BUILDINGENERGY BOSTON

Stretch Code… It's Electrifying!

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Northeast Sustainable Energy Association (NESEA)
March 1, 2022

Stretch Code…

It's Electrifying!

March 1, 2022
BuildingEnergy Boston

DOER
Massachusetts Department of Energy Resources

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Session Abstract

Over the past two years, Massachusetts and its consultant team has studied cost-effective commercial building approaches aligned with climate goals. This session will present a building-level review of the analysis done to inform Massachusetts's upcoming stretch energy code. We will focus on a) Thermal Energy Demand Intensity (TEDI), b) critical role of envelope, thermal bridges, and air infiltrations, c) implications to carbon emission and fossil fuel use, and d) cost optimization for different commercial building types. The session will contain an opportunity for discussion between the design community and the DOER staff and consultants involved in the study.

Learning Objectives

- Describe the role that building envelope plays in GHG emission reduction goals and building life cycle costs.
- Summarize the building science considerations that are being used to inform updates to building code development.
- Define Thermal Energy Demand Intensity (TEDI) metric and how it can be used for low carbon building design.
- Explore how to optimize costs when following the proposed stretch code.

Scope of this presentation

- Analysis that supports the proposed updates to Commercial Stretch Code
  - Provides underlying energy efficiency requirements
  - Thermal energy demand limits
  - Envelope/air infiltration
  - Thermal bridging
  - Cost optimization

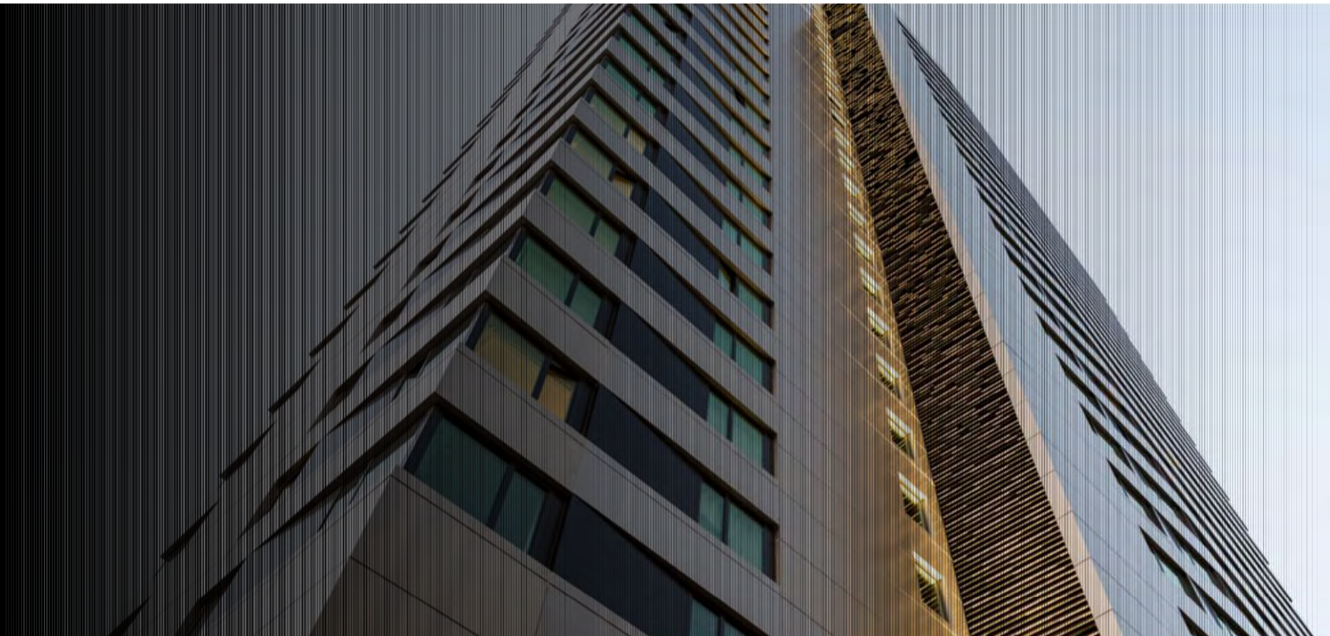
Scope of this presentation

- Residential Proposed Stretch Code

- Specialized Opt-in Code
  - Net Zero definition
  - Electric pre-wiring
  - Solar requirements

1

Building electrification



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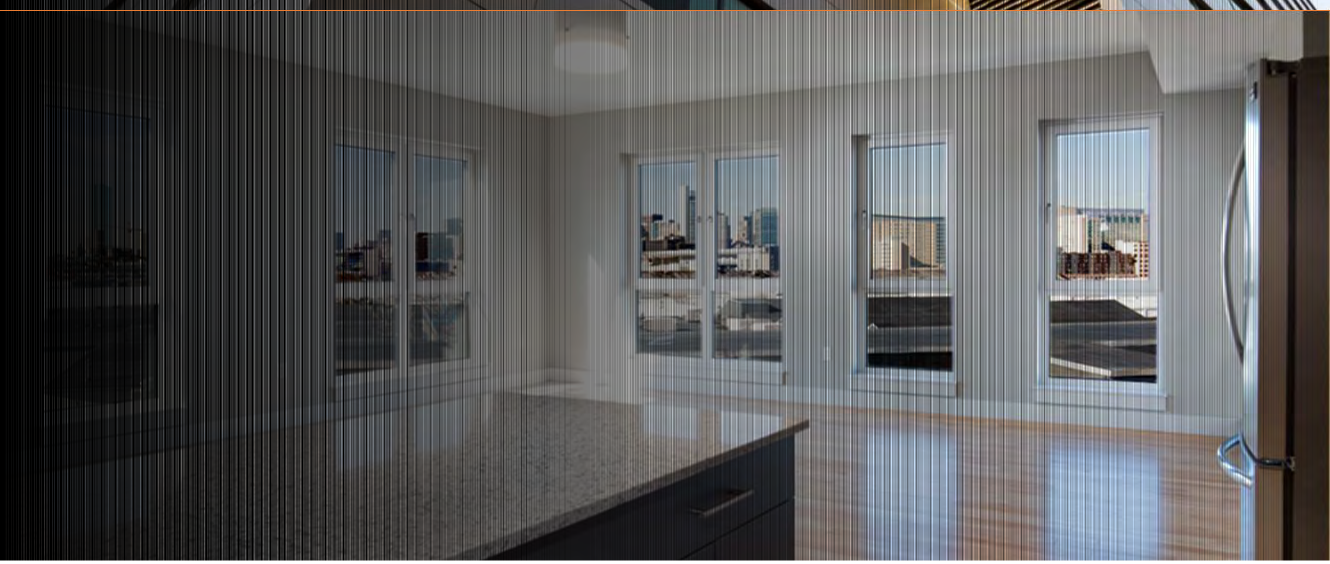
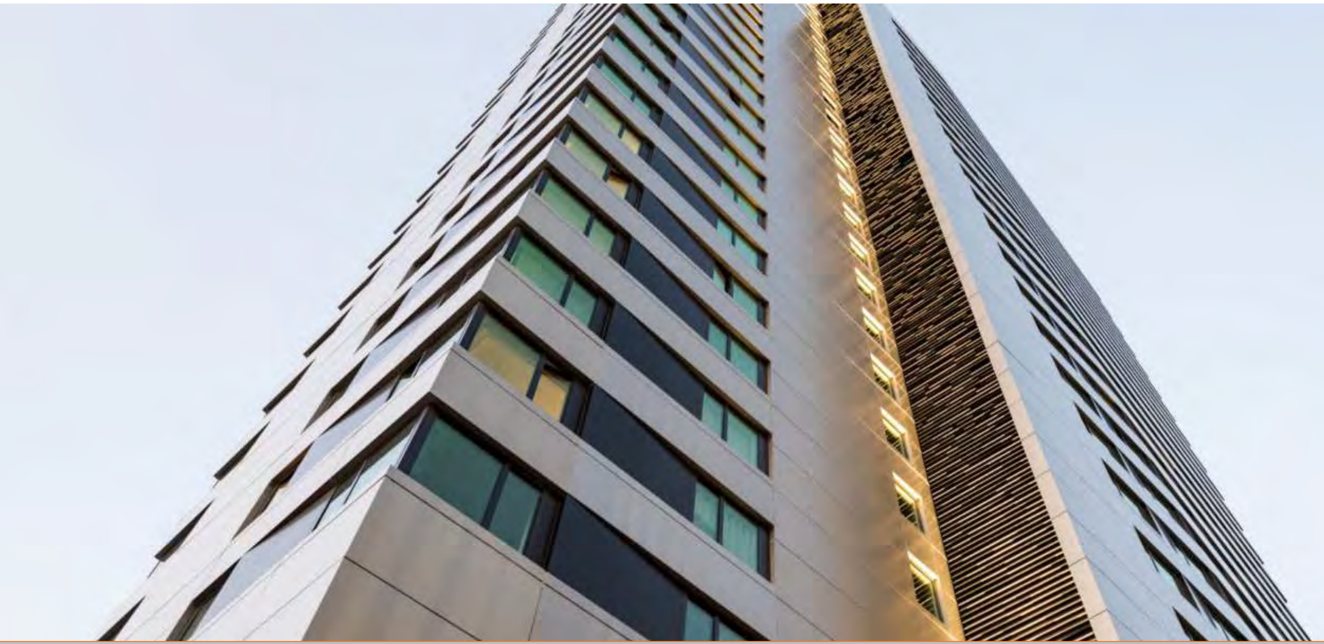
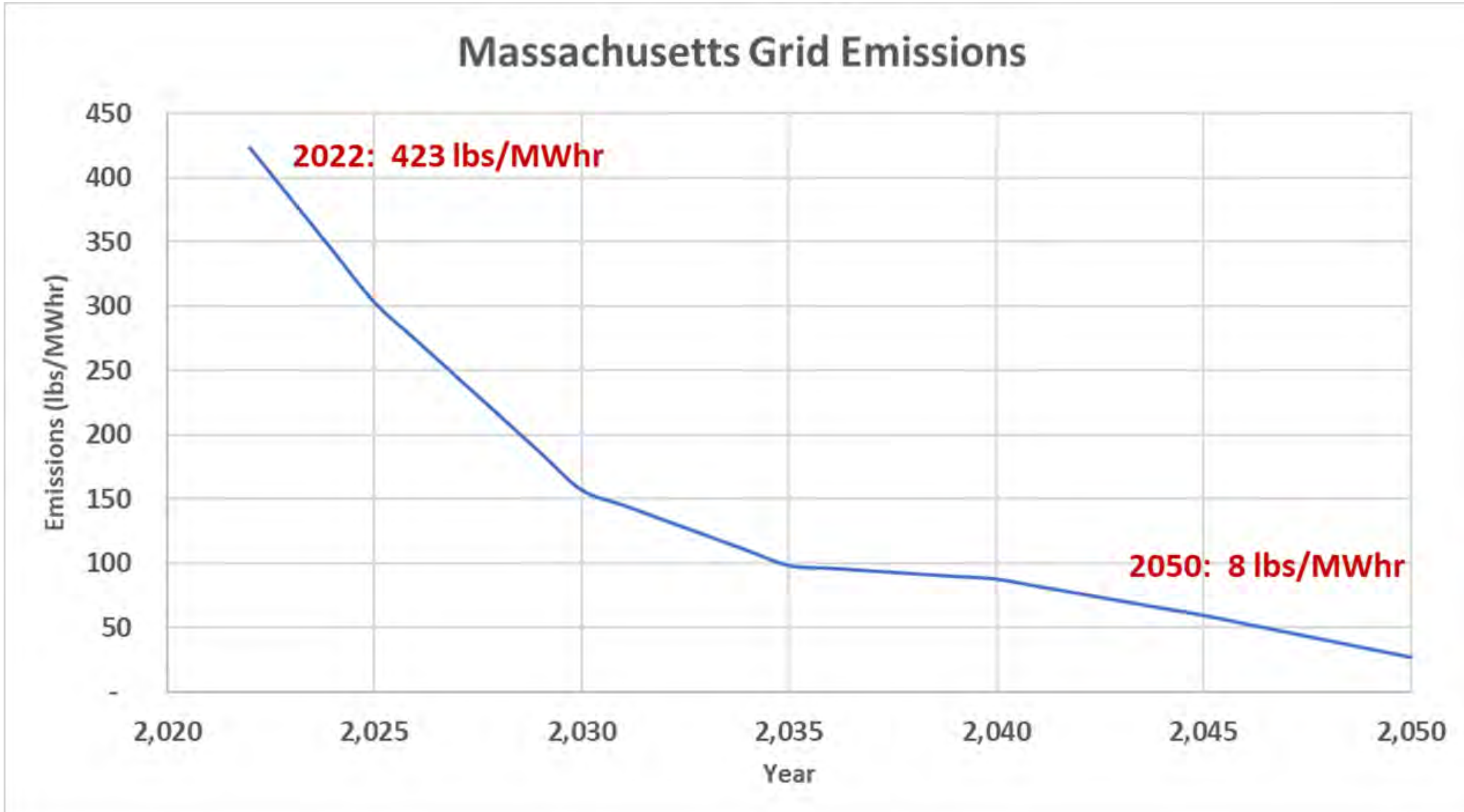
Heating reduction



