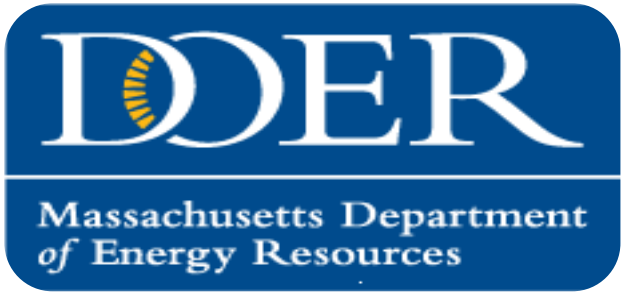
Creating A Clean, Affordable, Equitable and Resilient Energy Future For the Commonwealth



COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF ENERGY RESOURCES
Patrick Woodcock, Commissioner

Summary of Stretch Code Study Energy Efficiency Analysis

February 2022

Agenda for the Summary Analysis

The goal of this slide deck is to provide an overview of the analytical work and findings commissioned by DOER to support the development of new specialized opt-in municipal energy code, and updates to the existing stretch energy code. This slide deck supplements the presentation by DOER staff on February 8, 2022 that introduces and walks through the Building Energy Code Straw Proposal & Information on the Specialized Stretch Code (presentation & webinar).

Agenda

Residential:

- Study approach and baseline
- Cost and Emissions Results & Case Studies

Commercial:

- Study approach & baseline
- TEDI Targets
- Cost and Emissions Results

Goal of Analysis: Achieve Least-Cost Decarbonization

Energy Code Analysis

- In 2019, DOER commissioned analysis of different building code standards specific to the Massachusetts climate.
- Building Type Variety: 12 building use types and size-specific analysis to align with needs of different building types
- Analyzed up-front costs, operational costs, and total cost of ownership for multiple fuel sources.

Residential Low-Rise Team

PERFORMANCE SYSTEMS DEVELOPMENT

NORESCO

Commercial & Large Multi-Family Team

Steven Winter Associates, Inc.
Improving the Built Environment Since 1972

BRA+

BURO HAPPOLD

CONSIGLI
Est. 1905

DOER
Massachusetts Department of Energy Resources

12 Building types for in-depth analysis

- Small office
- Large office
- Office-lab
- Elementary school
- High school
- Large multi-family tower
- 4 story multi-family
- Multi-family mid-rise podium
- 6-unit multi-family
- Townhouse
- Single family Small
- Single family Large






Residential Analysis

DOER
Massachusetts Department of Energy Resources

Residential Analysis Approach

1. HERS 52 base code baseline cost & efficiency

2. Ran 10,000 home scenarios to evaluate emissions and cost impacts

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

3. Representative homes selected for detailed analysis

ekotrope
REM/Rate™

4. Detailed cost-benefit building case studies

DOER
Massachusetts Department of Energy Resources

Residential – Survey of Massachusetts Res. Building Practices

1

- RESNET HERS Registry data
  - PSD's HERS QA Provider Services – 4,058 homes
  - Statewide RESNET Registry Data – 10,387 homes
- Extract common building practices (1-4 Units)
  - 95% of homes – 2x6 16"OC framed walls
  - 80% of homes – forced air heating systems
  - 86% of homes have basements

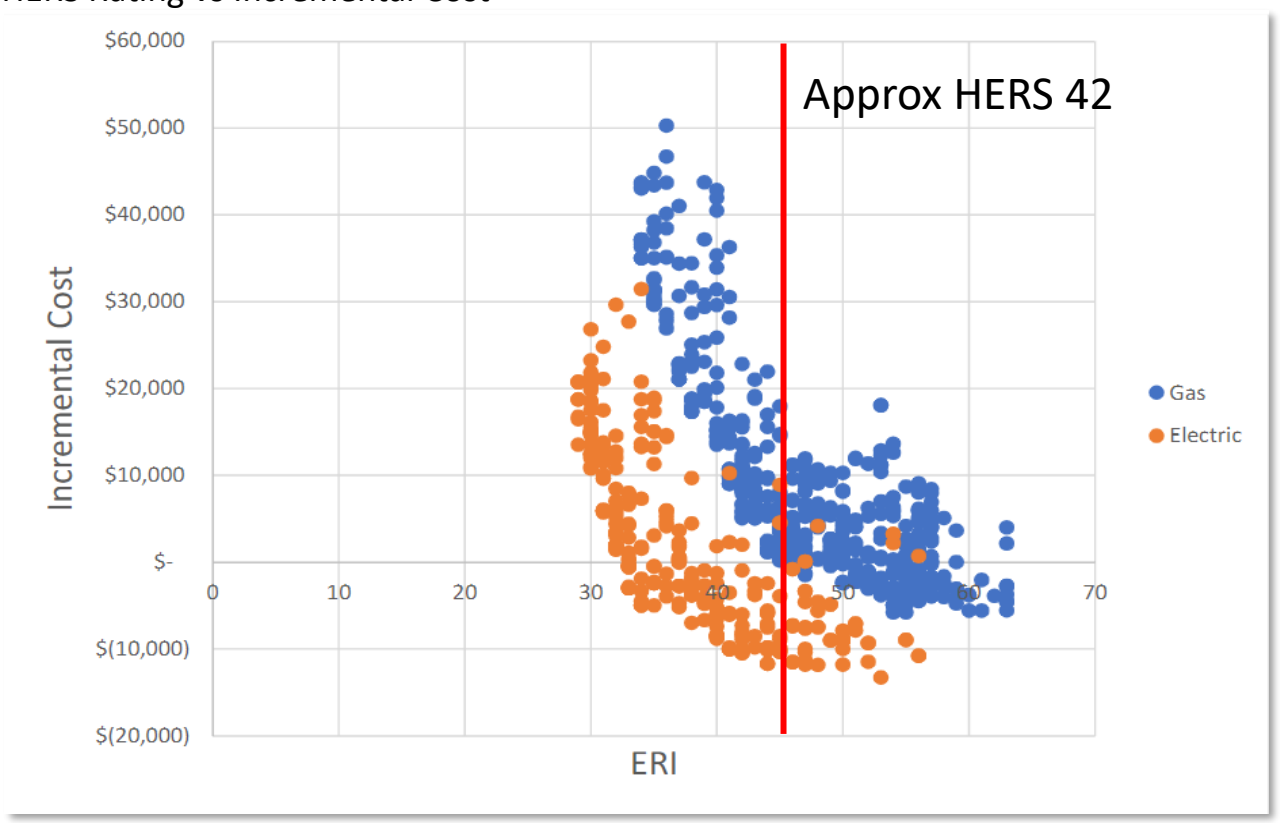
	PSD Provider	Statewide
Single-family		
Count	4,058	10,387
Avg. CFA	3,159	3,103
Low-rise multifamily		
Count	1,262	6,434
Avg. CFA	1,314	1,174

Recent MA low-rise residential construction data was analyzed to determine common home designs and building practices in Massachusetts in order to establish representative baseline building prototypes. The following baseline home types were established using this data: Small Single-family, Large single family, Townhouse, and 6-unit Multifamily

Residential – HERS Target & Cost Optimization

Large single-family example

- ~900 Unique Scenarios
- HERS (ERI) Range: 29 – 63, Mean: 44
- 100's of configurations more affordable than base scenario before incentives or solar PV
- Electric (heat pump) heat costs less to build & easier to meet lower HERS scores



The study team analyzed 100's of design configurations for each home type, comparing resulting Energy ratings with incremental construction costs over baseline in order to inform what HERS rating to set. The chart above shows the example of this approach for a Large single-family home using ERI values from Be-Opt software as a proxy for HERS ratings.

Residential Analysis – Statewide emissions impacts

The following two slides present the emissions implications of the analyzed scenarios, for the 4 different low-rise home types.

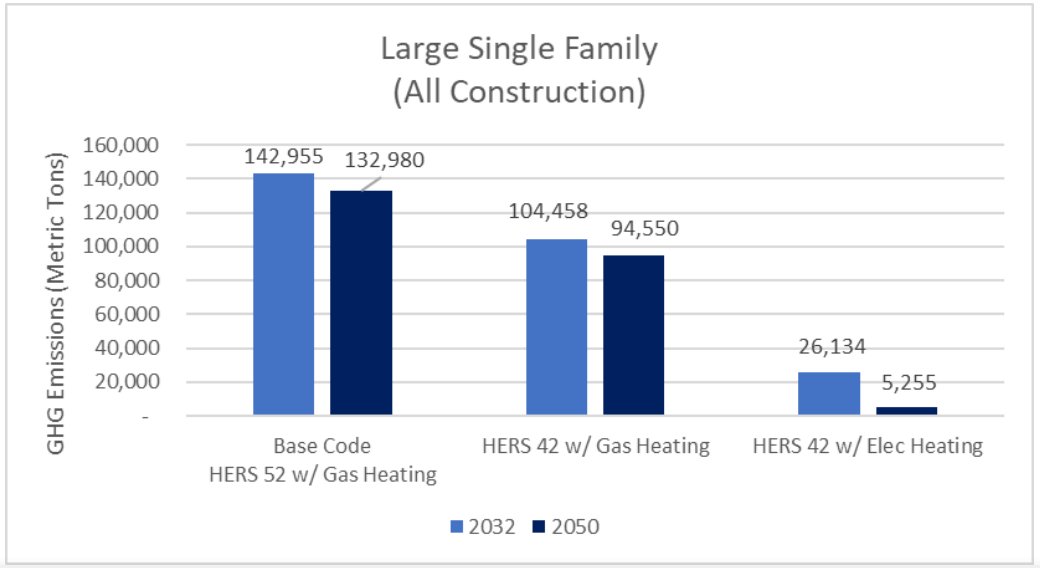
Emissions Analysis: compares 3 “what if” scenarios for the next 10 years of construction to show what the emissions outcome would be in 2032 and 2050 for each home type:

- Building all low-rise homes to 2021 base code (HERS 52) with Gas or propane heating
- Building all low-rise homes to HERS 42 w/ Gas Space Heating, or
- Building all low-rise homes to HERS 42 w/ Electric Heating

