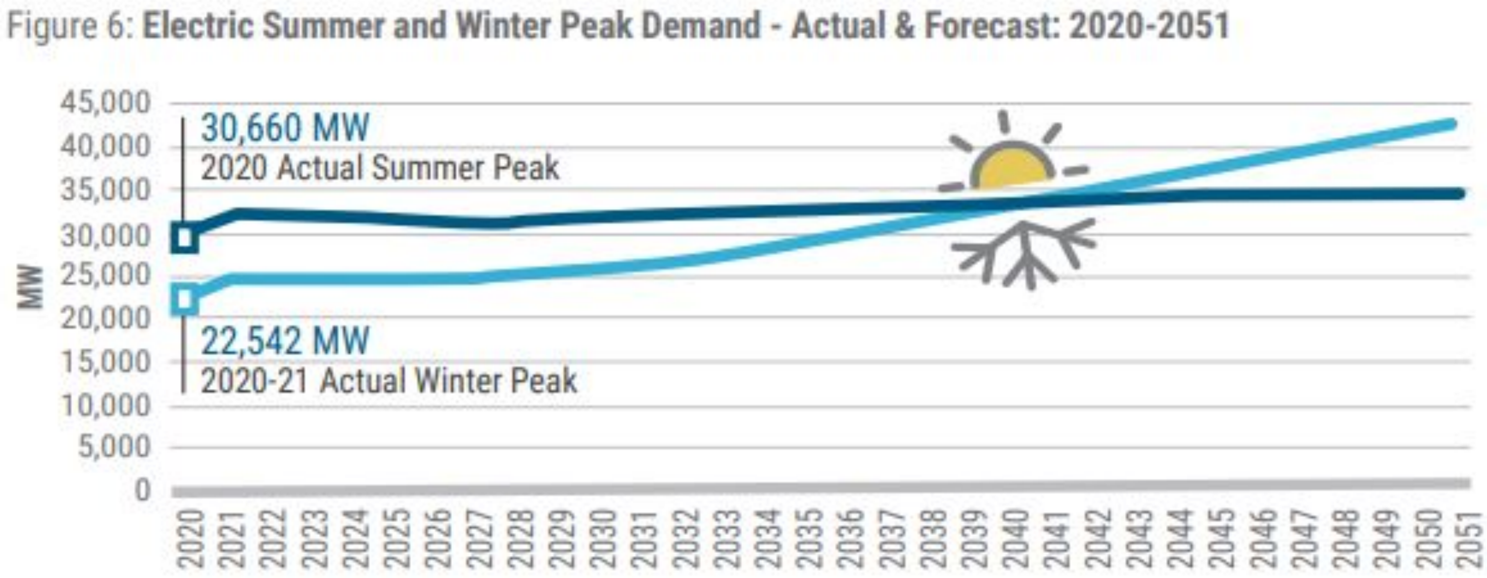

NYISO – Power Trends 2021 – State of the Grid

Grid Carbon Intensity Projections through 2050

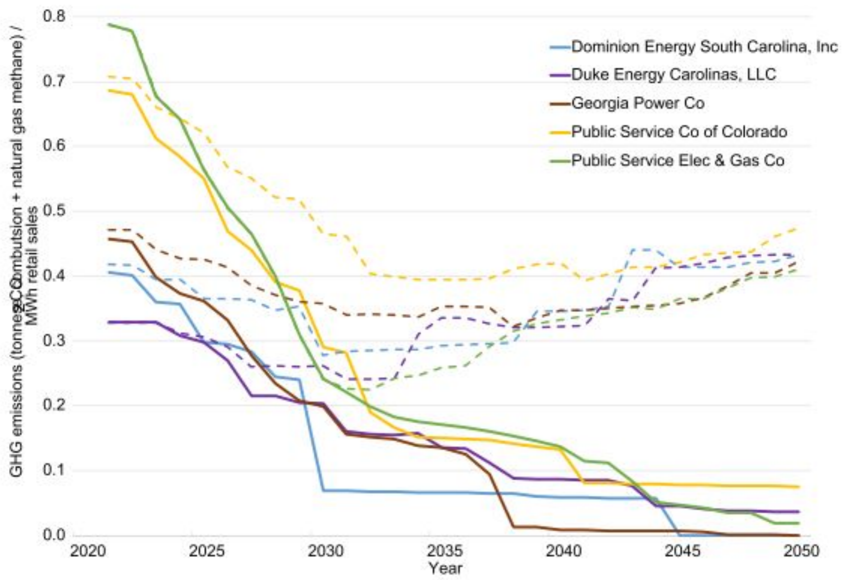

Figure 2. Projected annual average GHG emissions factors for five example utilities with net-zero carbon goals, 2021–2050. Solid lines show model projections if all new build power is zero carbon; dashed lines show model projections if all new build power is supplied by NGCC units, assuming national average methane intensity for the natural gas supply.