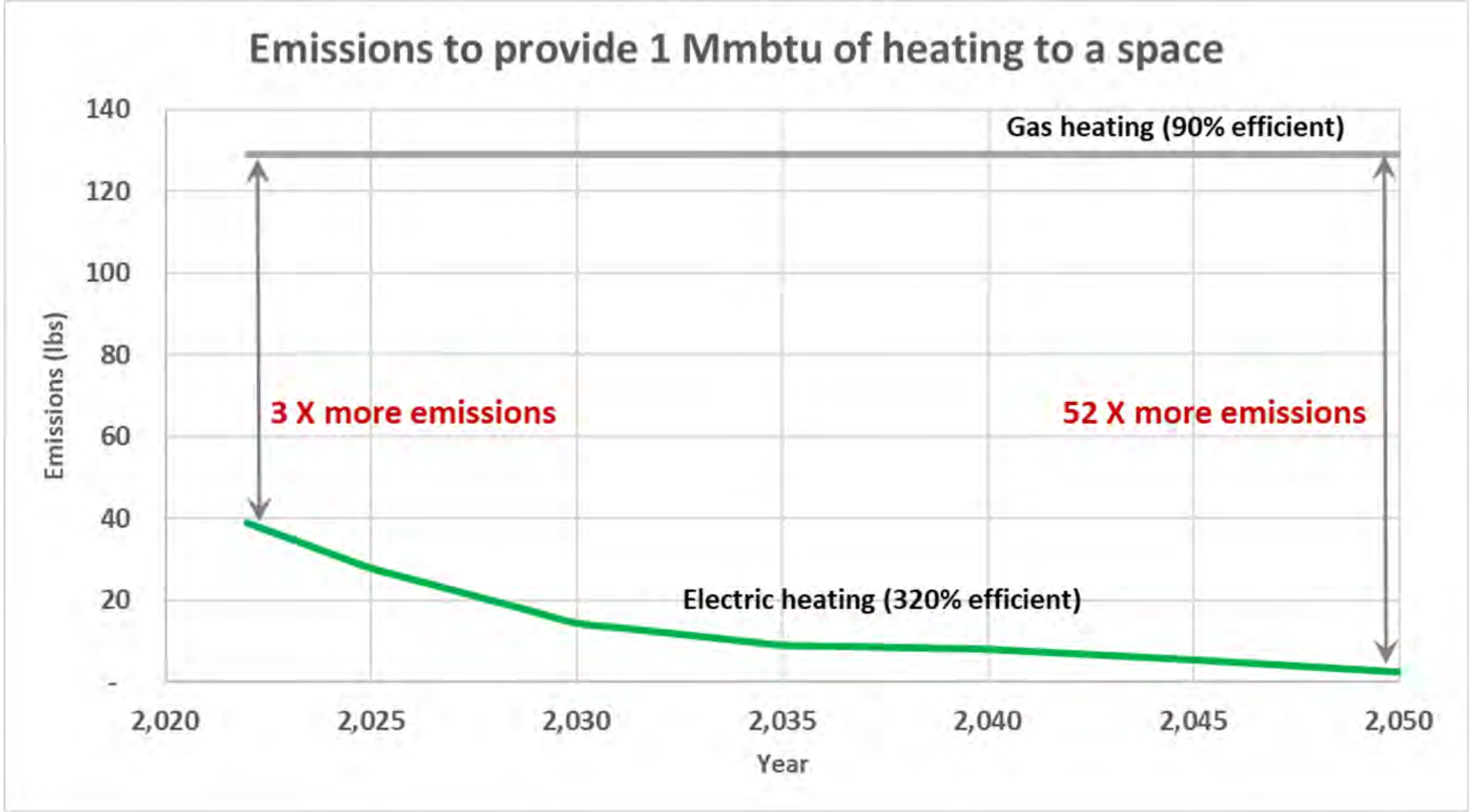


① Why building electrification?



Massachusetts Grid Emissions
2022: 423 lbs/MWhr
2050: 8 lbs/MWhr
Emissions (lbs/MWhr)
450
400
350
300
250
200
150
100
50
-
2,020
2,025
2,030
2,035
2,040
2,045
2,050
Year



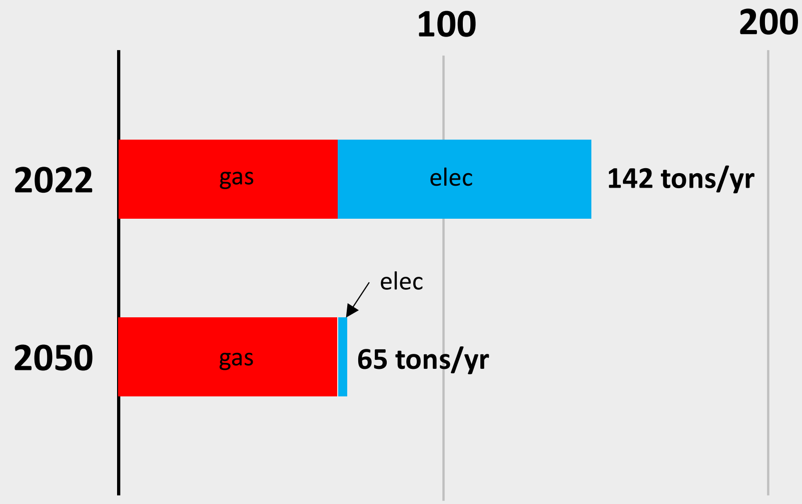
Emissions to provide 1 Mmbtu of heating to a space
140
120
100
80
60
40
20
-
Emissions (lbs)
Gas heating (90% efficient)
3 X more emissions
52 X more emissions
Electric heating (320% efficient)
2,020
2,025
2,030
2,035
2,040
2,045
2,050
Year

50,000-sf multifamily

Choice 1

All gas

- 95% natural gas space heating
- 95% natural gas water heating

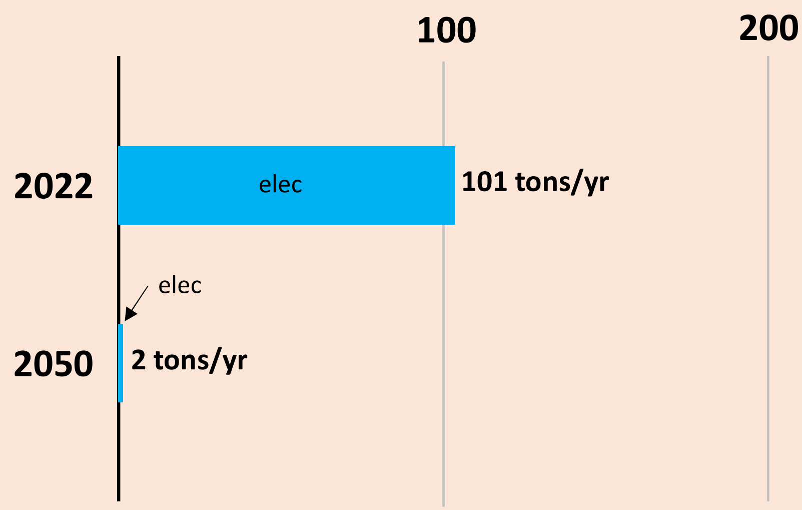


50,000-sf multifamily

Choice 2

All elec

- 320% air source heat pump space heating
- 250% air source heat pump water heating



② Why heating reduction?

Quality envelope

+

Low air infiltration

+

Energy recovery

The "trifecta"