Stretch Code - Residential Emissions in 2032 (10-year) & 2050

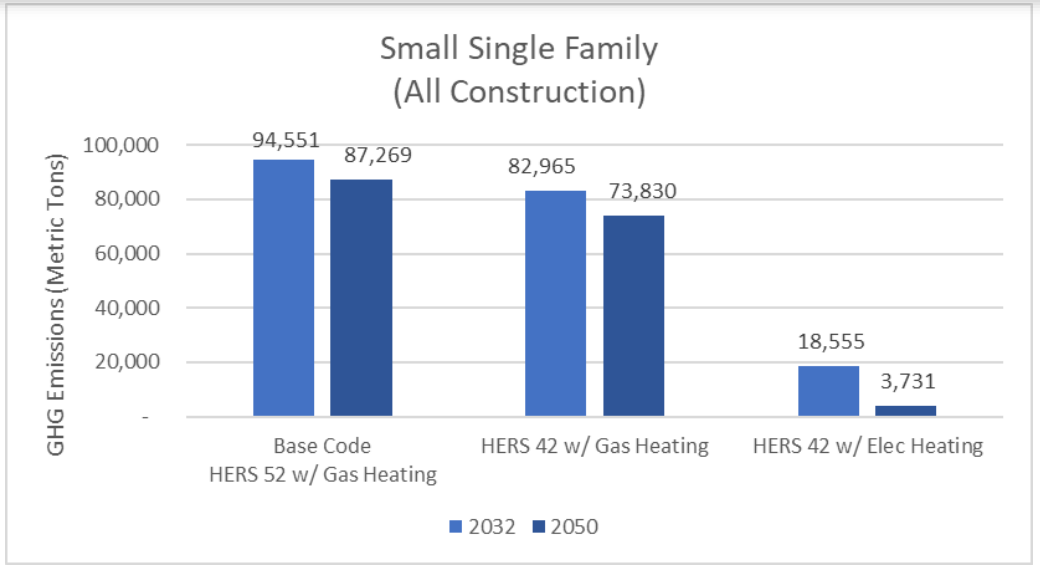
Large Single Family

- HERS 42 Electric Offers significant emissions savings compared to gas
- Both have savings relative to base code



Small Single Family

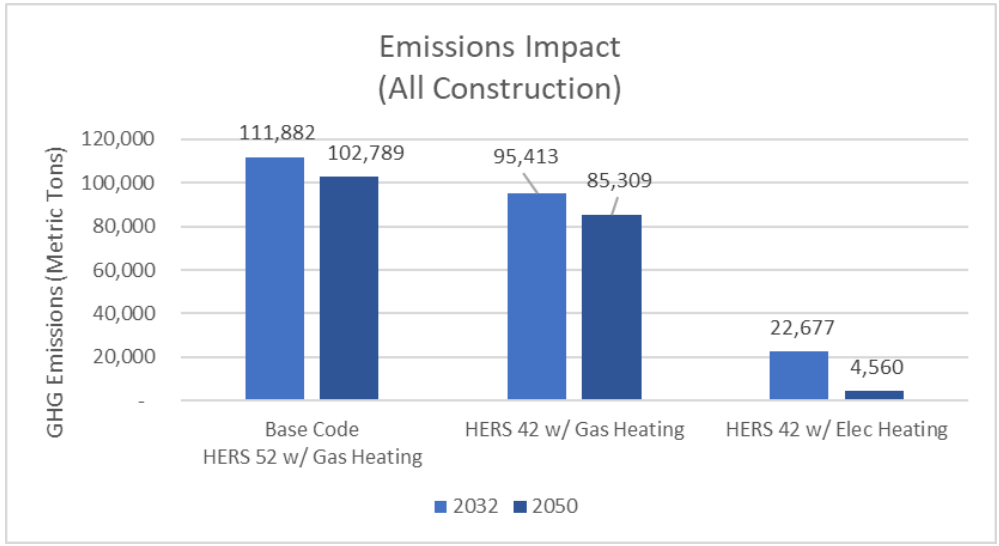
- HERS 42 Electric Offers significant emissions savings compared to gas



Stretch Code - Residential Emissions in 2032 (10-year) & 2050

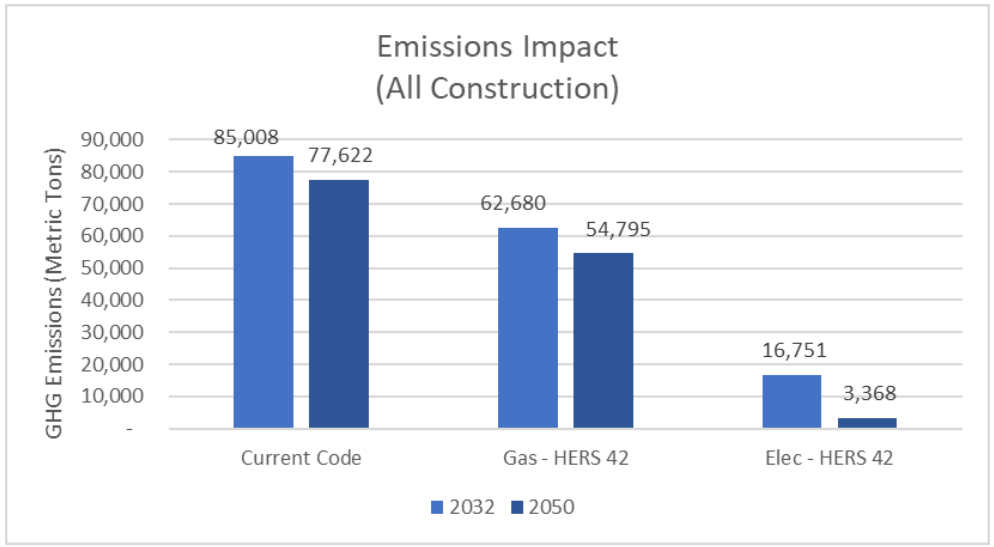
Townhouse

- HERS 42 Electric Offers significant emissions savings compared to gas



6-Unit Multifamily

- HERS 42 Electric Offers significant emissions savings compared to gas



Residential Analysis – Costs by home type

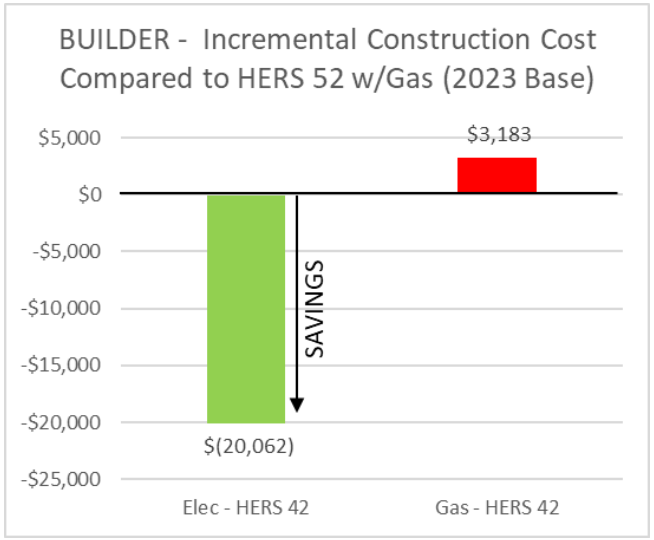
Cost Analysis: The next 2 cost analysis slides look at each home type and illustrate expected costs to build for the developer and expected costs to purchase and operate for the homebuyer. In both cases HERS 42 w/ Gas Heating and HERS 42 w/ Electric Heating are compared to building to the base code of HERS 52

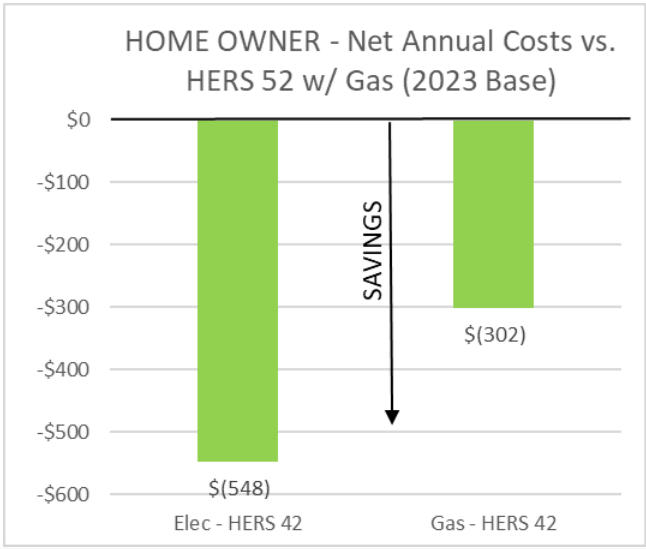
- Builder Construction Cost: The construction cost factors incorporates both upfront cost to builder and applicable utility incentives and tax rebates.
- Homeowner Net Annual Cost: Net annual cost factors in any mortgage savings/costs and utility savings/costs over the course of a year, based on purchasing a home with a 30year fixed rate mortgage

Stretch Code - Residential Cost Analysis – HERS 42 (vs. Base code 52)

Large Single Family

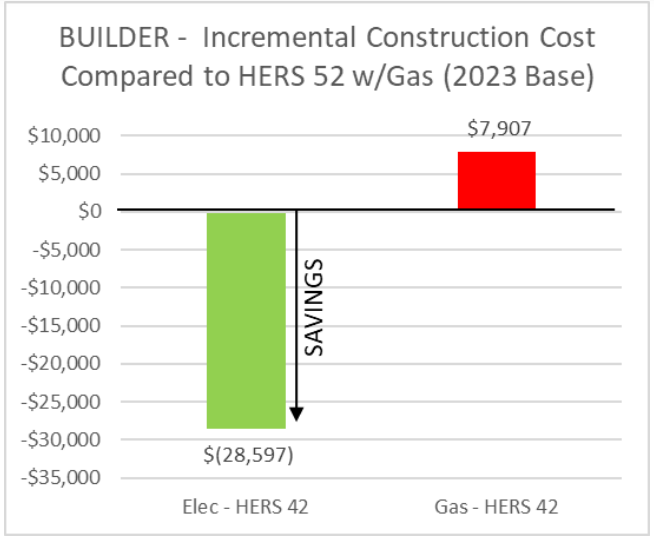
- HERS 42 Electric offers less savings for builders, and both gas and electric homes lower costs for homeowners from year 1