https://www.researchgate.net/publication/353729298_Emissions_projections_for_US_utilities_through_2050/download

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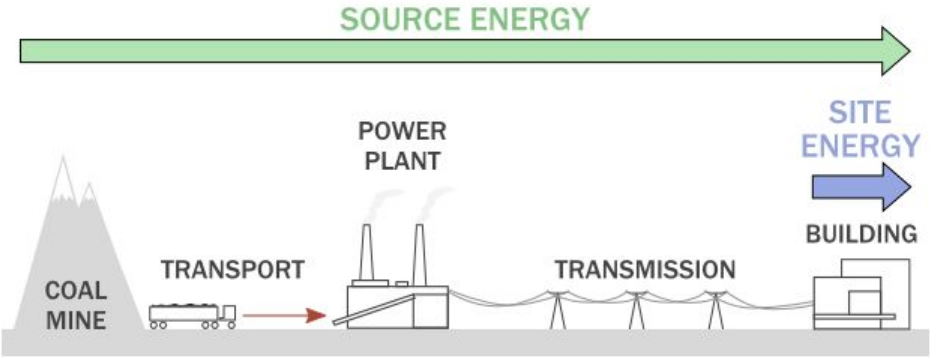
Terminology: Site v Source Energy

- How much actual energy does your building use.

- How much energy was used to generate + transmit the



Source-Site Ratios for all Portfolio Manager Energy Meter Types

Energy Type	U.S. Ratio	Canadian Ratio
Electricity (Grid Purchase)	2.80	1.96
Electricity (Onsite Solar or Wind - regardless of REC ownership)	1.00	1.00
Natural Gas	1.05	1.01
Fuel Oil (No. 1,2,4,5,6, Diesel, Kerosene)	1.01	1.01
Propane & Liquid Propane	1.01	1.04
Steam	1.20	1.33
Hot Water	1.20	1.33
Chilled Water	0.91	0.57
Wood	1.00	1.00
Coal/Coke	1.00	1.00
Other	1.00	1.00

Credit: archtoolbox.com, U.S. EPA ENERGY STAR Portfolio Manager

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GHG Footprint – Commercial Real Estate