Yields

Less equipment

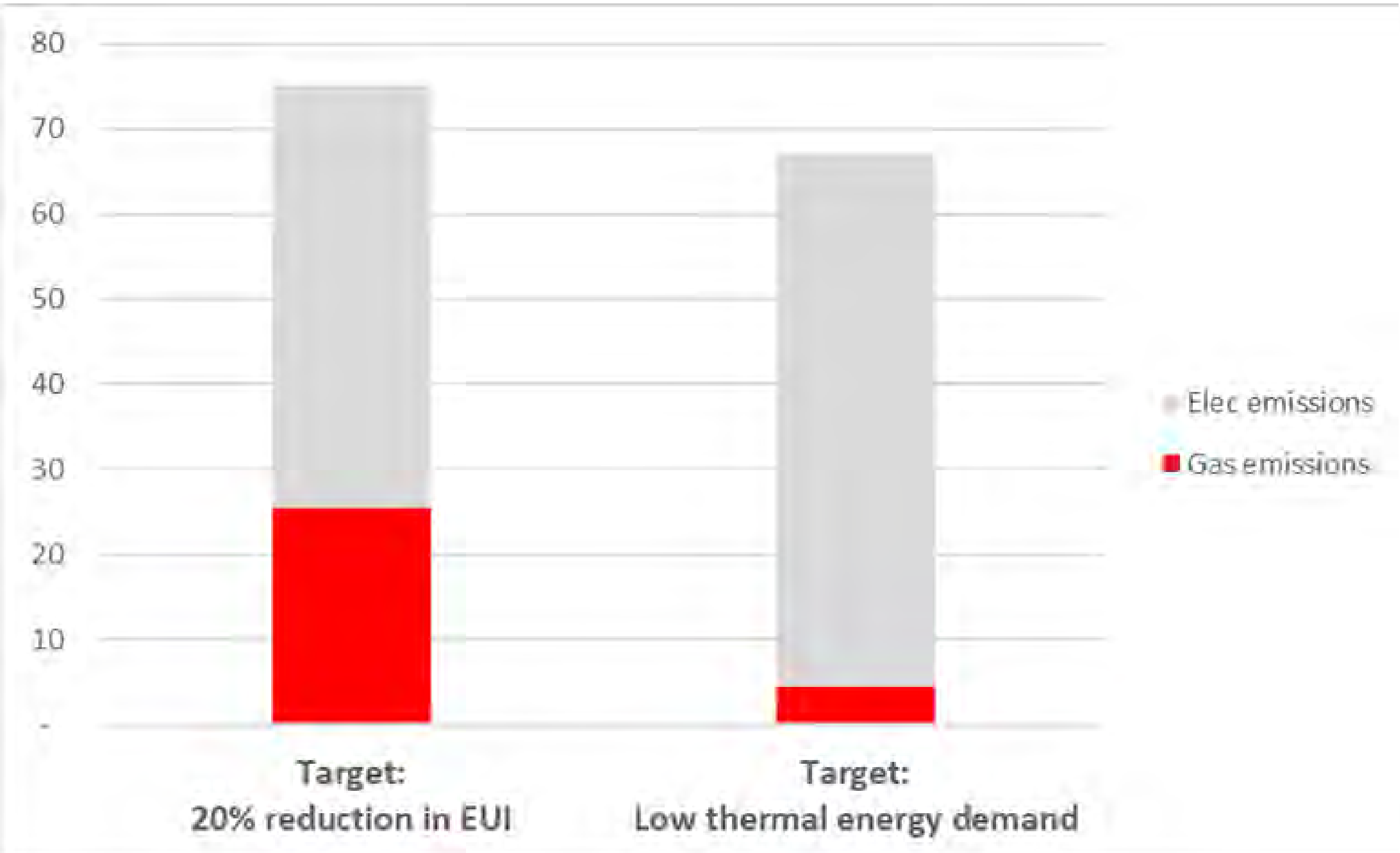
Improved comfort

More durable

Almost no heating loads

Easier electrification, if you choose it

Very low emissions, if you stick with gas



Targets matter!

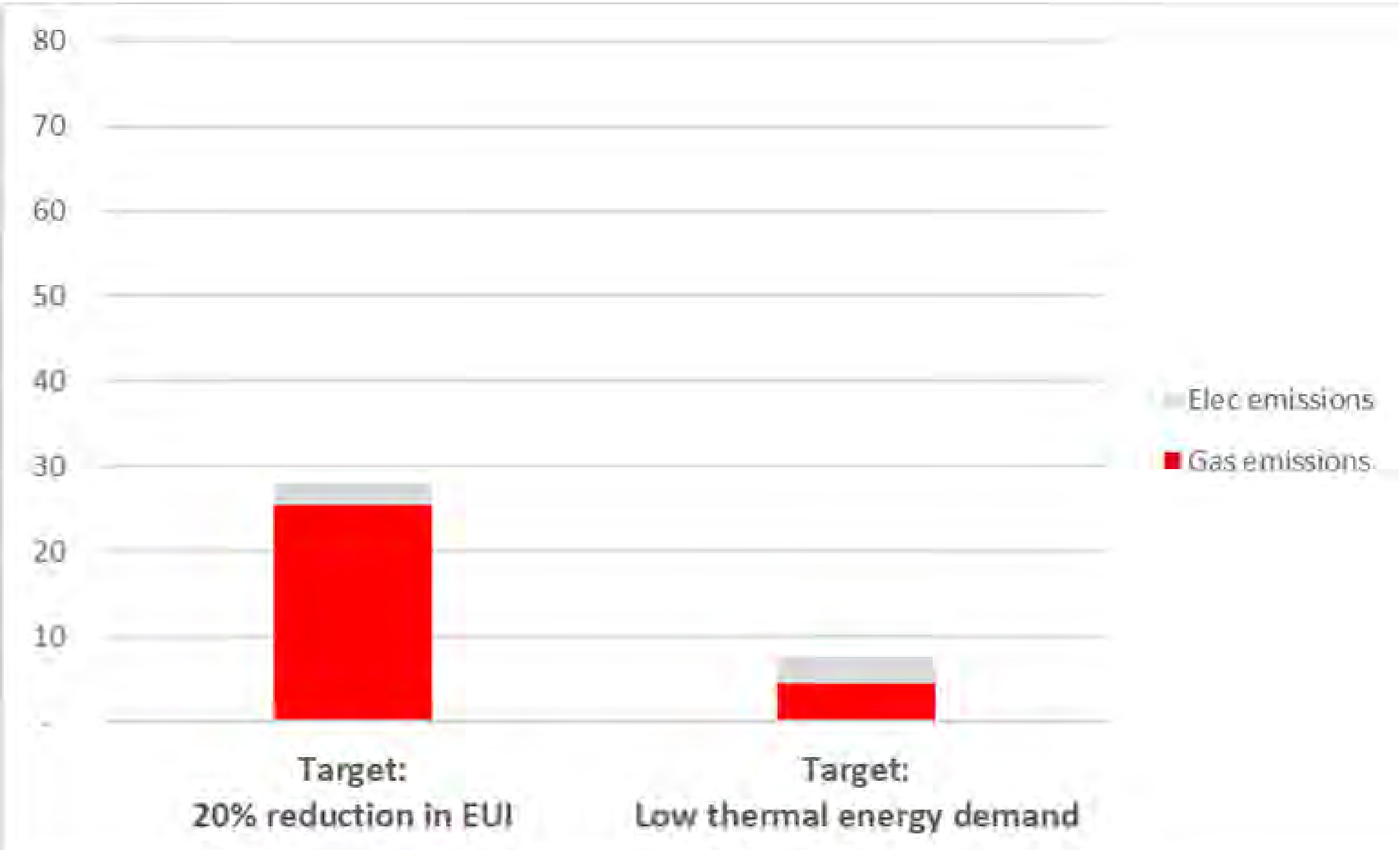
Left: Targeting EUI reduction

Right: Targeting heating demand reduction

Year: 2030

Grid emission rate: 157 lbs/MWhr

Secondary school, gas space heating



Year: 2050

Grid emission rate: 8 lbs/MWhr

Secondary school, gas space heating

Quality envelope

+

Low air infiltration

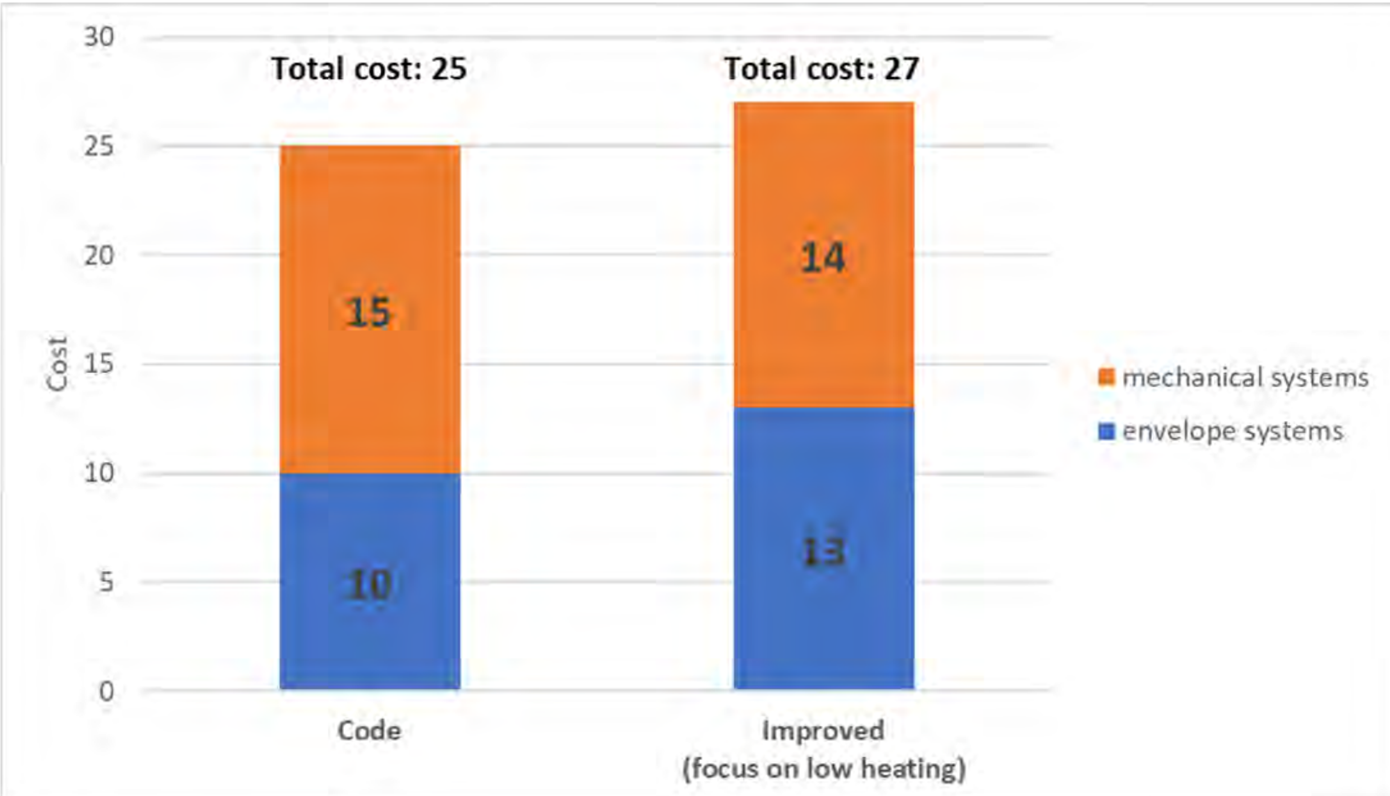
+

Energy recovery

The "trifecta"