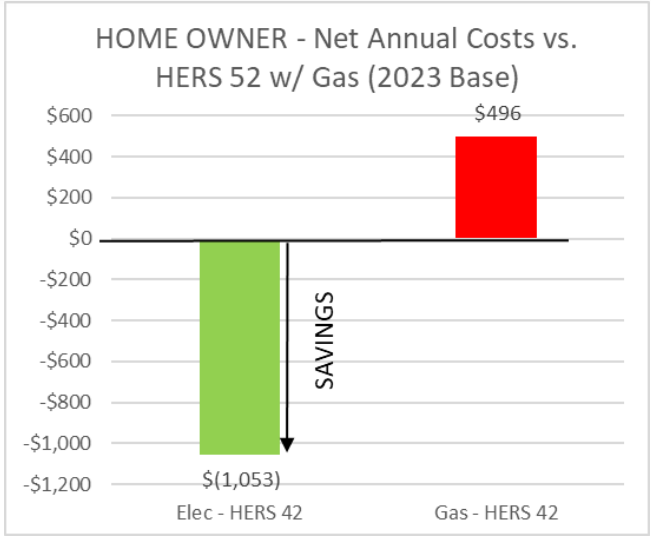




Small Single Family

- HERS 42 Electric Offers Cost Savings on Construction for Builders

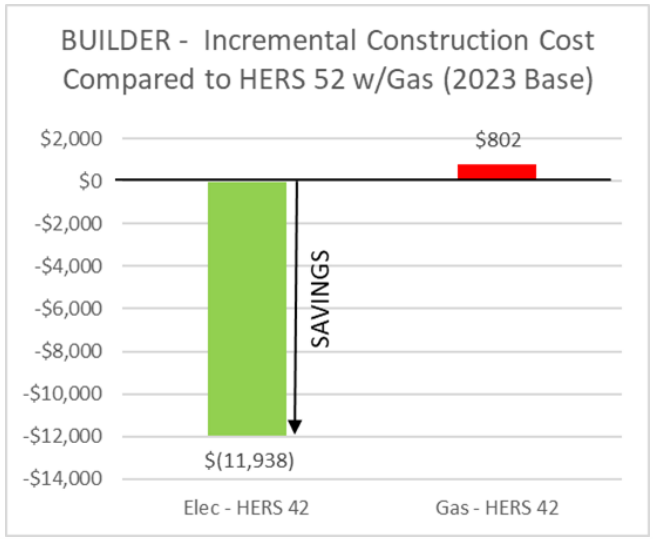


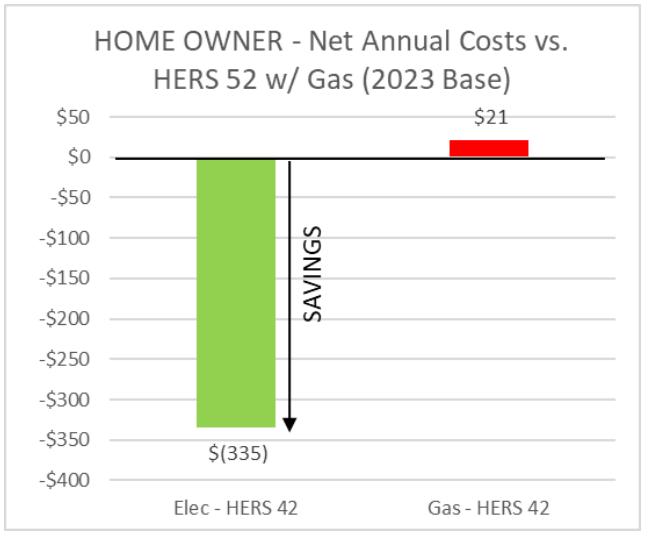


Stretch Code - Residential Cost Analysis - HERS 42 (vs. Base code 52)

Townhouse

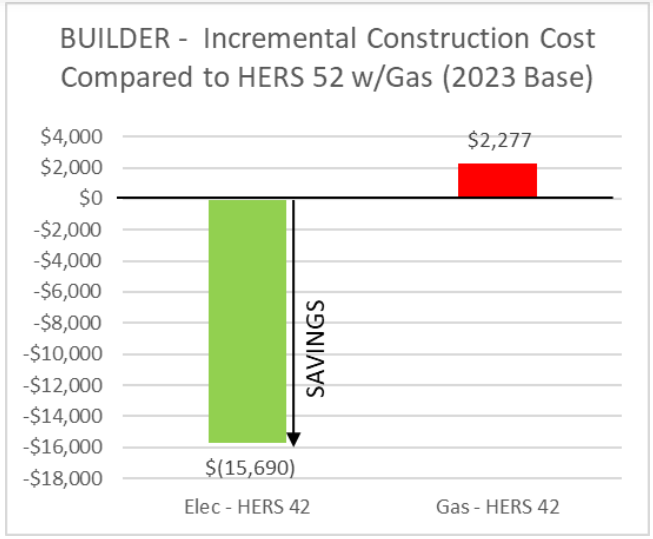
- HERS 42 Electric Offers Cost Savings on Construction for Builders & lower cost to own

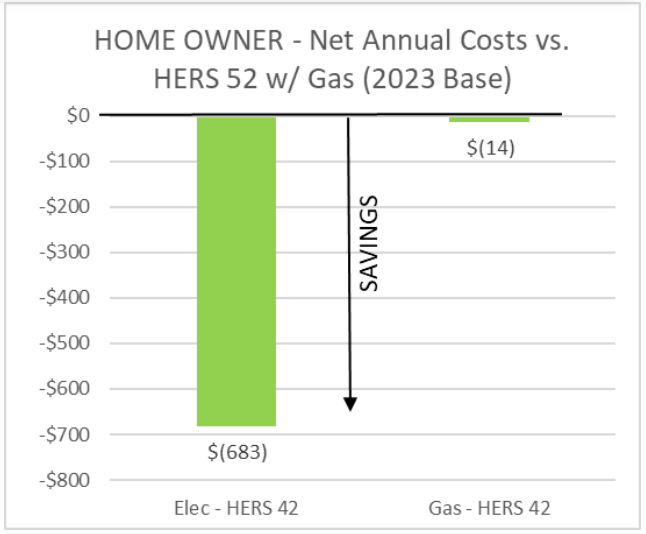




6-Unit Multifamily

- HERS 42 Electric Offers Cost Savings for Builders, and both electric & gas offer lower cost to own/rent





Residential Case Study Overview

The following slides present detailed case studies of HERS 42 w/ Gas space heat and HERS 42 w/ Electric Space heat for each of each of the residential building types.

Each Case Study is composed of two pages:

First Page: An overview of the building studied, energy and emissions savings, as well as comprehensive cost information.

Second Page: Detailed incremental cost information compared to the HERS 52 w/ Gas Space heating baseline

MA 10th Edition Building Code | 2023

Large Single Family - Electric

HERS Index

52 Base ▶ **42** Stretch

Electric Heat Pump

2030 Annual Greenhouse Gas

1.19 Stretch Tons | 4.43 Tons Saved

CO_2

Home Details

- 4000 sq.ft.
- Large Single Family
- 5 Bedrooms
- Worcester, MA

DOER Massachusetts Department of Energy Resources

PERFORMANCE SYSTEMS DEVELOPMENT

Costs and Benefits to Meet Stretch Code

	COSTS		BENEFITS	NET
BUILDER	-$3,062 Total Adjustments		$17,000 Rebates & Tax Rebates[1]	-$20,062 Cost Compared to Base Code
HOME BUYER	-$4,013 Change to Downpayment[3]	-$873 Change to Annual Mortgage Payment[3]	-$325 Estimated Energy Cost Savings per Year[2]	-$548 Buyer Annual Net

1. Rebates are calculated on a per unit basis, using Mass Save® residential new home construction incentives & Tax credit allows for up to $2,000 for new homes independently rated below HERS 50.
2. Energy costs are based on 22 cents/kWh, $1.53/therm, and $3.09/gal propane
3. 30-year mortgage assumes 10% down payment at 4% APR
4. In addition to the Mass Save® rebates, HERS Rated homes are eligible for the $2,000/unit residential builder energy efficiency tax credit under section 1332, Credit for Construction of New Energy Efficient Homes, of the Energy Policy Act of 2005

MA 10th Edition Building Code | 2023

Large Single Family - Electric

HERS Index (ERI)

52 Base ▶ **42** Stretch

Electric Heat Pump

4000 sq.ft. Large Single Family
5 Bedroom - Worcester, MA

Breakdown of Construction Costs to Meet Stretch Code

FEATURE	BASE CODE	STRETCH CODE	ADDITIONAL COSTS[1]
HERS INDEX	**52**	**42**	
Windows (U-Value/SHGC)	U-0.25, 0.29 SHGC	U-0.28, 0.29 SHGC	**-$4,110**
DHW	**Gas Tankless 0.94 EF**	**HPWH, 50 gal, 2.35 EF**	**-$316**
Heating	**Gas, 98% AFUE**	**SEER 20, 12 HSPF, Ducted**	**-$35**
Cooling	**SEER 14.2**		
Duct Leakage to Outside	**2 CFM25 per 100ft2, R-6**	**In Conditioned Space***	$0
Foundation Insulation	NA	NA	$0
Floor Insulation	R-30 Fiberglass Batt	R-30 Fiberglass Batt	$0
Walls Insulation	R-21, 2x6, 16 in o.c.	R-21, 2x6, 16 in o.c.	$0
High Efficacy Lighting	100% LED	100% LED	$0
Ceiling Insulation	**Ceiling R-49, Vented**	**R-38 Open Cell Spray Foam, Unvented**	**-$1,847**
Air Infiltration	**3 ACH50**	**1.5 ACH50**	**$3,246**
Mechanical Ventilation	HRV, 75%	HRV, 75%	$0
TOTAL			**-$3,062**

1. Additional Cost are the costs above Base Code to reach Stretch Code.
2. *Cost included in basement and/or attic thermal boundary change
3. Base Code home features are based on an analysis of typical practices for achieving a HERS 52 using HERS Provider data on previously built homes in Massachusetts.
4. Stretch Code home features are based on cost optimization modeling using BEopt software. Some individual features are less efficient than the Base Code home, but they are more than offset by other features that are more efficient. One benefit of using a HERS Index target as the basis of the Stretch Code is that it give builders the flexibility to make different design choice to allow for optimization of cost effectiveness, work around other design constraints, and accommodate client-specific requests.