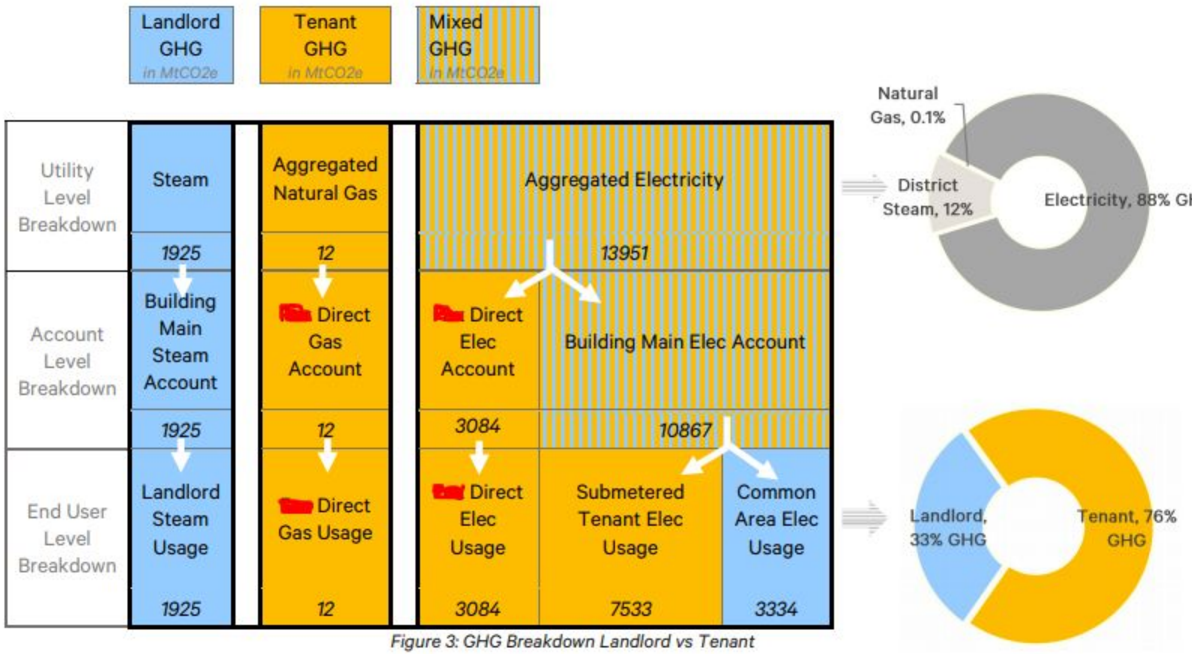

Figure 3: GHG Breakdown Landlord vs Tenant

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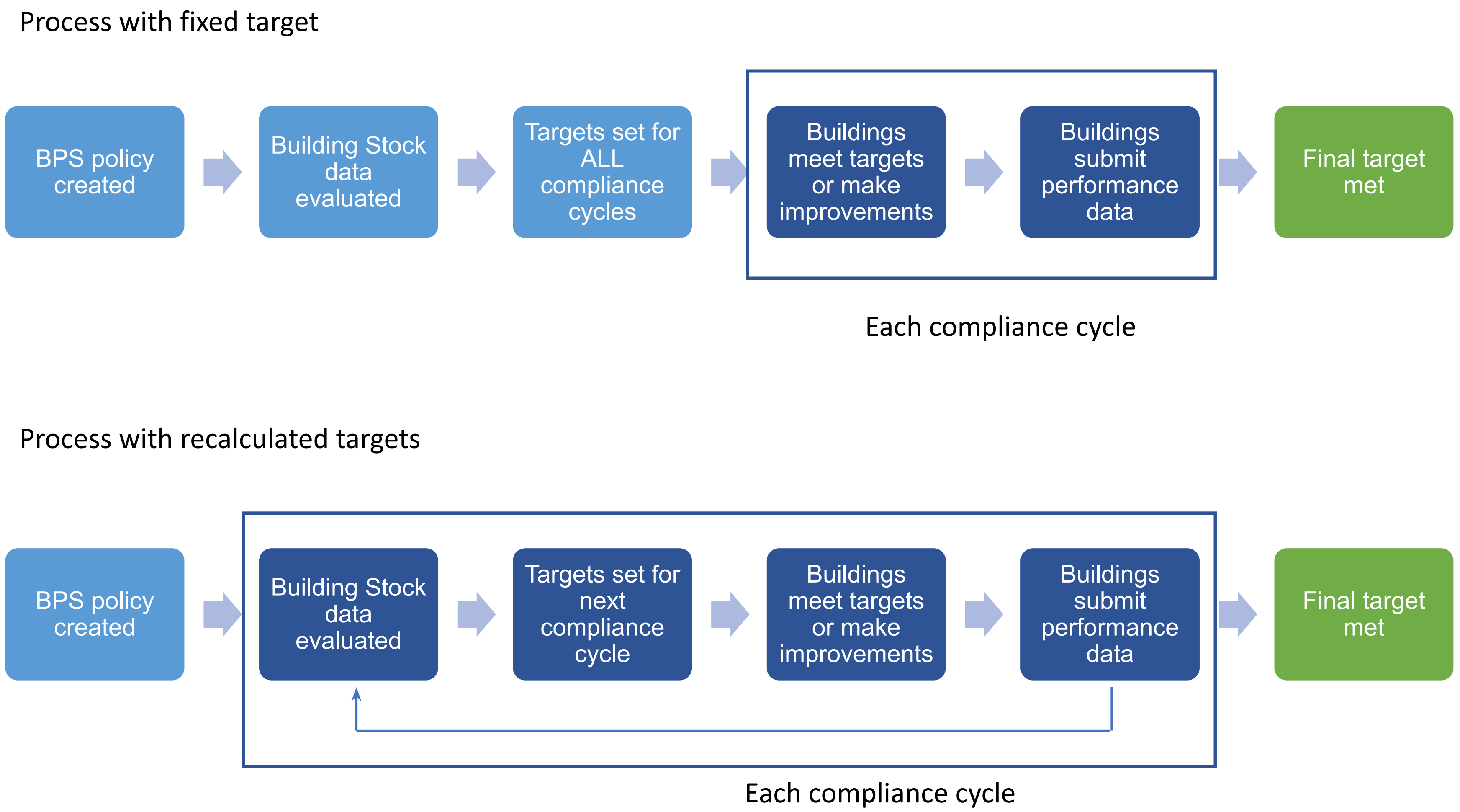
Process with fixed target
BPS policy created
Building Stock data evaluated
Targets set for ALL compliance cycles
Buildings meet targets or make improvements
Buildings submit performance data
Final target met
Each compliance cycle
Process with recalculated targets
BPS policy created
Building Stock data evaluated
Targets set for next compliance cycle
Buildings meet targets or make improvements
Buildings submit performance data
Final target met
Each compliance cycle

Background: Reducing emissions with BPS