Yields

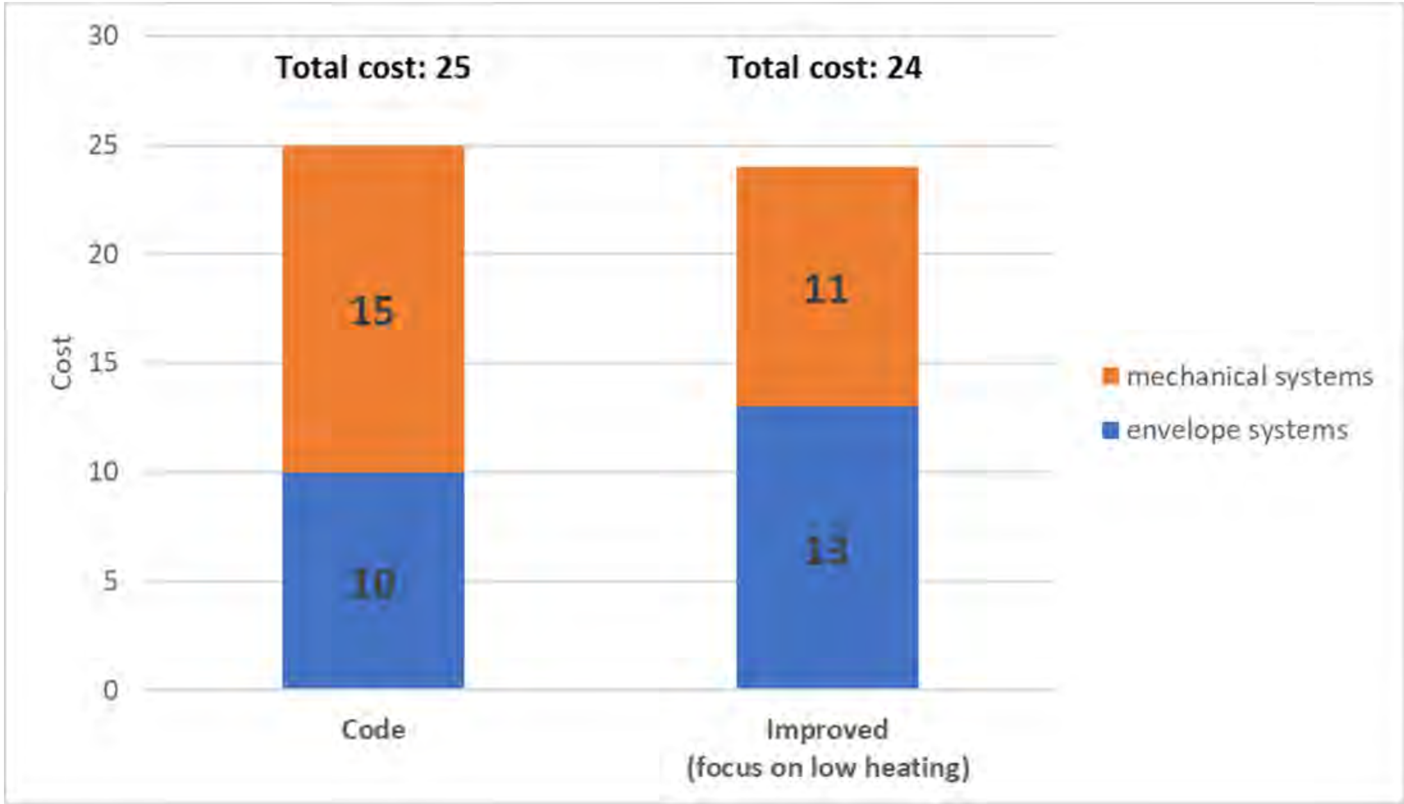
Less premium cost than you'd think



Total cost: 25
Total cost: 27
30
25
20
15
10
5
0
Cost
15
10
14
13
Code
Improved
(focus on low heating)
mechanical systems
envelope systems

More

Less


Total cost: 25
Total cost: 24
30
25
20
15
10
5
0
Cost
15
10
11
13
Code
Improved
(focus on low heating)
mechanical systems
envelope systems

More

Less

Quality envelope

+

Low air infiltration

+

Energy recovery

The "trifecta"

Yields

Lower peak loads to help building electrification

Commercial Stretch Code Study

- Establish Industry Standard Energy Models
- Passive House Feasibility – how low can each typology go?
- Investigate
  - Industry Research
  - Comparable Codes
- Sensitivity Analysis
  - Optimizing system performance
  - Identifying inflection point of diminishing returns
- Cost Analysis
- Evaluate Impact – Peak energy, Emissions, Resiliency

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Establish Industry Standard for 8 Building Typologies

Office

- Small
- Large (40% & 50% WWR)
- Office-Lab (40% & 50% WWR)

K-12 Schools

- Primary (Elementary)
- Secondary (High School)

Multifamily

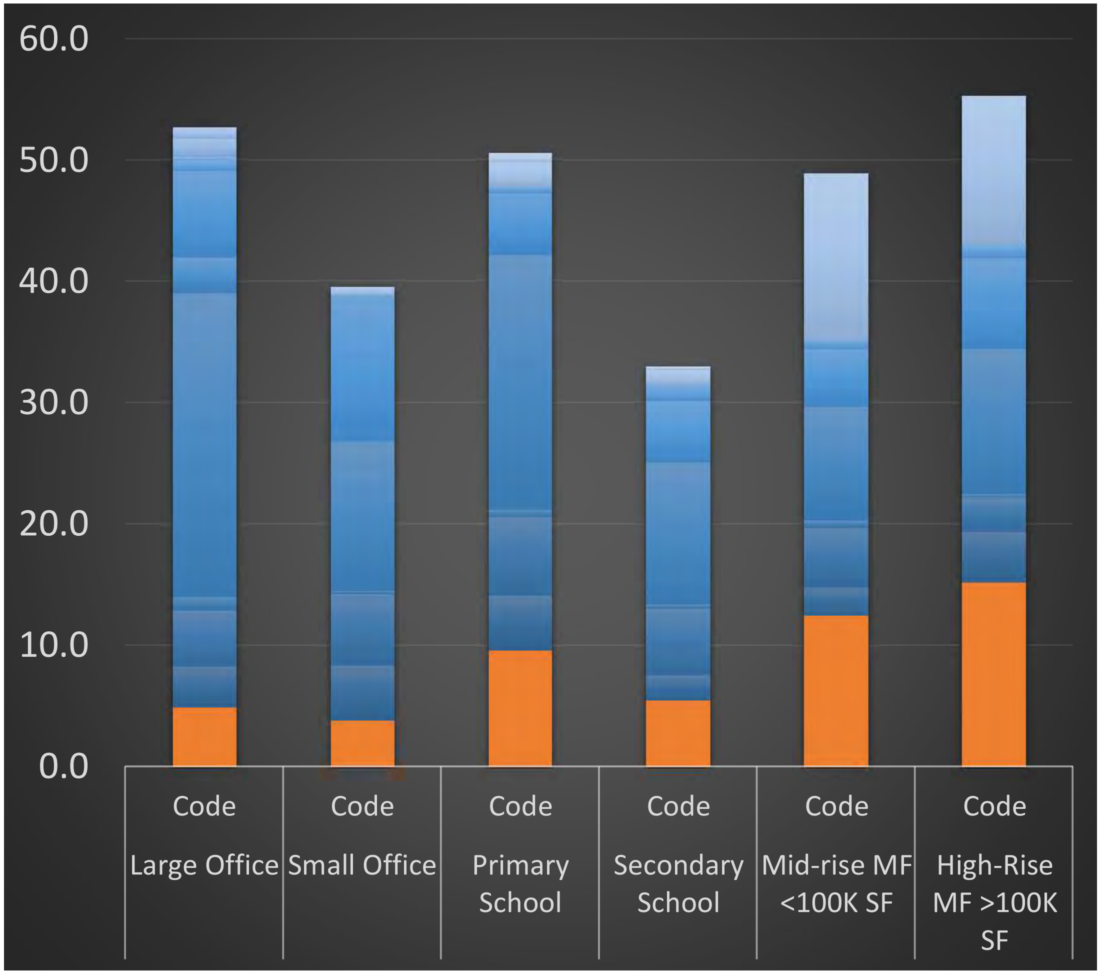
- Midrise, 4 stories, slab-on-grade
- Midrise, 8 stories over podium <100,000 sf
- Highrise, 26 stories >100,000 sf

Current Energy Code

- Buildings over 100,000 sf modeled to just meet 10% site energy savings required
- Buildings under 100,000 sf modeled to meet 2018 IECC with MA Amendments

Real-World Design Assumptions

- Plug loads
- Schedules and thermostats
- Ventilation rates (+30%)

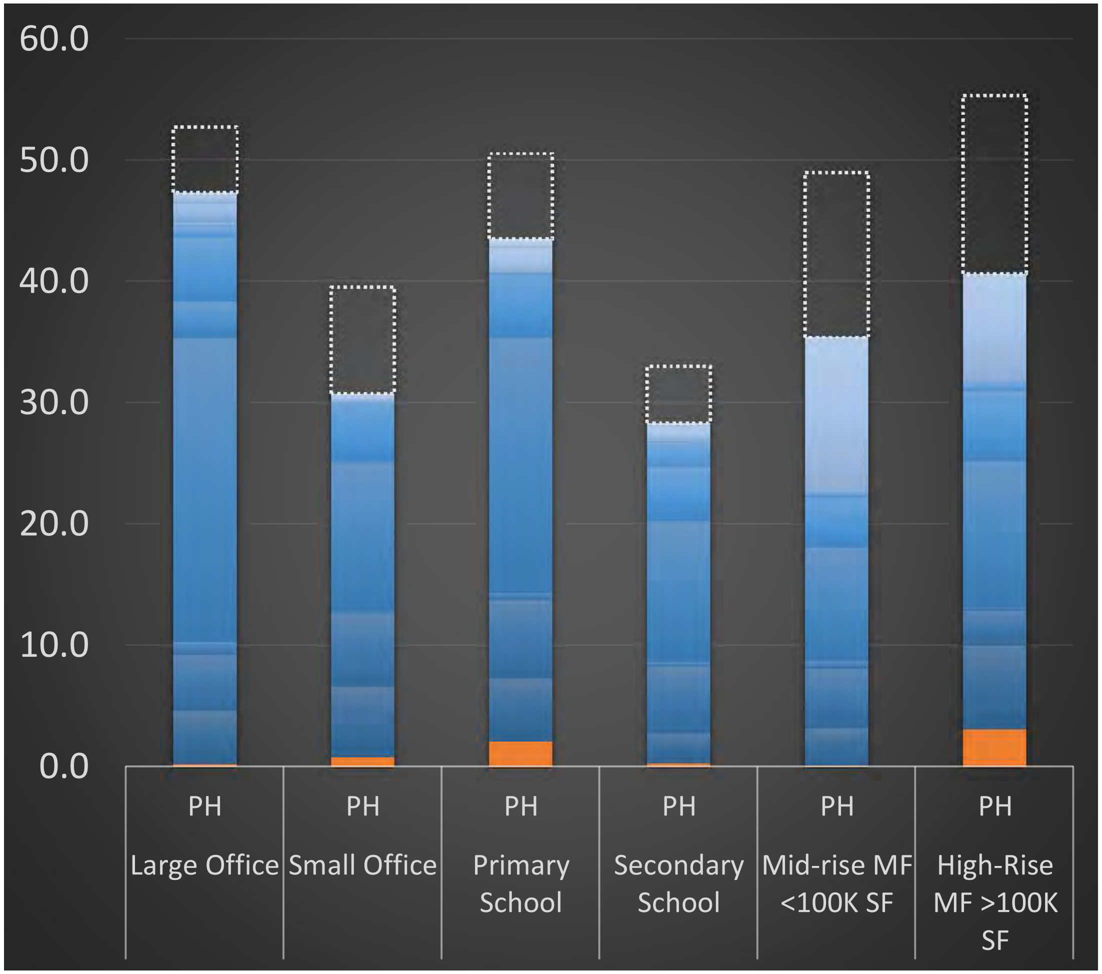


Site EUI in kBtu/sf/yr

Passive House Feasibility (PHPP)