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PERFORMANCE SYSTEMS DEVELOPMENT

MA 10th Edition Building Code | 2023

Large Single Family - Gas

HERS Index

52 Base ▶ **42** Stretch

Gas

2030 Annual Greenhouse Gas

4.13 Stretch Tons | 1.49 Tons Saved

CO_2

Home Details

- 4000 sq.ft.
- Large Single Family
- 5 Bedrooms
- Worcester, MA

Costs and Benefits to Meet Stretch Code

	COSTS		BENEFITS	NET
BUILDER	**$10,892** Total Adjustments		**$7,708** Rebates & Tax Rebates[1]	**$3,184** Cost Compared to Base Code
HOME BUYER	**$637** Change to Downpayment[3]	**$139** Change to Annual Mortgage Payment[3]	**$440** Estimated Energy Cost Savings per Year[2]	**-$302** Buyer Annual Net

1. Rebates are calculated on a per unit basis, using Mass Save® new construction program pay-for-savings Incentive calculations & Tax credit allows for up to $2,000 for new homes independently rated below HERS 50.
2. Energy costs are based on 22 cents/kWh, $1.53/therm, and $3.09/gal propane
3. 30-year mortgage assumes 10% down payment at 4% APR
4. In addition to the Mass Save® rebates, HERS Rated homes are eligible for the $2,000/unit residential builder energy efficiency tax credit under section 1332, Credit for Construction of New Energy Efficient Homes, of the Energy Policy Act of 2005

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PERFORMANCE SYSTEMS DEVELOPMENT

MA 10th Edition Building Code | 2023

Large Single Family - Gas

HERS Index (ERI)

52 Base

42 Stretch

Gas

4000 sq.ft. Large Single Family
5 Bedrooms - Worcester, MA

Breakdown of Construction Costs to Meet Stretch Code

FEATURE	BASE CODE	STRETCH CODE	ADDITIONAL COSTS[1]
HERS INDEX	**52**	**42**	$0
Windows (U-Value/SHGC)	**U-0.25, 0.29 SHGC**	**U-0.18, 0.29 SHGC**	**$4,951**
DHW	Gas Tankless 0.94 EF	Gas Tankless 0.94 EF	$0
Heating	Gas, 98% AFUE	Gas, 98% AFUE	-$361
Cooling	**SEER 14.2**	**SEER 16**	**$553**
Duct Leakage to Outside	**2 CFM25 per 100ft2, R-6**	**In Conditioned Space***	$0
Foundation Insulation	NA	NA	$0
Floor Insulation	R-30 Fiberglass Batt	R-30 Fiberglass Batt	$0
Walls Insulation	**R-21, 2x6, 16 in o.c.**	**R-21, 2x6, 16 in o.c., R-5 XPS**	**$4,728**
High Efficacy Lighting	100% LED	100% LED	$0
Ceiling Insulation	**Ceiling R-49, Vented**	**R-38 Open Cell Spray Foam, Unvented**	**-$2,226**
Air Infiltration	**3 ACH50**	**1.5 ACH50**	**$3,246**
Mechanical Ventilation	HRV, 75%	HRV, 75%	$0
TOTAL			**$10,892**

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PERFORMANCE SYSTEMS DEVELOPMENT

1. *Cost included in basement and/or attic thermal boundary change
2. Base Code home features are based on an analysis of typical practices for achieving a HERS 52 using HERS Provider data on previously built homes in Massachusetts.
3. Stretch Code home features are based on cost optimization modeling using BEopt software. Some individual features are less efficient than the Base Code home, but they are more than offset by other features that are more efficient. One benefit of using a HERS Index target as the basis of the Stretch Code is that it give builders the flexibility to make different design choice to allow for optimization of cost effectiveness, work around other design constraints, and accommodate client-specific requests.
4. Additional Costs are the costs above Base Code to reach Stretch Code.

MA 10th Edition Building Code | 2023

Small Single Family - Electric

HERS Index (ERI)

52 Base ▶ **42** Stretch

Electric Heat Pump

2030 Annual Greenhouse Gas

0.75 Stretch Tons | 2.56 Tons Saved

CO_2

Home Details

- 2,100 sq.ft.
- Small Single Family
- 3 Bedrooms
- Worcester, MA

DOER Massachusetts Department of Energy Resources

PERFORMANCE SYSTEMS DEVELOPMENT

Costs and Benefits to Meet Stretch Code

	COSTS		BENEFITS	NET
BUILDER	-$11,597 Total Adjustments		$17,000 Rebates & Tax Rebates[1]	-$28,597 Cost Compared to Base Code
HOME BUYER	-$5,719 Change to Downpayment[3]	-$1,244 Change to Annual Mortgage Payment[3]	-$191 Estimated Energy Cost Savings per Year[2]	-$1,053 Buyer Annual Net

1. Rebates are calculated on a per unit basis, using Mass Save® residential new home construction incentives & Tax credit allows for up to $2,000 for new homes independently rated below HERS 50.
2. Energy costs are based on 22 cents/kWh, $1.53/therm, and $3.09/gal propane
3. 30-year mortgage assumes 20% down payment at 3.5% APR
4. In addition to the Mass Save® rebates, HERS Rated homes are eligible for the $2,000/unit residential builder energy efficiency tax credit under section 1332, Credit for Construction of New Energy Efficient Homes, of the Energy Policy Act of 2005

MA 10th Edition Building Code | 2023

Small Single Family - Electric

HERS Index (ERI)

52 Base ▶ **42** Stretch

Electric Heat Pump

2100 sq.ft. Small Single Family
3 Bedrooms - Worcester, MA

Breakdown of Construction Costs to Meet Stretch Code

FEATURE	BASE CODE	STRETCH CODE	ADDITIONAL COSTS[1]
HERS INDEX	52	42	
Windows (U-Value/SHGC)	U-0.18, 0.29 SHGC	U-0.28, 0.29 SHGC	-$5,343
DHW	Gas Tankless 0.94 EF	HPWH, 50 gal	-$316
Heating	Gas, 95% AFUE	SEER 20, 12 HSPF, Ductless	-$2,487
Cooling	SEER 14.2		
Duct Leakage to Outside	2 CFM25 per 100ft2, R-6	Ductless	-$6,749
Foundation Insulation	NA	NA	$0
Floor Insulation	Basement Ceiling R-30	Basement Ceiling R-30	$0
Wall Insulation	R-21, 2x6, 16 in o.c.	R-21, 2x6, 16 in o.c.	$0
High Efficacy Lighting	100% LED	100% LED	$0
Ceiling Insulation	Ceiling R-49, Vented	Roof R-38 Spray Foam, Unvented	$2,511
Air Infiltration	3 ACH50	2 ACH50	$787
Mechanical Ventilation	HRV, 75%	HRV, 75%	$0
TOTAL			-$11,597

DOER Massachusetts Department of Energy Resources

PERFORMANCE SYSTEMS DEVELOPMENT

1. Additional Cost are the costs above Base Code to reach Stretch Code.
2. Base Code home features are based on an analysis of typical practices for achieving a HERS 52 using HERS Provider data on previously built homes in Massachusetts.
3. Stretch Code home features are based on cost optimization modeling using BEopt software. Some individual features are less efficient than the Base Code home, but they are more than offset by other features that are more efficient. One benefit of using a HERS Index target as the basis of the Stretch Code is that it give builders the flexibility to make different design choice to allow for optimization of cost effectiveness, work around other design constraints, and accommodate client-specific requests.

MA 10th Edition Building Code | 2023

Small Single Family - Gas

HERS Index

52 Base ▶ **42** Stretch

Gas

2030 Annual Greenhouse Gas

2.92 Stretch Tons | 0.38 Tons Saved

CO_2

Home Details

- 2,100 sq.ft.
- Small Single Family
- 3 Bedrooms
- Worcester, MA

DOER Massachusetts Department of Energy Resources

PERFORMANCE SYSTEMS DEVELOPMENT

Costs and Benefits to Meet Stretch Code

	COSTS		BENEFITS	NET
BUILDER	**$14,064** Total Adjustments		**$6,157** Rebates & Tax Credits[1]	**$7,907** Cost Compared to Base Code
HOME BUYER	**$1,581** Change to Downpayment[3]	**$344** Change to Annual Mortgage Payment[3]	**-$153** Estimated Energy Cost Savings per Year[2]	**$496** Buyer Annual Net

1. Rebates are calculated on a per unit basis, using Mass Save® new construction program pay-for-savings Incentive calculations & Tax credit allows for up to $2,000 for new homes independently rated below HERS 50.
2. Energy costs are based on 22 cents/kWh, $1.53/therm, and $3.09/gal propane
3. 30-year mortgage assumes 20% down payment at 3.5% APR
4. In addition to the Mass Save® rebates, HERS Rated homes are eligible for the $2,000/unit residential builder energy efficiency tax credit under section 1332, Credit for Construction of New Energy Efficient Homes, of the Energy Policy Act of 2005

MA 10th Edition Building Code | 2023

Small Single Family - Gas

HERS Index (ERI)

52 Base ▶ **42** Stretch

Gas

2100 sq.ft. Small Single Family
3 Bedrooms - Worcester, MA

Breakdown of Construction Costs to Meet Stretch Code

FEATURE	BASE CODE	STRETCH CODE	ADDITIONAL COSTS[1]
HERS INDEX	**52**	**42**	
Windows (U-Value/SHGC)	U-0.18, 0.29 SHGC	U-0.18, 0.29 SHGC	$0
DHW	Gas Tankless 0.94 EF	Gas Tankless 0.94 EF	$0
Heating	Gas, 95% AFUE	Gas, 98% AFUE	**708**
Cooling	**SEER 14.2**	**SEER 16**	**671**
Duct Leakage to Outside	**2 CFM25 per 100ft2, R-6**	**In Finished Space***	$0
Foundation Insulation	**NA**	**Basement Walls R-21**	**$6,547**
Floor Insulation	**Basement Ceiling R-30**	**NA**	**-$1,426**
Walls Insulation	**R-21, 2x6, 16 in o.c.**	**R-21, 2x6, 16 in o.c. R-5 XPS**	**$3,015**
High Efficacy Lighting	100% LED	100% LED	$0
Ceiling Insulation	**Ceiling R-49, Vented**	**Roof R-38 Spray Foam, Unvented**	**$2,187**
Air Infiltration	**3 ACH50**	**1 ACH50**	**$2,362**
Mechanical Ventilation	HRV, 75%	HRV, 75%	$0
TOTAL			**$14,064**

1. Additional Cost are the costs above Base Code to reach Stretch Code.
2. *Cost included in basement and/or attic thermal boundary change
3. Base Code home features are based on an analysis of typical practices for achieving a HERS 52 using HERS Provider data on previously built homes in Massachusetts.
4. Stretch Code home features are based on cost optimization modeling using BEopt software. Some individual features are less efficient than the Base Code home, but they are more than offset by other features that are more efficient. One benefit of using a HERS Index target as the basis of the Stretch Code is that it give builders the flexibility to make different design choice to allow for optimization of cost effectiveness, work around other design constraints, and accommodate client-specific requests.

DOER Massachusetts Department of Energy Resources

PERFORMANCE SYSTEMS DEVELOPMENT

MA 10th Edition Building Code | 2023

Townhouse - Electric

HERS Index

52 Base ▶ **42** Stretch

Electric Heat Pump

2030 Annual Greenhouse Gas 0.72 Stretch Tons | 2.35 Tons Saved

CO_2

Home Details

- 2,100 sq.ft.
- Townhouse
- 3 Bedrooms
- Worcester, MA

DOER Massachusetts Department of Energy Resources

PERFORMANCE SYSTEMS DEVELOPMENT

Costs and Benefits to Meet Stretch Code

	COSTS		BENEFITS	NET
BUILDER	**$5,508** Total Adjustments		**$17,000** Rebates & Tax Rebates[1]	**$-11,492** Cost Compared to Base Code
HOME BUYER	**$-2,298** Change to Downpayment[3]	**$-500** Change to Annual Mortgage Payment[3]	**-$184** Estimated Energy Cost Savings per Year[2]	**$316** Buyer Annual Net

1. Rebates are calculated on a per unit basis, using Mass Save® residential new home construction incentives & Tax credit allows for up to $2,000 for new homes independently rated below HERS 50.
2. Energy costs are based on 22 cents/kWh, $1.53/therm, and $3.09/gal propane
3. 30-year mortgage assumes 10% down payment at 4% APR
4. In addition to the Mass Save® rebates, HERS Rated homes are eligible for the $2,000/unit residential builder energy efficiency tax credit under section 1332, Credit for Construction of New Energy Efficient Homes, of the Energy Policy Act of 2005
5. Additional Costs are the costs above Base Code to reach Stretch Code.

MA 10th Edition Building Code | 2023

Townhouse - Electric

HERS Index (ERI)

52 Base ▶ **42** Stretch

Electric Heat Pump

2100 sq.ft. Townhouse
3 Bedrooms - Worcester, MA

Breakdown of Construction Costs to Meet Stretch Code

FEATURE	BASE CODE	STRETCH CODE	ADDITIONAL COSTS[1]
HERS INDEX	52	42	
Windows (U-Value/SHGC)	U-0.28, 0.29 SHGC	U-0.18, 0.29 SHGC	$1,530
DHW	Gas Tankless 0.94 EF	HPWH, 50 gal, 2.35 EF	-$316
Heating	Gas, 95% AFUE	HP SEER 20, 12 HSPF	-$4,276
Cooling	SEER 14.2		
Duct Leakage to Outside	2 CFM25 per 100ft2, R-6	In Conditioned Space*	$0
Foundation Insulation	NA	Basement Walls R-21	$2,740
Floor Insulation	R-30 Fiberglass Batt	NA	
Walls Insulation	R-21, 2x6, 16 in o.c.	R-21, 2x6, 16 in o.c.	$0
High Efficacy Lighting	100% LED	100% LED	$0
Ceiling Insulation	Ceiling R-49, Vented	R-30 Open Cell Spray Foam, Unvented	$5,054
Air Infiltration	3 ACH50	2 ACH50	$776
Mechanical Ventilation	HRV, 75%	HRV, 75%	$0
TOTAL			$5,508

DOER Massachusetts Department of Energy Resources

PERFORMANCE SYSTEMS DEVELOPMENT

1. Additional Cost are the costs above Base Code to reach Stretch Code.
2. *Cost included in basement and/or attic thermal boundary change
3. Base Code home features are based on an analysis of typical practices for achieving a HERS 52 using HERS Provider data on previously built homes in Massachusetts.
4. Stretch Code home features are based on cost optimization modeling using BEopt software. Some individual features are less efficient than the Base Code home, but they are more than offset by other features that are more efficient. One benefit of using a HERS Index target as the basis of the Stretch Code is that it give builders the flexibility to make different design choice to allow for optimization of cost effectiveness, work around other design constraints, and accommodate client-specific requests.

MA 10th Edition Building Code | 2023

Townhouse - Gas

HERS Index

52 Base ▶ **42** Stretch

Gas

2030 Annual Greenhouse Gas

2.63 Stretch Tons | 0.44 Tons Saved

CO_2

Home Details

- 2,100 sq.ft.
- Townhouse
- 3 Bedroom
- Worcester, MA

DOER Massachusetts Department of Energy Resources

PERFORMANCE SYSTEMS DEVELOPMENT

Costs and Benefits to Meet Stretch Code

	COSTS		BENEFITS	NET
BUILDER	**$5,707** Total Adjustments		**$5,646** Rebates & Tax Credits[1]	**$61** Cost Compared to Base Code
HOME BUYER	**$12** Change to Downpayment[3]	**$3** Change to Annual Mortgage Payment[3]	**$14** Estimated Energy Cost Savings per Year[2]	**$-11** Buyer Annual Net

1. Rebates are calculated on a per unit basis, using Mass Save® new construction program pay-for-savings Incentive calculations & Tax credit allows for up to $2,000 for new homes independently rated below HERS 50.
2. Energy costs are based on 22 cents/kWh, $1.53/therm, and $3.09/gal propane
3. 30-year mortgage assumes 10% down payment at 4% APR
4. In addition to the Mass Save® rebates, HERS Rated homes are eligible for the $2,000/unit residential builder energy efficiency tax credit under section 1332, Credit for Construction of New Energy Efficient Homes, of the Energy Policy Act of 2005

MA 10th Edition Building Code | 2023

Townhouse - Gas

HERS Index (ERI)

52 Base ▶ **42** Stretch

Gas

2100 sq.ft. Townhouse
3 Bedrooms - Worcester, MA

Breakdown of Construction Costs to Meet Stretch Code

FEATURE	BASE CODE	STRETCH CODE	ADDITIONAL COSTS[1]
HERS INDEX	52	42	
Windows (U-Value/SHGC)	U-0.28, 0.29 SHGC	U-0.18, 0.29 SHGC	$1,530
DHW	Gas Tankless 0.94 EF	Gas Tankless 0.94 EF	$0
Heating	Gas, 95% AFUE	Gas, 98% AFUE	$688
Cooling	SEER 14.2	SEER 16	$646
Duct Leakage to Outside	2 CFM25 per 100ft2, R-6	2 CFM25 per 100ft2, R-6	$0
Foundation Insulation	NA	Basement Walls R-21	$1,955
Floor Insulation	R-30 Fiberglass Batt	NA	-$1,110
Walls Insulation	R-21, 2x6, 16 in o.c.	R-21, 2x6, 16 in o.c., R-5 XPS	$1,746
High Efficacy Lighting	100% LED	100% LED	$0
Ceiling Insulation	Ceiling R-49, Vented	Ceiling R-38, Vented	-$1,446
Air Infiltration	3 ACH50	1.5 ACH50	$1,698
Mechanical Ventilation	HRV, 75%	HRV, 75%	$0
TOTAL			$5,707

DOER Massachusetts Department of Energy Resources

PERFORMANCE SYSTEMS DEVELOPMENT

1. Additional Cost are the costs above Base Code to reach Stretch Code.
2. Base Code home features are based on an analysis of typical practices for achieving a HERS 52 using HERS Provider data on previously built homes in Massachusetts.
3. Stretch Code home features are based on cost optimization modeling using BEopt software. Some individual features are less efficient than the Base Code home, but they are more than offset by other features that are more efficient. One benefit of using a HERS Index target as the basis of the Stretch Code is that it give builders the flexibility to make different design choice to allow for optimization of cost effectiveness, work around other design constraints, and accommodate client-specific requests.

HERS Index

52 Base ▶ **42** Stretch

Electric Heat Pump

2030 Annual Greenhouse Gas **0.51** Stretch Tons | **1.75** Tons Saved

CO_2

Home Details

- 1,400 sq.ft. per unit
- 6-Unit Multifamily
- 3 Bedrooms
- Worcester, MA

DOER Massachusetts Department of Energy Resources

PERFORMANCE SYSTEMS DEVELOPMENT

MA 10th Edition Building Code | 2023

6-unit Multifamily - Electric

Costs and Benefits to Meet Stretch Code

	COSTS		BENEFITS	NET
BUILDER	-$11,086 Total Adjustments		$4,604 Rebates & Tax Credits[1]	-$15,690 Cost Compared to Base Code
HOME BUYER	-$3,138 Change to Downpayment[3]	-$683 Change to Annual Mortgage Payment[3]	$0 Estimated Energy Cost Savings per Year[2]	-$683 Buyer Annual Net

1. Rebates are calculated on a per unit basis, using Mass Save® new construction program pay-for-savings Incentive calculations & Tax credit allows for up to $2,000 for new homes independently rated below HERS 50.
2. Energy costs are based on 22 cents/kWh, $1.53/therm, and $3.09/gal propane
3. 30-year mortgage assumes 10% down payment at 4% APR
4. In addition to the Mass Save® rebates, HERS Rated homes are eligible for the $2,000/unit residential builder energy efficiency tax credit under section 1332, Credit for Construction of New Energy Efficient Homes, of the Energy Policy Act of 2005

MA 10th Edition Building Code | 2023

6-unit Multifamily - Electric

HERS Index (ERI)

52 Base ▶ **42** Stretch

Electric Heat Pump

1400 sq.ft. per unit
6-Unit Multifamily
3 Bedrooms - Worcester, MA

Breakdown of Construction Costs to Meet Stretch Code

FEATURE	BASE CODE	STRETCH CODE	ADDITIONAL COSTS[1]
HERS INDEX	**52**	**42**	
Windows (U-Value/SHGC)	U-0.28, 0.29 SHGC	U-0.28, 0.29 SHGC	$0
DHW	**Gas Tankless 0.94 EF**	**HPWH, 50 gal, 2.35 EF**	**-$316**
Heating	**Gas, 95% AFUE**	**SEER 20, 12 HSPF, Ductless**	**-$5,898**
Cooling	**SEER 14.2**		
Duct Leakage to Outside	**2 CFM25 per 100ft2, R-6**	**Ductless**	**-$4,591**
Foundation Insulation	NA (upper-level unit)	NA (upper-level unit)	$0
Floor Insulation	NA (upper-level unit)	NA (upper-level unit)	$0
Walls Insulation	R-21, 2x6, 16 in o.c.	R-21, 2x6, 16 in o.c.	$0
High Efficacy Lighting	100% LED	100% LED	$0
Ceiling Insulation	**Ceiling R-49, Vented**	**Ceiling R-38, Vented**	**-$803**
Air Infiltration	**3 ACH50**	**2 ACH50**	**$521**
Mechanical Ventilation	Exhaust Only	Exhaust Only	$0
TOTAL			**-$11,086**

DOER Massachusetts Department of Energy Resources

PERFORMANCE SYSTEMS DEVELOPMENT

1. Additional Cost are the costs above Base Code to reach Stretch Code.
2. Base Code home features are based on an analysis of typical practices for achieving a HERS 52 using HERS Provider data on previously built homes in Massachusetts.
3. Stretch Code home features are based on cost optimization modeling using BEopt software. Some individual features are less efficient than the Base Code home, but they are more than offset by other features that are more efficient. One benefit of using a HERS Index target as the basis of the Stretch Code is that it give builders the flexibility to make different design choice to allow for optimization of cost effectiveness, work around other design constraints, and accommodate client-specific requests.