Identify system performance required to achieve Passive House:

- Windows primarily triple pane
- Infiltration per PH standards (0.4 vs. 0.06 cfm/sf)
- DOAS systems with ERVs at 80%+ heat recovery effectiveness
- High performing H/AC systems that are commonly used in new construction (C406 compliant)
- Opaque envelope systems designed with thermal bridge accounting, but meet prescribed maximum code U-factors with C406 15% improvement applied



Site EUI in kBtu/sf/yr

Industry Research

- Passive House vs. Code
- Net Zero and Deep Energy Reduction Case Studies
- ASHRAE RP-1651 Development of Maximum Technically Achievable Energy Targets for Commercial Buildings (2016)
  - Reduce internal loads
  - Reduce building envelope loads
  - Reduce HVAC distribution system losses
  - Decrease HVAC equipment energy consumption
  - Major HVAC reconfigurations

Other Energy Codes

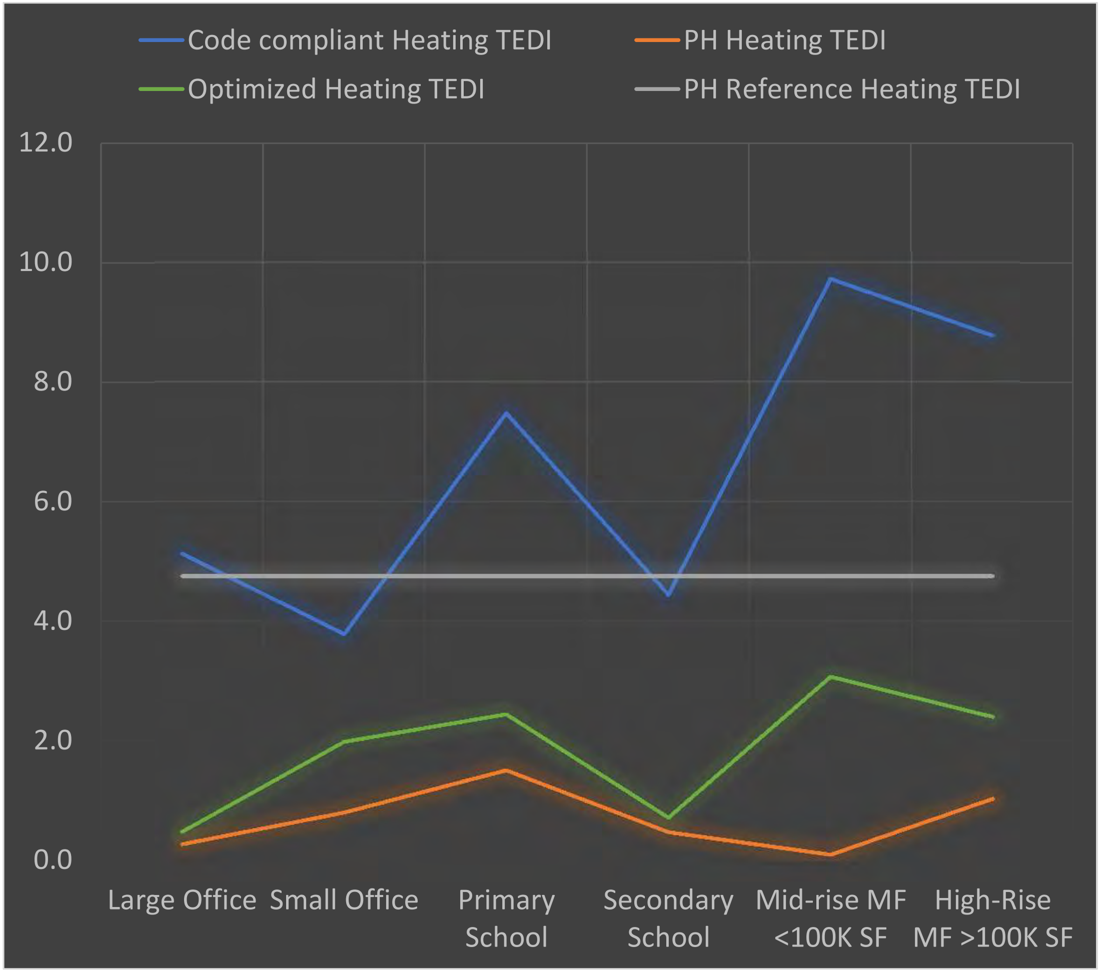
- What are other codes and standards doing?
  - IECC 2021
    - new C406 point distribution
    - infiltration testing and enclosure cx
  - ASHRAE 90.1 – Addendum av: Thermal Bridge accounting for Appendix A
  - Seattle Energy Code: focus on improved envelopes and electrified heating and DHW systems
  - Heating TEDI Codes – minimize heating demand with improved envelopes and heat recovery in ventilation systems
    - Toronto Green Standard (CZ5)
    - British Columbia Step Code (CZ4-8)
    - Both of the above target 4.75 kBtu/sf/yr as highest Step / Tier

TEDI – Thermal Energy Demand Intensity

- Units: kBtu/sf/yr
- Intensity: gross-heated square foot
  - Passive House: Treated Floor Area (TFA)
- Thermal Energy Demand: required thermal energy needed to be added (or removed) to meet the thermostat setpoints
  - Not end use-value: must be thermal energy output BEFORE equipment efficiency
  - Heating TEDI (added energy) and Cooling (removed energy) TEDI
- eQuest: SS-D Building HVAC Load Summary
  - Building Heating Total in kBtu / sf = Heating TEDI
  - Building Cooling Total in kBtu / sf = Cooling TEDI

TEDI – Thermal Energy Demand Intensity

- Using actual internal heat gain assumptions, Heating TEDIs all are below 10.
- Passive House Heating TEDIs all are below 2.0
- Next step – optimization: where is the point of diminishing returns related to cost and effort?



Heating TEDIs in kBtu/sf/yr

Optimizing for Performance

Did NOT investigate reduction of internal loads

Opportunities for reduction in lighting and equipment loads

Focused on Envelope performance optimization FIRST

Second, evaluated Mechanical system optimization

Optimizing for Performance

Infiltration

	Site EUI savings	Peak Cooling demand savings (btu/h/sf)	Peak Heating Demand savings (btu/h/sf)
Infil.-1: 1	0.00	0.00	0.00
Infil.-2: 0.6	0.68	-0.03	1.01
Infil.-3: 0.4	1.05	-0.07	1.37
Infil.-4: 0.25	1.30	-0.03	1.96
Infil.-5: 0.129	1.48	-0.03	2.53
Infil.-6: 0.075	1.57	-0.04	2.64

Optimizing for Performance

Window Thermal and Shading

	Site EUI savings	Peak Cooling demand savings (btu/h/sf)	Peak Heating Demand savings (btu/h/sf)
Wind U-Perf-1: 0.5	-0.29	0.00	-0.23
Wind U-Perf-2: 0.42	0.15	0.05	0.17
Wind U-Perf-3: 0.38	0.35	0.02	0.35
Wind U-Perf-4: 0.35	0.48	0.07	0.46
Wind U-Perf-5: 0.32	0.60	0.06	0.43
Wind U-Perf-6: 0.29	0.71	0.14	0.22
Wind U-Perf-7: 0.26	0.84	0.14	0.71
Wind U-Perf-8: 0.24	0.90	0.14	0.90
Wind U-Perf-9: 0.21	0.97	0.14	0.75
Wind U-Perf-10: 0.19	1.00	0.14	1.09
Wind SHGC-1: 0.4	-0.09	-0.04	0.12
Wind SHGC-2: 0.36	0.00	0.00	0.00
Wind SHGC-3: 0.32	0.06	0.08	-0.17
Wind SHGC-4: 0.28	0.12	0.12	-0.65
Wind SHGC-5: 0.26	0.13	0.15	-0.31

Optimizing for Performance

Above Grade Walls and Roof

	Site EUI savings	Peak Cooling demand savings (btu/h/sf)	Peak Heating Demand savings (btu/h/sf)
Ext. Wall-1: 0.167	-1.14	-0.01	-0.80
Ext. Wall-2: 0.118	-0.69	0.00	-0.50
Ext. Wall-3: 0.092	-0.46	0.07	-0.37
Ext. Wall-4: 0.075	-0.30	-0.01	-0.26
Ext. Wall-5: 0.063	-0.20	0.05	-0.52
Ext. Wall-6: 0.055	-0.12	0.00	-0.11
Ext. Wall-7: 0.048	-0.06	0.04	-0.02
Ext. Wall-8: 0.043	-0.01	0.02	0.00
Ext. Wall-9: 0.039	0.03	0.00	0.05
Ext. Wall-10: 0.036	0.06	0.02	-0.27
Ext. Wall-11: 0.033	0.08	0.04	0.09
Ext. Wall-12: 0.03	0.10	0.03	0.12
Ext. Roof-1: 0.033	-0.05	0.02	-0.31
Ext. Roof-2: 0.028	-0.03	0.02	-0.14
Ext. Roof-3: 0.025	0.00	0.00	0.00
Ext. Roof-4: 0.022	0.00	0.00	0.18
Ext. Roof-5: 0.02	0.02	0.00	0.00

Thermal Bridge Impact

- Industry Standard Design
  - Design target R-20
  - R-19 + R-8.4 mineral wool
  - No thermal bridge accounting
  - Actual performance R-12?
- Thermal Bridge Mitigation
  - Design Target R-20
  - R-19 + **R-21** mineral wool
  - Thermal bridge accounting with mitigation, non-metal / thermally broken supports and interfaces
  - Actual performance R-20

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Optimized Design Scenarios

Thermal Bridge Mitigation & Accounting

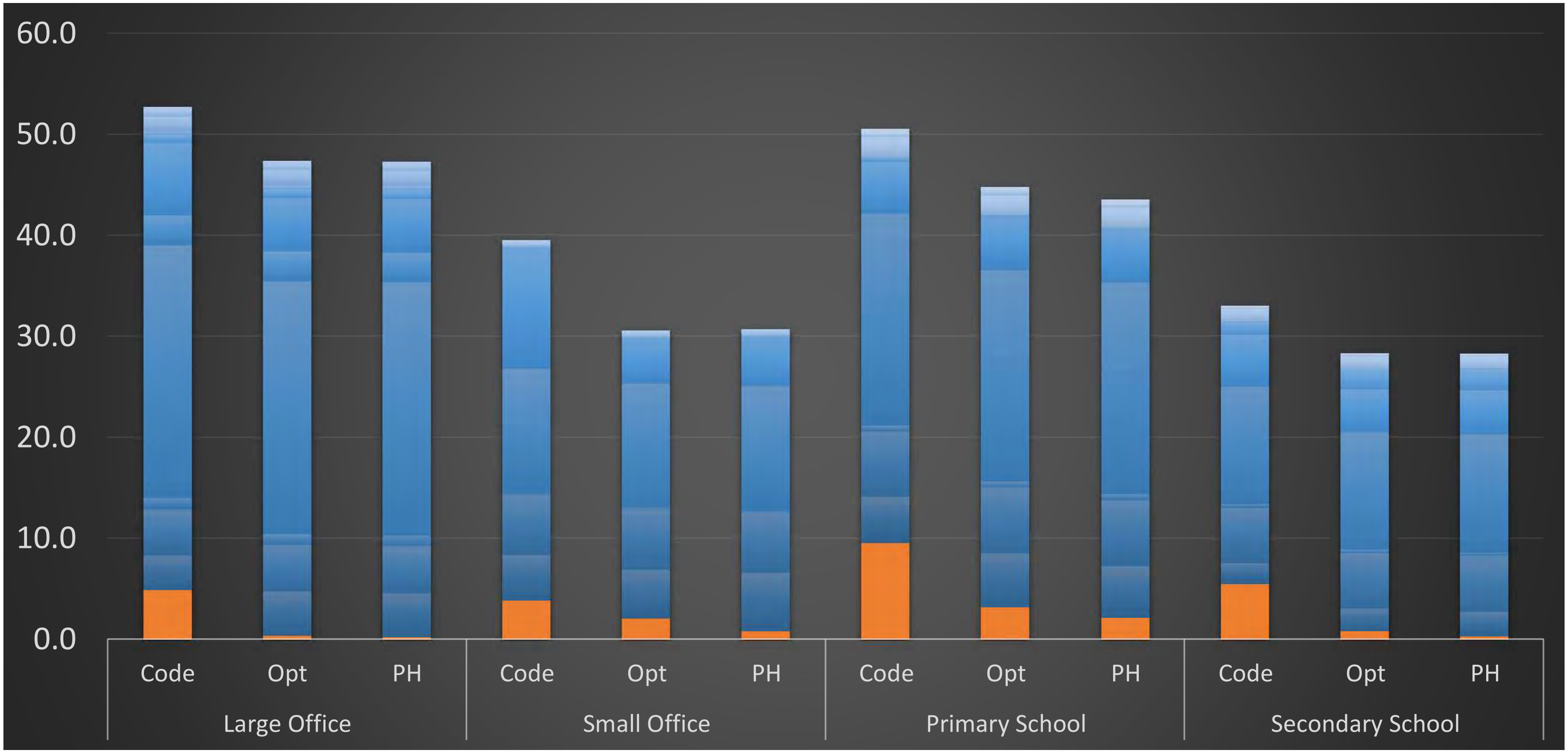
Improved window performance – good double pane windows

Reduced infiltration

Dedicated OA Systems with Energy Recovery

High performance mechanical systems (10% better than code minimum)

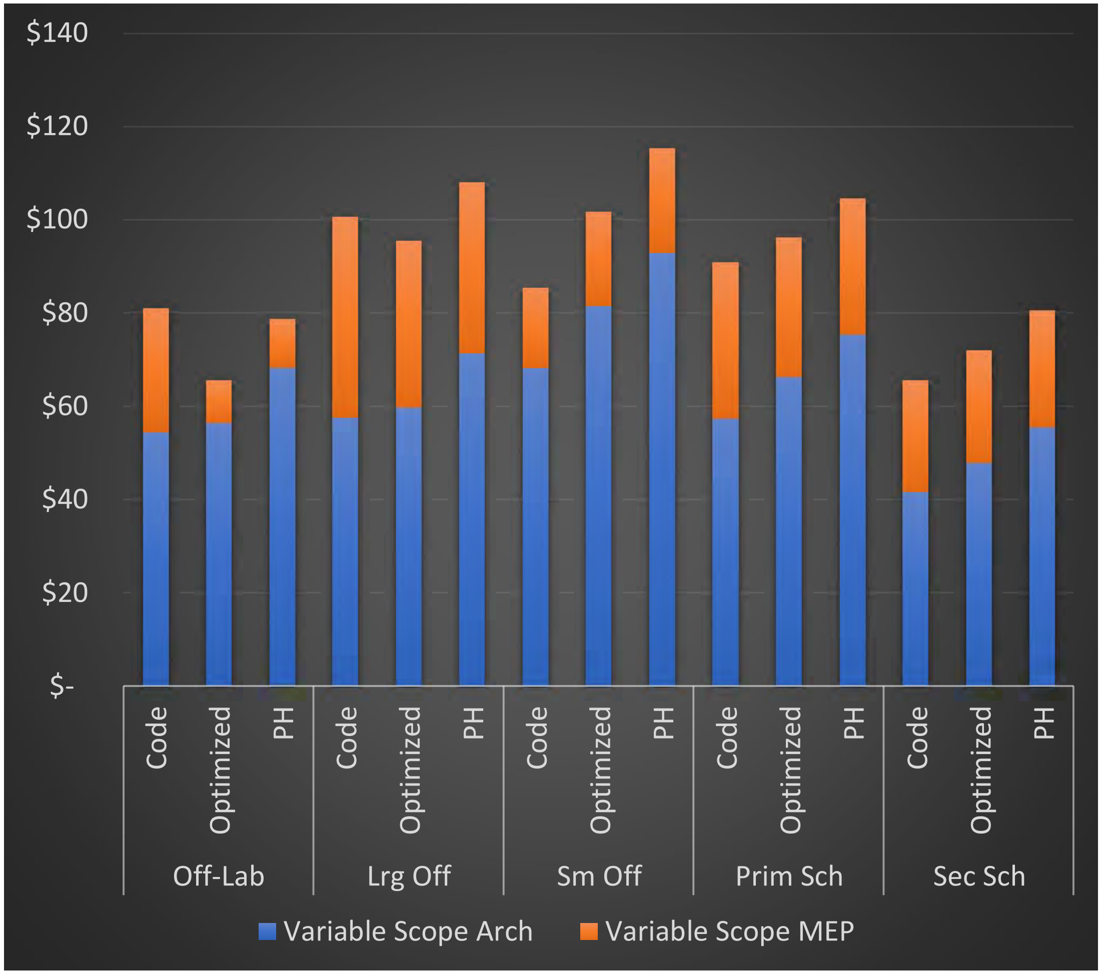
Optimized Site EUI



First Cost Impact

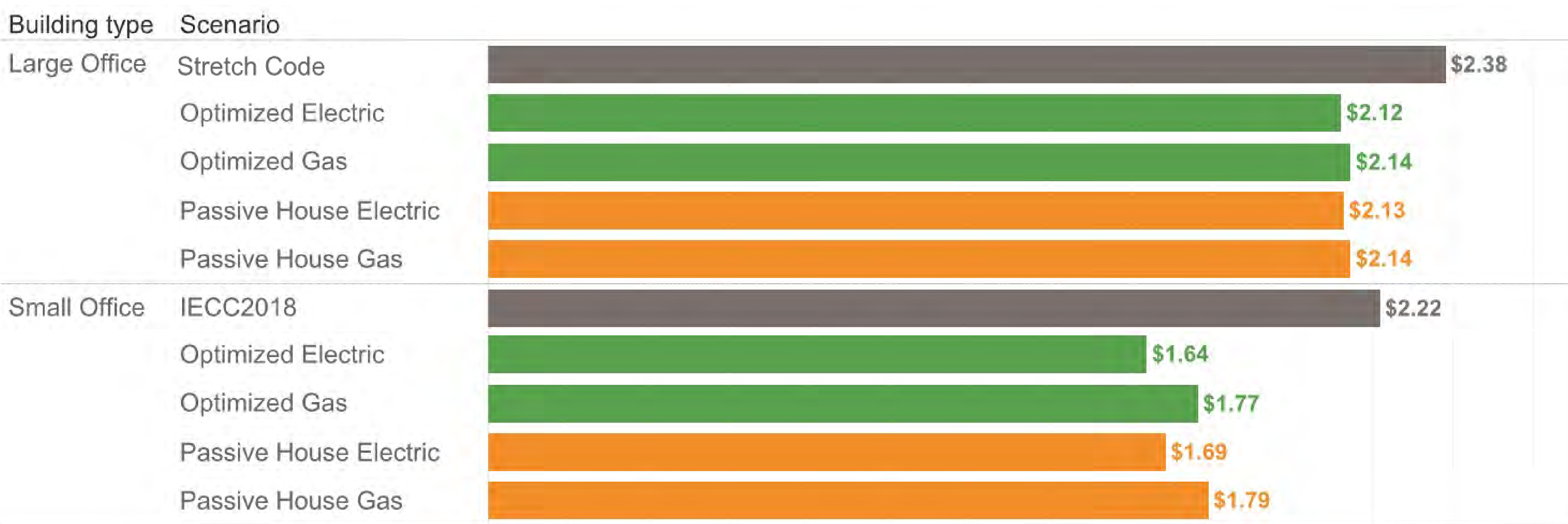
Percent change of total first cost for Optimized and Passive House design parameters

	Opt	PH
Off-Lab	-4.7%	-0.7%
Lrg Off	-1.3%	2.0%
Sm Off	3.4%	6.2%
Prim Sch	1.1%	2.8%
Sec Sch	1.2%	2.8%