MA 10th Edition Building Code | 2023

6-unit Multifamily - Gas

HERS Index

52 Base ▶ **42** Stretch

Gas

2030 Annual Greenhouse Gas

1.68 Stretch Tons | 0.58 Tons Saved

CO_2

Home Details

- 1,400 sq.ft. per unit
- 6-Unit Multifamily
- 3 Bedrooms
- Worcester, MA

DOER Massachusetts Department of Energy Resources

PERFORMANCE SYSTEMS DEVELOPMENT

Costs and Benefits to Meet Stretch Code

	COSTS		BENEFITS	NET
BUILDER	**$5,848** Total Adjustments		**$3,571** Rebates & Tax Credits[1]	**$2,277** Cost Compared to Base Code
HOME BUYER	**$455** Change to Downpayment[3]	**$99** Change to Annual Mortgage Payment[3]	**$114** Estimated Energy Cost Savings per Year[2]	**-$14** Buyer Annual Net

1. Rebates are calculated on a per unit basis, using Mass Save® new construction program pay-for-savings Incentive calculations & Tax credit allows for up to $2,000 for new homes independently rated below HERS 50.
2. Energy costs are based on 22 cents/kWh, $1.53/therm, and $3.09/gal propane
3. 30-year mortgage assumes 10% down payment at 4% APR
4. In addition to the Mass Save® rebates, HERS Rated homes are eligible for the $2,000/unit residential builder energy efficiency tax credit under section 1332, Credit for Construction of New Energy Efficient Homes, of the Energy Policy Act of 2005

MA 10th Edition Building Code | 2023

6-unit Multifamily - Gas

HERS Index (ERI)

52 Base ▶ **42** Stretch

Gas

1400 sq.ft. per unit
6-Unit Multifamily
3 Bedrooms - Worcester, MA

Breakdown of Construction Costs to Meet Stretch Code

FEATURE	BASE CODE	STRETCH CODE	ADDITIONAL COSTS[1]
HERS INDEX	52	42	
Windows (U-Value/SHGC)	U-0.28, 0.29 SHGC	U-0.18, 0.29 SHGC	$2,025
DHW	Gas Tankless 0.94 EF	Gas Tankless 0.94 EF	$0
Heating	Gas, 95% AFUE	Gas, 98% AFUE	$686
Cooling	SEER 14.2	SEER 16	408
Duct Leakage to Outside	2 CFM25 per 100ft2, R-6	In Conditioned Space*	$0
Foundation Insulation	NA (upper-level unit)	NA (upper-level unit)	$0
Floor Insulation	NA (upper-level unit)	NA (upper-level unit)	$0
Walls Insulation	R-21, 2x6, 16 in o.c.	R-21, 2x6, 16 in o.c., R-5 XPS	$1,038
High Efficacy Lighting	100% LED	100% LED	$0
Ceiling Insulation	Ceiling R-49, Vented	Ceiling R-38, Vented	-$803
Air Infiltration	3 ACH50	1.5 ACH50	$1,140
Mechanical Ventilation	Exhaust Only	HRV, 75%	$1,352
TOTAL			$5,848

DOER Massachusetts Department of Energy Resources

PERFORMANCE SYSTEMS DEVELOPMENT

1. Additional Cost are the costs above Base Code to reach Stretch Code.
2. Base Code home features are based on an analysis of typical practices for achieving a HERS 52 using HERS Provider data on previously built homes in Massachusetts.
3. Stretch Code home features are based on cost optimization modeling using BEopt software. Some individual features are less efficient than the Base Code home, but they are more than offset by other features that are more efficient. One benefit of using a HERS Index target as the basis of the Stretch Code is that it give builders the flexibility to make different design choice to allow for optimization of cost effectiveness, work around other design constraints, and accommodate client-specific requests.

Commercial Analysis

Commercial Analysis Approach

1. Identify representative projects for each building type, fuel source, glazing approach

2. Model base code and Passivehouse scenarios to bracket construction and energy costs

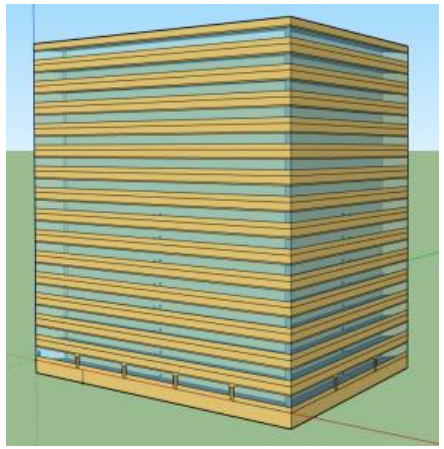
3. Iterate and stress-test designs with a focus on reducing heating loads (emissions) to find 'optimized' performance targets for code

4. Detailed pricing of each building type leading to building case studies

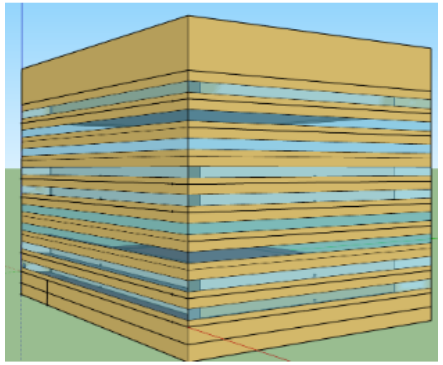
Baseline and improved scenarios

1 2

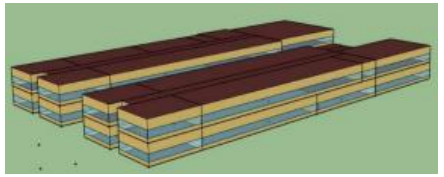
Category	Building Type	Small Office	Large Office	Office/Lab	Primary School	Secondary School
Baseline	IECC 2018	x			x	
	10% Stretch		x	x		x
Improved	Proposed - Gas Heat	x	x	x	x	x
	Proposed - Electric Heat	x	x	x	x	x
	Passive House - Gas Heat	x	x	x	x	x
	Passive House Electric Heat	x	x	x	x	x



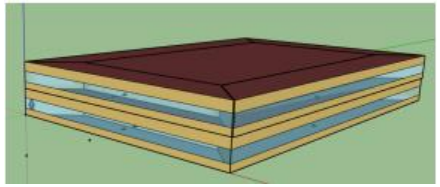
Large Office



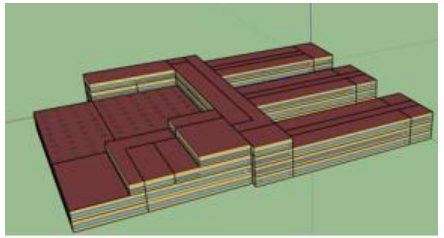
Lab-Office



Primary School



Small Office



Secondary School

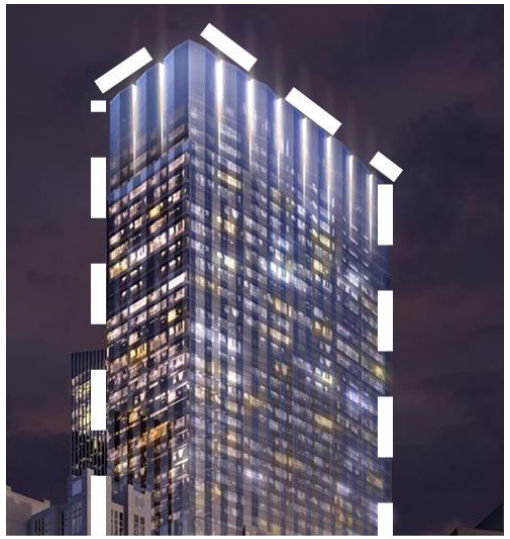
Code baseline and improved models were developed, both gas heated and electric heated. Proposed models used strategy of optimizing envelope and heat recovery improvements to reduce heating thermal demands, reduce HVAC equipment, and improve ease of electrification.