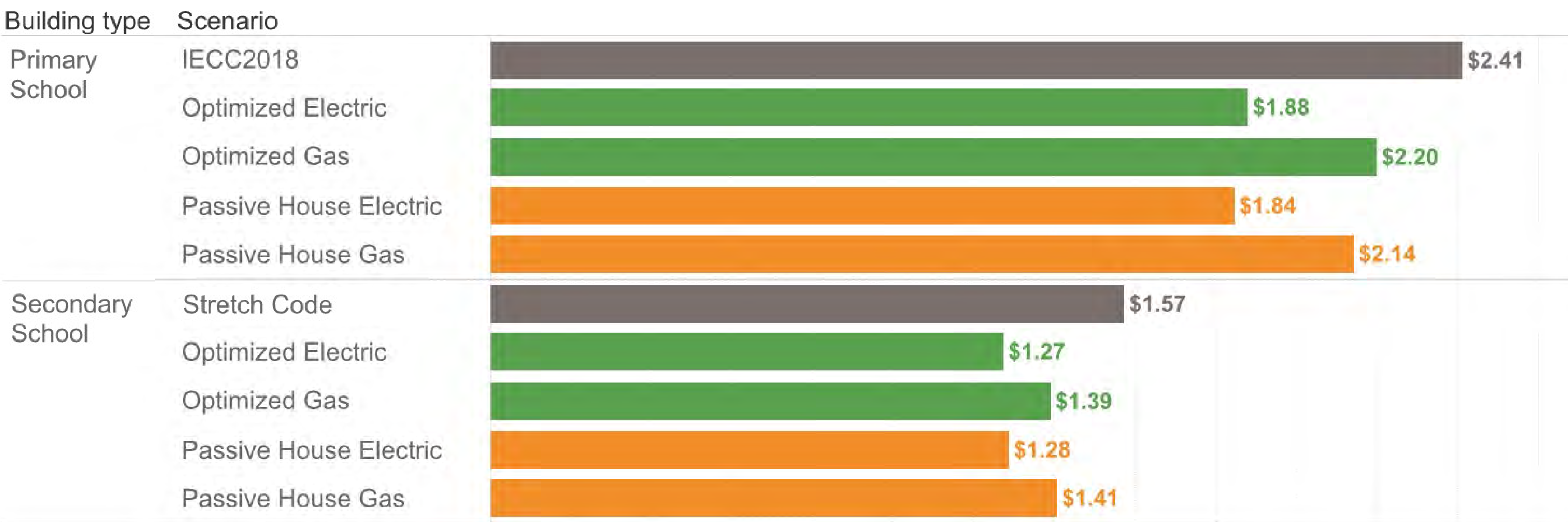


First Cost $/sf

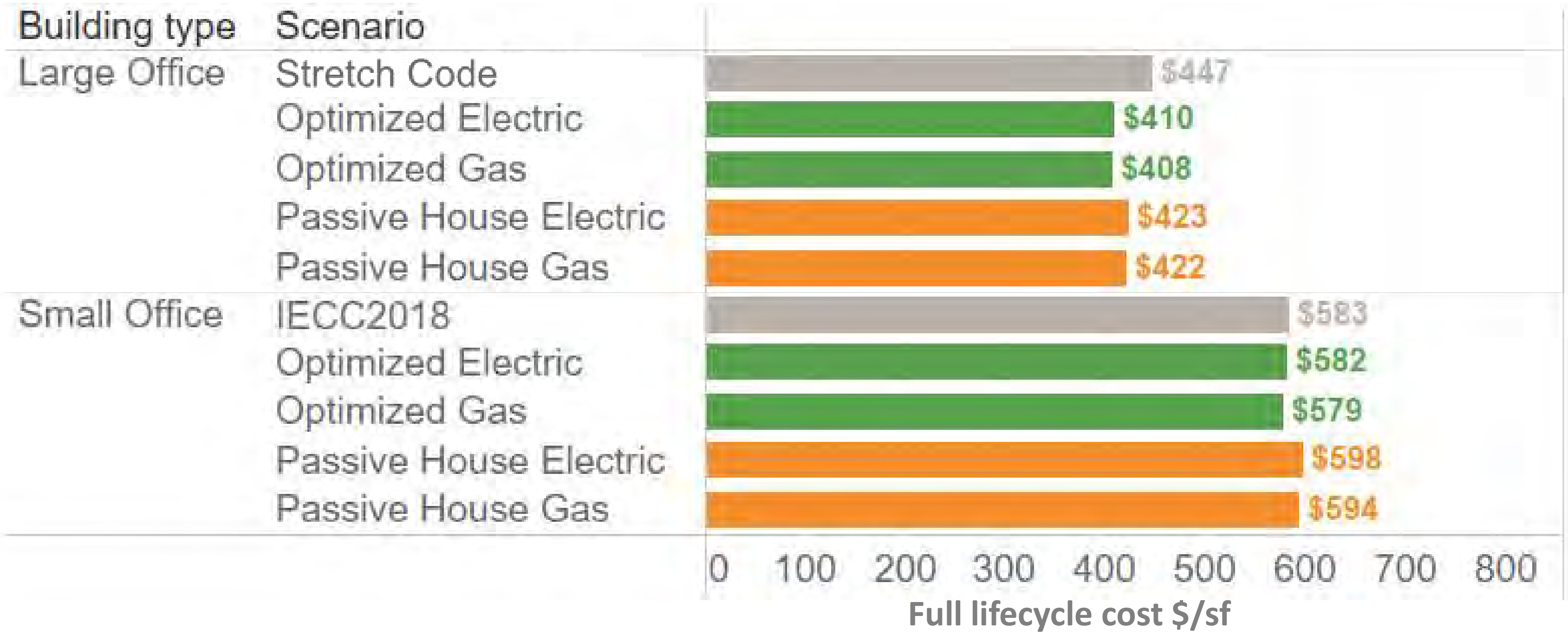
Utility Cost ($/sf)



Utility Cost ($/sf)



Total building lifecycle cost per square foot over 50-years



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Total building lifecycle cost per square foot over 50-years

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CO2 impact of building operations over 50-years

Building type	Scenario	Lifecycle CO2 (metric tons)
Small Office	IECC2018	0.8K
	Optimized Electric	0.4K
	Optimized Gas	0.6K
	Passive House Electric	0.4K
	Passive House Gas	0.5K
Large Office	Stretch Code	24.8K
	Optimized Electric	16.5K
	Optimized Gas	17.2K
	Passive House Electric	16.5K
	Passive House Gas	17.0K

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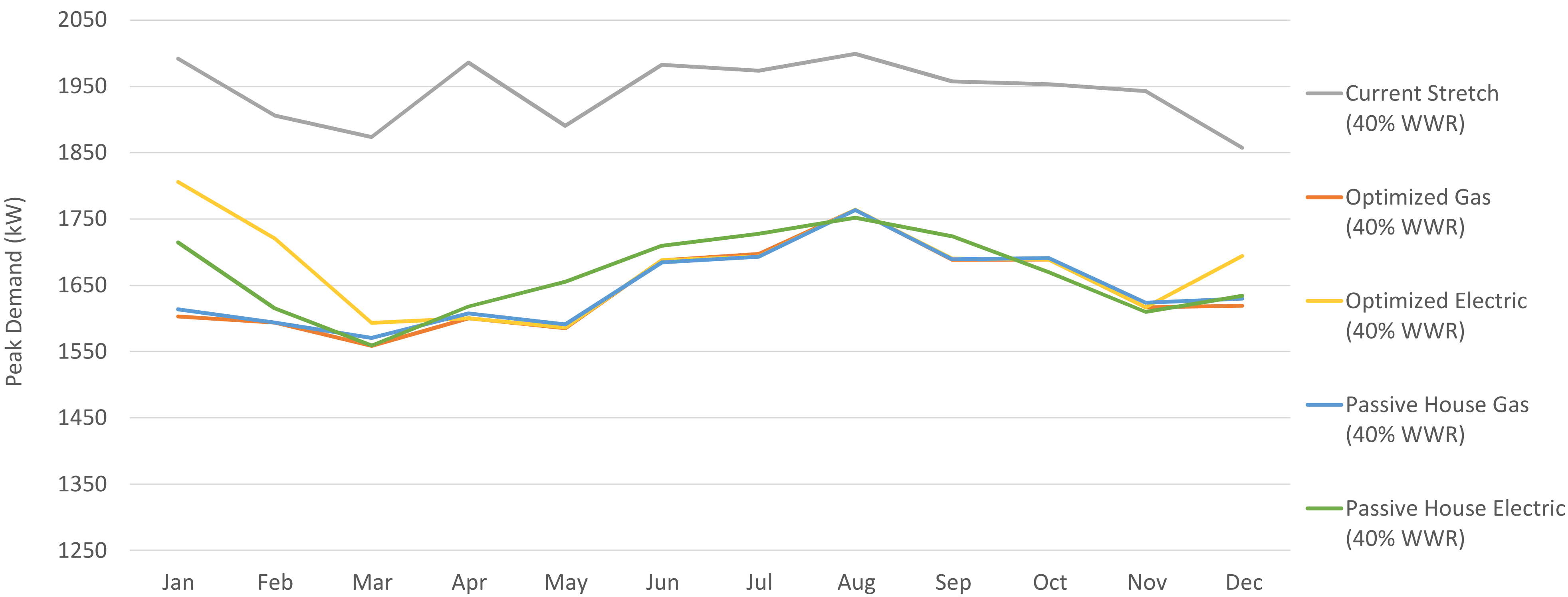
CO2 impact of building operations over 50-years

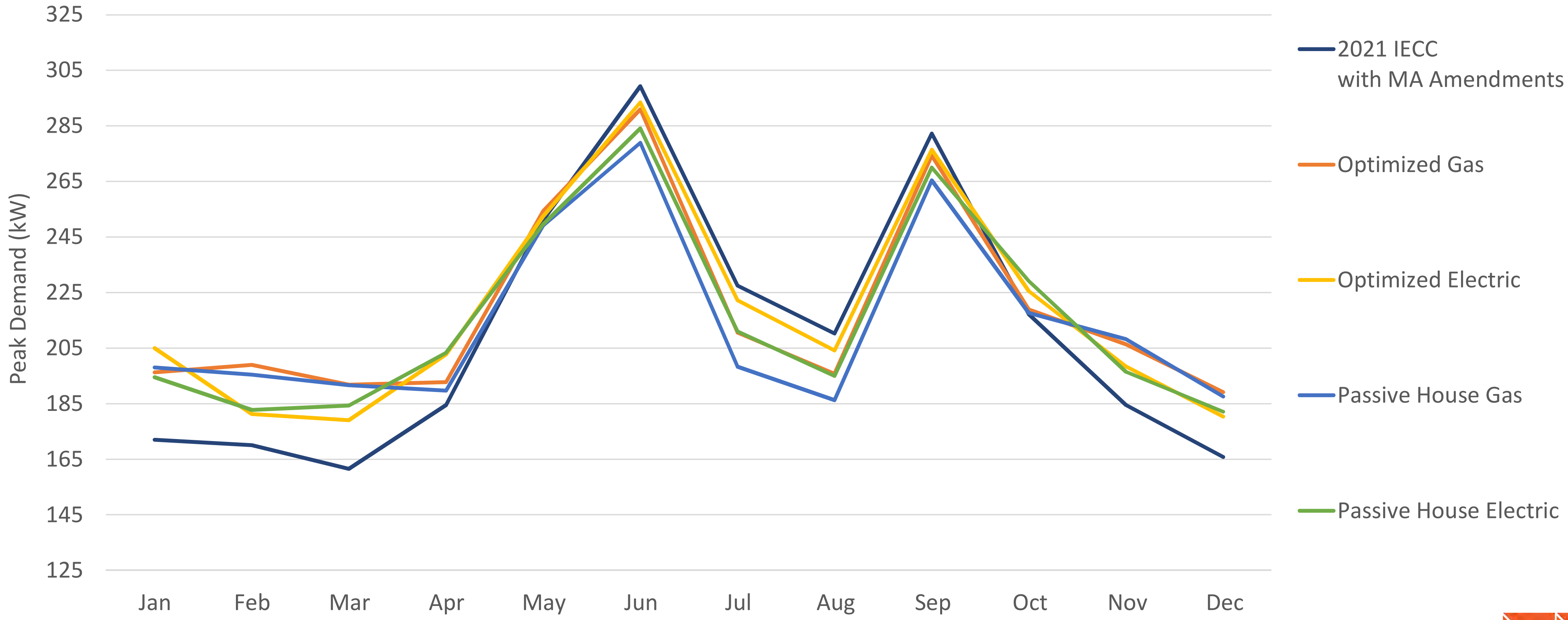
Building type	Scenario	Lifecycle CO2 (metric tons)
Primary School	IECC2018	4.6K
	Optimized Electric	2.8K
	Optimized Gas	3.4K
	Passive House Electric	2.8K
	Passive House Gas	3.1K
Secondary School	Stretch Code	11.8K
	Optimized Electric	7.2K
	Optimized Gas	7.8K
	Passive House Electric	7.2K
	Passive House Gas	7.7K

Lifecycle CO2 (metric tons)