Optimization Process

3

Improved envelope + heat recovery

COST ADD



- Reduced air infiltration
- Wall “R” values
- Window “U” values
- Ventilation heat recovery

Reduced HVAC

COST DEDUCT

- Less distribution systems
- Smaller equipment
- Less rooftop equipment

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Example of detailed cost report

4

MA DOER - Stretch Code Study
Office High Rise - Core & Shell Only
VARIABLE SCOPE ONLY
June 11, 2021

CONSIGLI

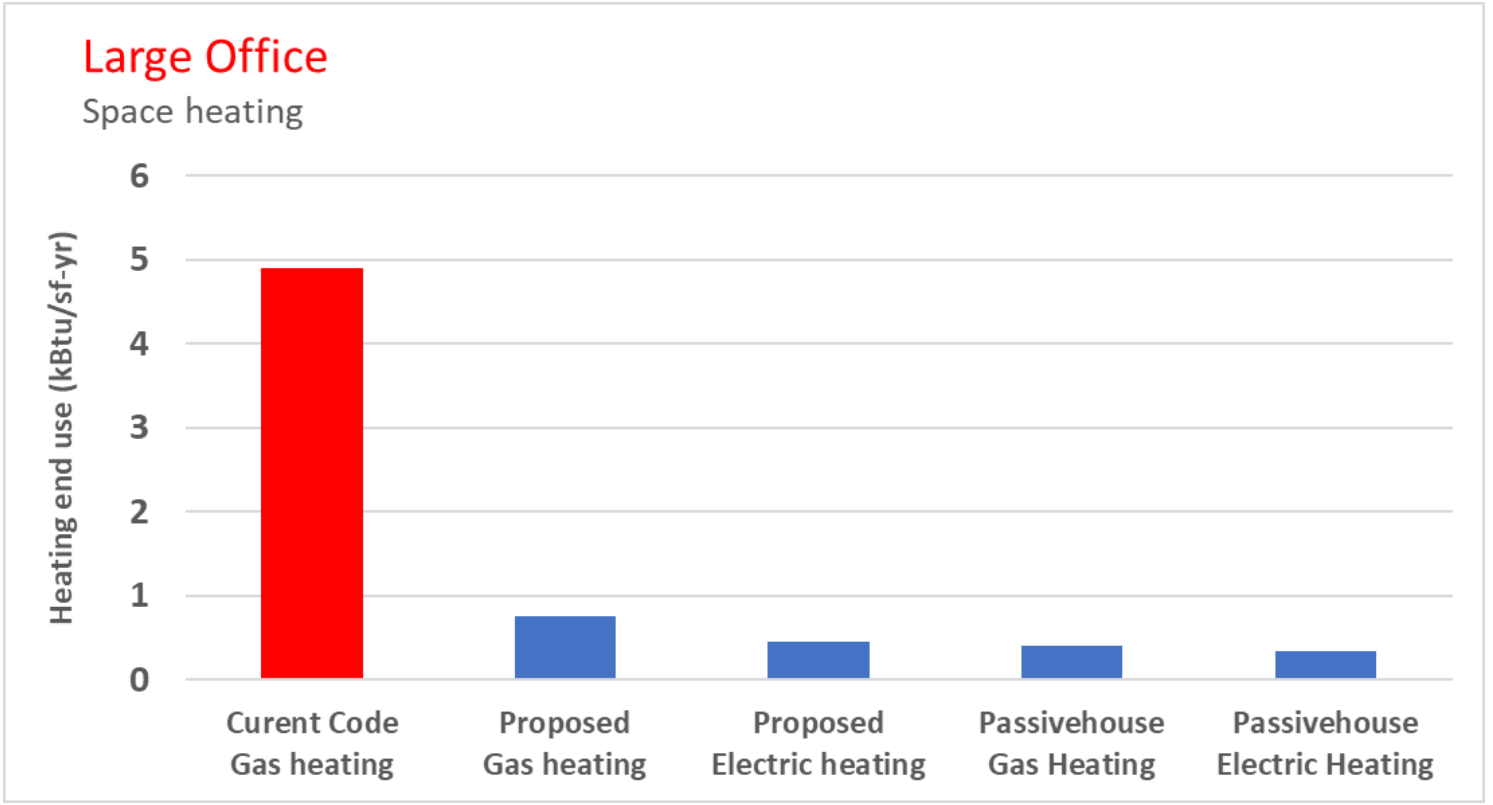
			BASE CASE - 10% Stretch				BASE CASE - 20% Stretch				OPTIMIZED								PASSIVE HOUSE							
			40% Vision		50% Vision		40% Vision		50% Vision		40% Vision				50% Vision				40% Vision				50% Vision			
			Gas Heat		Gas Heat		Gas Heat		Gas Heat		Gas Heat		Electric Heat		Gas Heat		Electric Heat		Gas Heat		Electric Heat		Gas Heat		Electric Heat	
WBS	DESCRIPTION		Total Cost 652,800 SF		Total Cost 652,800 SF		Total Cost 652,800 SF		Total Cost 652,800 SF		Total Cost 652,800 SF		Total Cost 652,800 SF		Total Cost 652,800 SF		Total Cost 652,800 SF		Total Cost 652,800 SF		Total Cost 652,800 SF		Total Cost 652,800 SF		Total Cost 652,800 SF	
01-10	Testing		- $	-	- $	-	- $	-	- $	-	0.32 $	210,840	0.32 $	210,840	0.32 $	210,840	0.32 $	210,840	0.32 $	210,840	0.32 $	210,840	0.32 $	210,840	0.32 $	210,840
05-12	Structural Steel		- $	-	- $	-	- $	-	- $	-	0.21 $	138,400	0.21 $	138,400	0.21 $	138,400	0.21 $	138,400	0.21 $	138,400	0.21 $	138,400	0.21 $	138,400	0.21 $	138,400
07-50	Roofing & Sheet Metal		2.21 $	1,440,000	2.21 $	1,440,000	2.21 $	1,440,000	2.21 $	1,440,000	2.41 $	1,574,400	2.41 $	1,574,400	2.41 $	1,574,400	2.41 $	1,574,400	2.41 $	1,574,400	2.41 $	1,574,400	2.41 $	1,574,400	2.41 $	1,574,400
08-41	Façade		41.38 $	27,013,850	40.39 $	26,367,450	41.38 $	27,013,850	40.39 $	26,367,450	42.31 $	27,617,970	42.31 $	27,617,970	41.82 $	27,302,850	41.82 $	27,302,850	51.78 $	33,802,090	51.78 $	33,802,090	51.06 $	33,333,450	51.06 $	33,333,450
09-21	Drywall		1.71 $	1,115,040	1.42 $	929,200	1.71 $	1,115,040	1.42 $	929,200	1.71 $	1,115,040	1.71 $	1,115,040	1.42 $	929,200	1.42 $	929,200	2.08 $	1,357,440	2.08 $	1,357,440	1.73 $	1,131,200	1.73 $	1,131,200
SUBTOTAL (Architectural)			**45 $**	**29,568,890**	**44 $**	**28,736,650**	**45 $**	**29,568,890**	**44 $**	**28,736,650**	**47 $**	**30,656,650**	**47 $**	**30,656,650**	**46 $**	**30,155,690**	**46 $**	**30,155,690**	**57 $**	**37,083,170**	**57 $**	**37,083,170**	**56 $**	**36,388,290**	**56 $**	**36,388,290**
Back Up Item #			*1*		*2*		*1*		*2*		*3*		*3*		*4*		*4*		*5*		*5*		*6*		*6*	
22-01	Plumbing		0.26 $	171,360	0.26 $	171,360	0.26 $	171,360	0.26 $	171,360	0.16 $	102,816	- $	-	0.16 $	102,816	- $	-	0.16 $	102,816	- $	-	0.16 $	102,816	- $	-
23-01	HVAC		19.33 $	12,616,609	19.33 $	12,616,609	11.98 $	7,817,909	11.98 $	7,817,909	5.00 $	3,265,044	6.05 $	3,950,649	5.00 $	3,265,044	6.05 $	3,950,649	5.94 $	3,880,544	6.99 $	4,566,149	5.94 $	3,880,544	6.99 $	4,566,149
26-01	Electrical		2.63 $	1,713,600	2.63 $	1,713,600	2.63 $	1,713,600	2.63 $	1,713,600	2.63 $	1,713,600	3.15 $	2,056,320	2.63 $	1,713,600	3.15 $	2,056,320	2.63 $	1,713,600	3.15 $	2,056,320	2.63 $	1,713,600	3.15 $	2,056,320
26-02	Photovoltaics		-		0.34 $	225,000	0.69 $	450,000	1.08 $	705,000	-		-		- $	-	- $	-	-		-		- $	-	- $	-
SUBTOTAL (MEP)			**22 $**	**14,501,569**	**23 $**	**14,726,569**	**16 $**	**10,152,869**	**16 $**	**10,407,869**	**8 $**	**5,081,460**	**9 $**	**6,006,969**	**8 $**	**5,081,460**	**9 $**	**6,006,969**	**9 $**	**5,696,960**	**10 $**	**6,622,469**	**9 $**	**5,696,960**	**10 $**	**6,622,469**
Back Up Item #			*50*		*50*		*51*		*51*		*52*		*53*		*52*		*53*		*54*		*55*		*54*		*55*	
SUBTOTAL			**68 $**	**44,070,459**	**67 $**	**43,463,219**	**61 $**	**39,721,759**	**60 $**	**39,144,519**	**55 $**	**35,738,110**	**56 $**	**36,663,619**	**54 $**	**35,237,150**	**55 $**	**36,162,659**	**66 $**	**42,780,130**	**67 $**	**43,705,639**	**64 $**	**42,085,250**	**66 $**	**43,010,759**
	Indirects Costs	20.00%	13.50 $	8,814,092	13.32 $	8,692,644	12.17 $	7,944,352	11.99 $	7,828,904	10.95 $	7,147,622	11.23 $	7,332,724	10.80 $	7,047,430	11.08 $	7,232,532	13.11 $	8,556,026	13.39 $	8,741,128	12.89 $	8,417,050	13.18 $	8,602,152
TOTAL COST - VARIABLE SCOPES			**81 $**	**52,884,551**	**80 $**	**52,155,863**	**73 $**	**47,666,111**	**72 $**	**46,973,423**	**66 $**	**42,885,732**	**67 $**	**43,996,343**	**65 $**	**42,284,580**	**66 $**	**43,395,191**	**79 $**	**51,336,156**	**80 $**	**52,446,767**	**77 $**	**50,502,300**	**79 $**	**51,612,911**
TOTAL COST - ALL SCOPE			**327 $**	**213,630,000**	326 $	212,901,312	319 $	208,411,560	318 $	207,718,872	312 $	203,631,181	314 $	204,741,792	**311 $**	**203,030,029**	313 $	204,140,640	325 $	212,081,605	327 $	213,192,216	324 $	211,247,749	325 $	212,358,360
	+/- to baseline				**$**	**(728,688)**	**$**	**(5,218,440)**	**$**	**(5,911,128)**	**$**	**(9,998,819)**	**$**	**(8,888,208)**	**$**	**(10,599,971)**	**$**	**(9,489,360)**	**$**	**(1,548,395)**	**$**	**(437,784)**	**$**	**(2,382,251)**	**$**	**(1,271,640)**
	% change to baseline - on TOTAL COST			**NA**		**-0.34%**		**-2.44%**		**-2.77%**		**-4.68%**		**-4.16%**		**-4.96%**		**-4.44%**		**-0.72%**		**-0.20%**		**-1.12%**		**-0.60%**
	+/- to lowest cost		**$**	**10,599,971**	**$**	**9,871,283**	**$**	**5,381,531**	**$**	**4,688,843**	**$**	**601,152**	**$**	**1,711,763**			**$**	**1,110,611**	**$**	**9,051,576**	**$**	**10,162,187**	**$**	**8,217,720**	**$**	**9,328,331**
	% change to lowest cost - on TOTAL COST			**5.22%**		**4.86%**		**2.65%**		**2.31%**		**0.30%**		**0.84%**		**NA**		**0.55%**		**4.46%**		**5.01%**		**4.05%**		**4.59%**