Peak Elec Demand Impact – Large Office

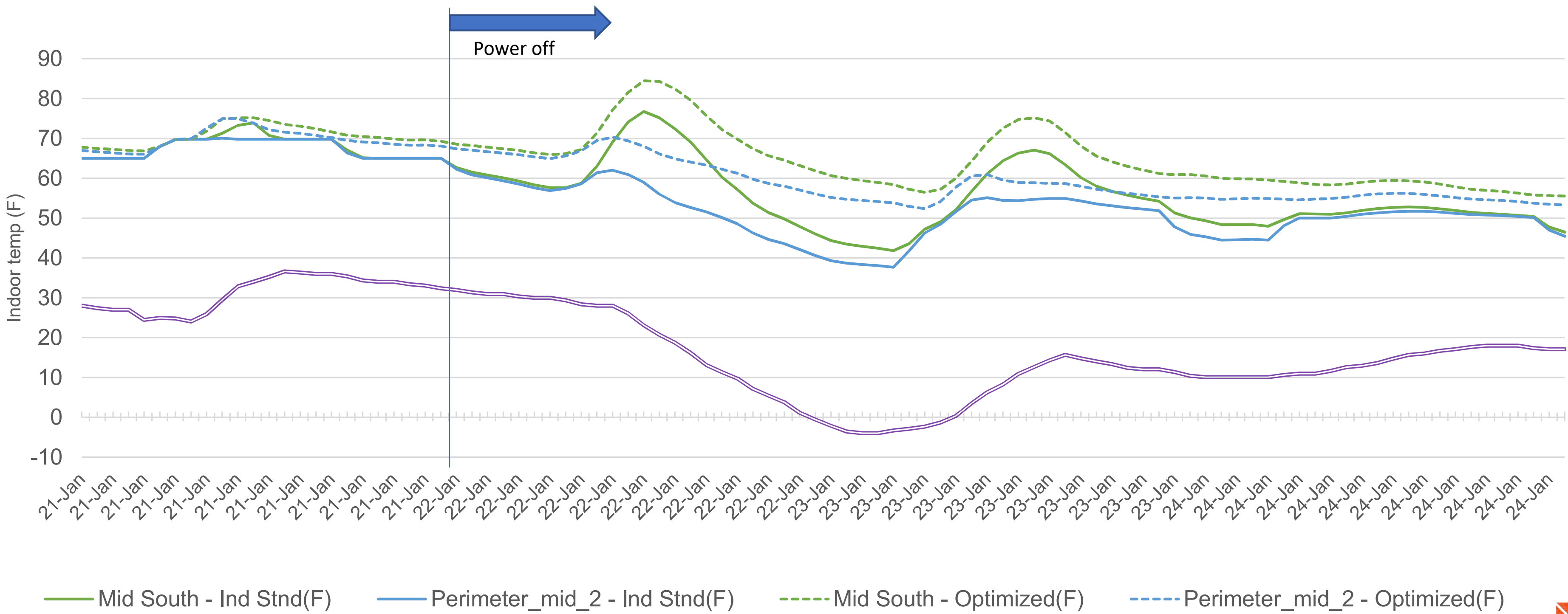


Peak Elec Demand impact – Primary School



Resiliency - Large Office

Temperature trends- ventilated office (Temp<0F)



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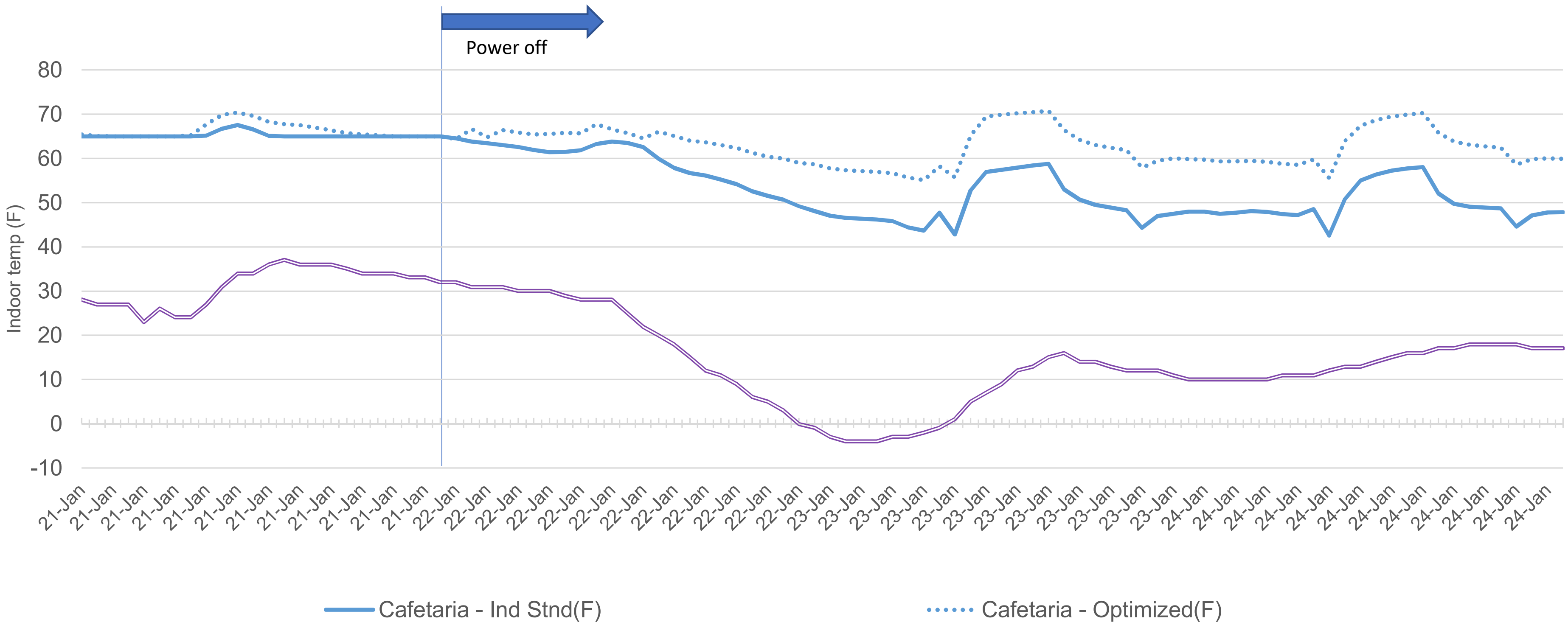
Resiliency - Primary School

Temperature trends- ventilated cafeteria (>10F OAT)



DOER Straw Proposal

- On 8 February, the DOER used results of this work to develop straw proposal for next stretch code, available here:

https://www.mass.gov/info-details/stretch-energy-code-development-2022

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Virtual Public Hearings on Straw Proposal

- Virtual Public Hearings, starting tomorrow!

Regional Focus	Date / Time
Western Region	March 2, 6:00 pm – 8:00 pm
Metro Boston and Northeastern Region	March 3, 9:00 am – 11:00 am
Environmental Justice Communities	March 4, 6:00 pm – 8:00 pm
Central Region	March 7, 3:00 pm – 5:00 pm
Southeastern Region	March 8, 3:00 pm – 5:00 pm

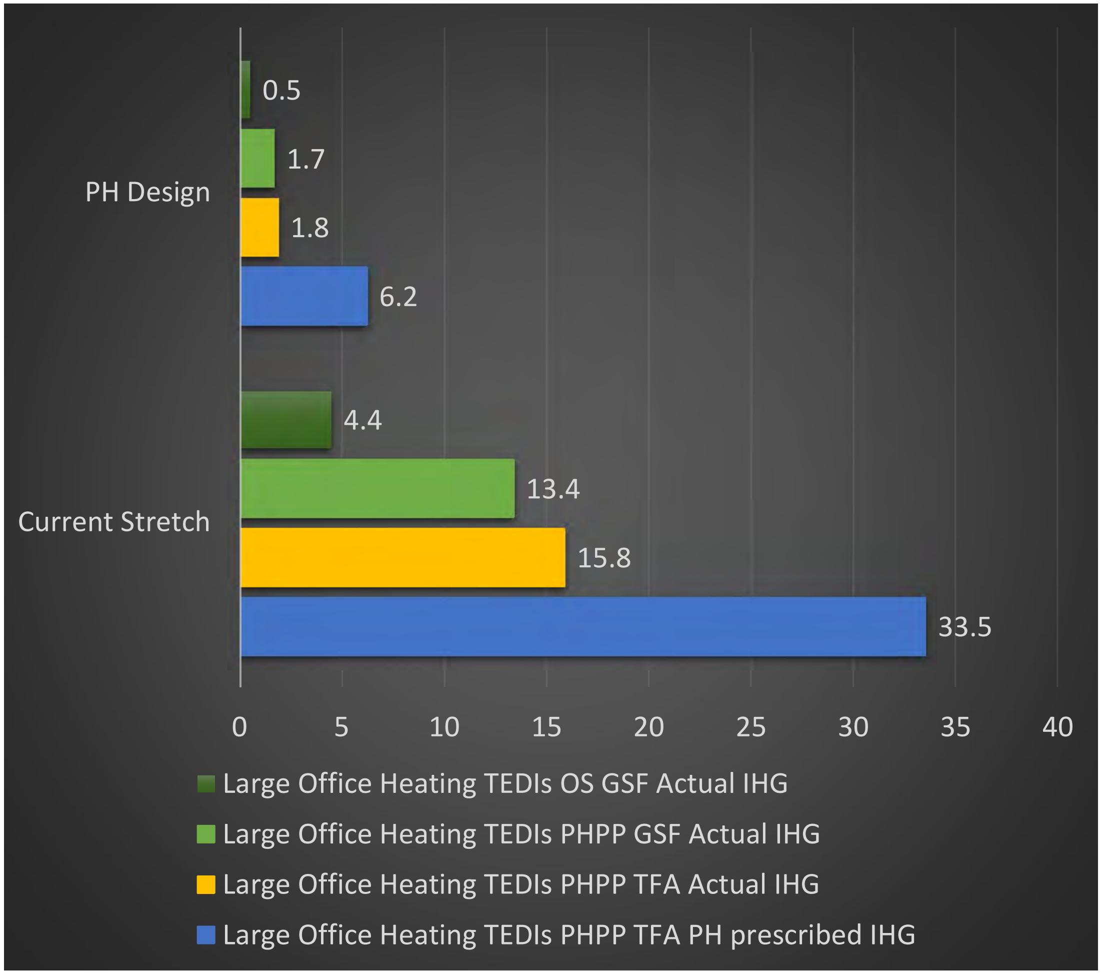
- Comments deadline: March 9th, 2022, 5pm EST.
  - Email comments to: stretchcode@mass.gov

Questions?

Thank you!

TEDI – Thermal Energy Demand Intensity

- PH=4.75 kBtu/sf/yr (15 kWh/m2/yr)
- Target includes PH mandated internal heat gain assumptions (low)
- Treated Floor Area vs. Gross Heated SF
- Added complication of different modeling tools.



Heating TEDIs in kBtu/sf/yr

Acknowledgements

- Lead Technical Consultant:

  Steven Winter Associates, Inc. (Paula Zimin)
- Codes Expert:

  New Buildings Institute (Mark Lyle)
- Advisor and Cost Consultant

  Consigli Construction (Jared)
- Industry Expert Advisor

  Buro Happold (Julie Janiski)