Key Metric – Thermal Energy Demand Intensity (TEDI)

A design approach focused on cost-effective emissions reduction led to a key metric of heating **T**hermal **E**nergy **D**emand **I**ntensity (TEDI). TEDI was first used in codes for Vancouver and Toronto in Canada

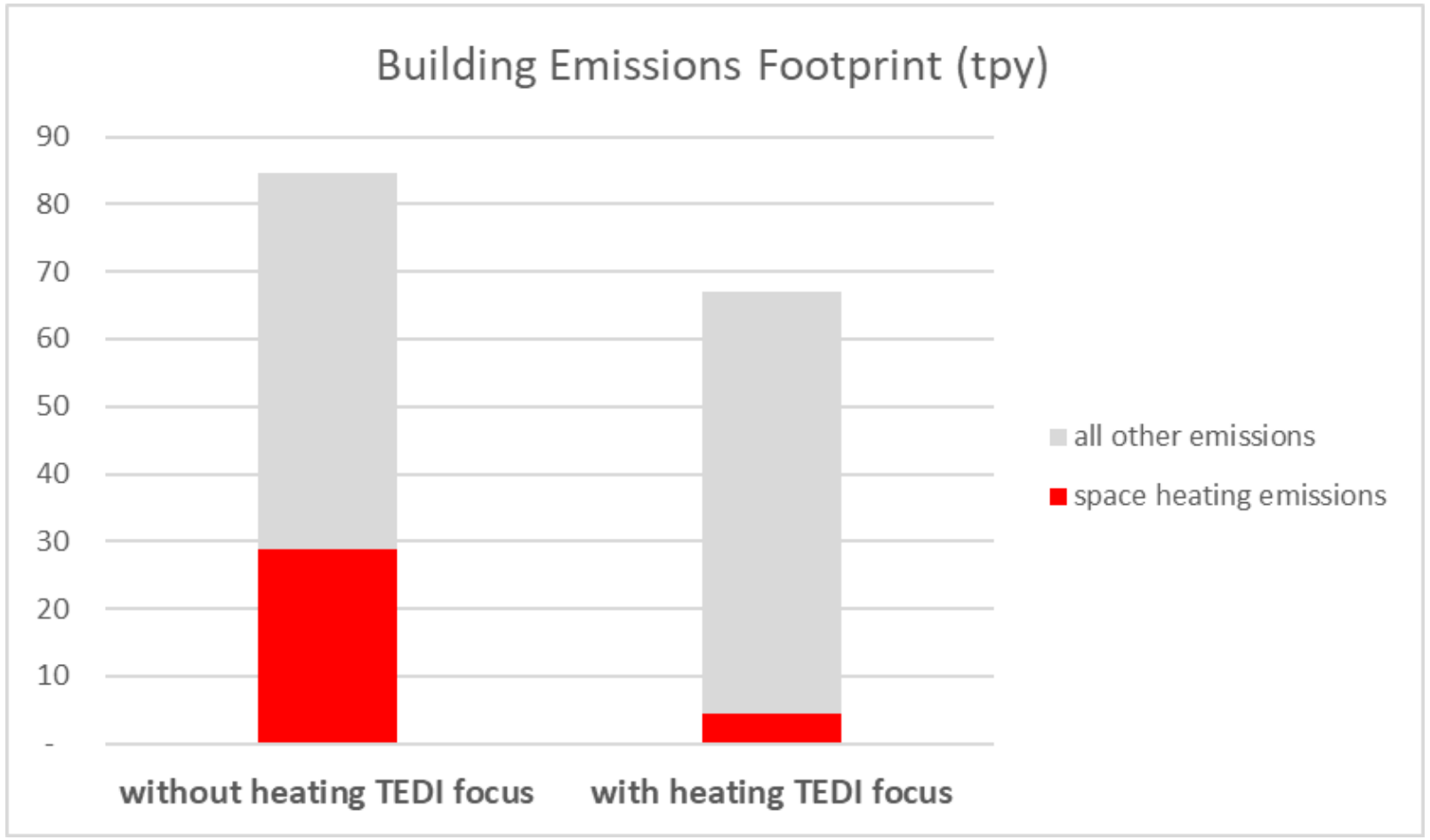
Targeting low heating TEDI means:

- Low emissions
- Easy electrification
- Reduced (or elim) fossil fuel
- Improved resiliency
- Improved comfort



With the proposed code, targeting low heating TEDI results in near elimination of space heating end use. Proposed TEDI code path has space heating end use comparable to Passivehouse at lower cost.

Reduction in heating TEDI yields GHG savings



Codes that focus on achieving low heating TEDI can significantly reduce, and sometimes near eliminate, heating related emissions. Example is shown for secondary school, 2030 emission rates.

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Commercial Analysis Results – Key Terms

Results arranged in pairs, by prototype

- First slide in pair: financial performance
- Second slide in pair: emissions performance

Cost to build

- Calculated as construction cost increase (or decrease) of Proposed compared to Baseline. No Mass Save® or Massachusetts School Building Authority (MSBA) incentives are included.

Cost to building and operate

Calculated as: construction cost increase (or decrease) plus operating cost decrease over 50 years of Proposed compared to Baseline. No Mass Save® or MSBA incentives include.

Emissions over 50 years

- Emissions from gas (if any) plus emissions from grid electricity, over 50 years of operation.
- Includes effect of declining grid emissions rates due to increased renewables.

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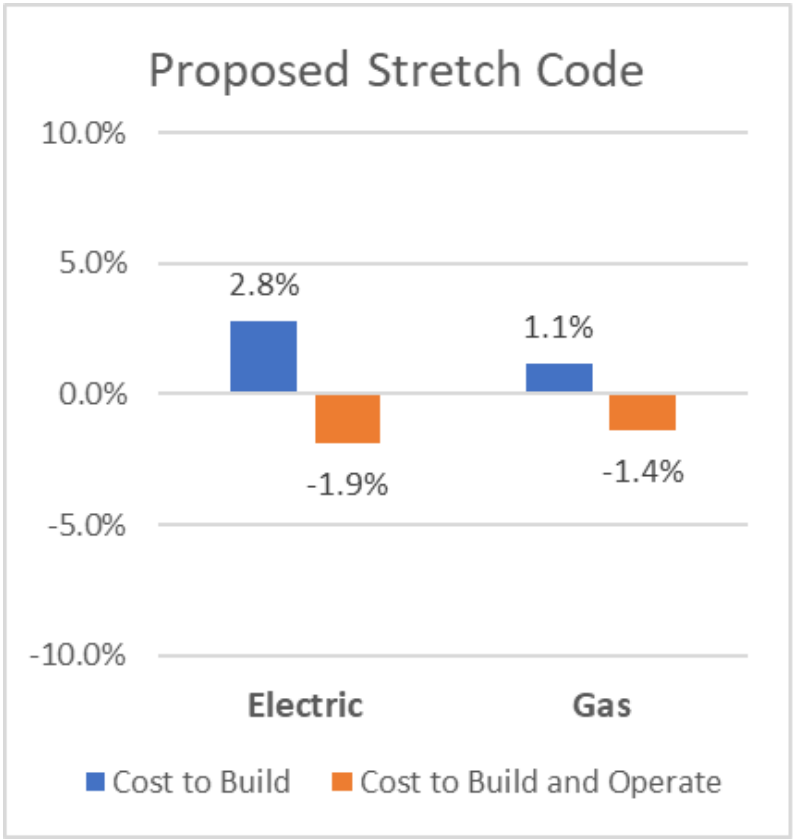
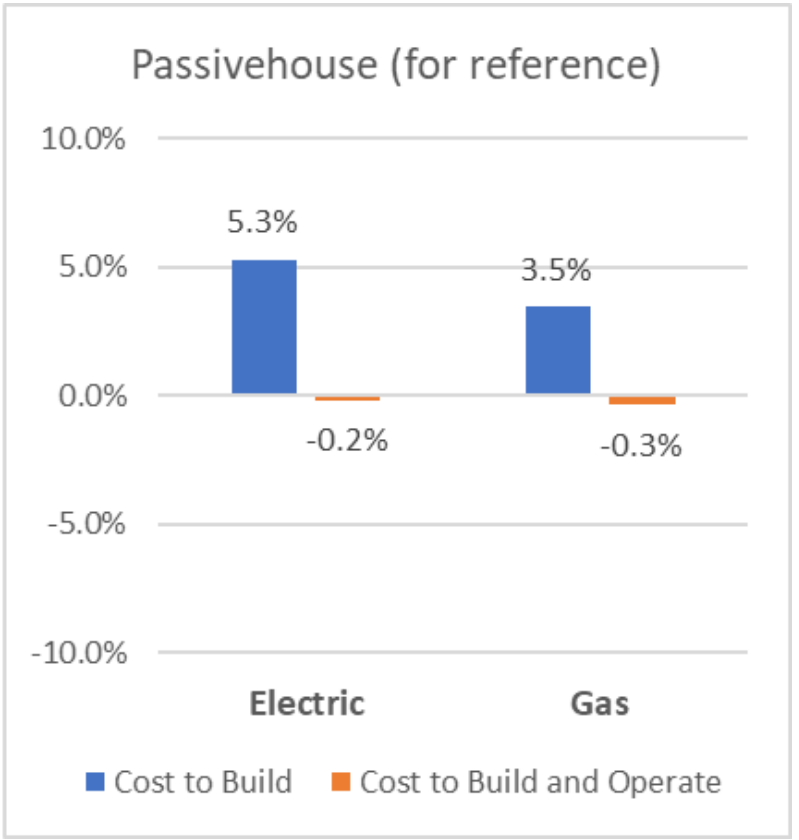
Primary School – Costs (TEDI path)

No MassSave or MSBA or other incentives included

- Cost to Build
  1.1% to 2.8% more
- Cost to Build and Operate (50 yr)
  1.4% to 1.9% less





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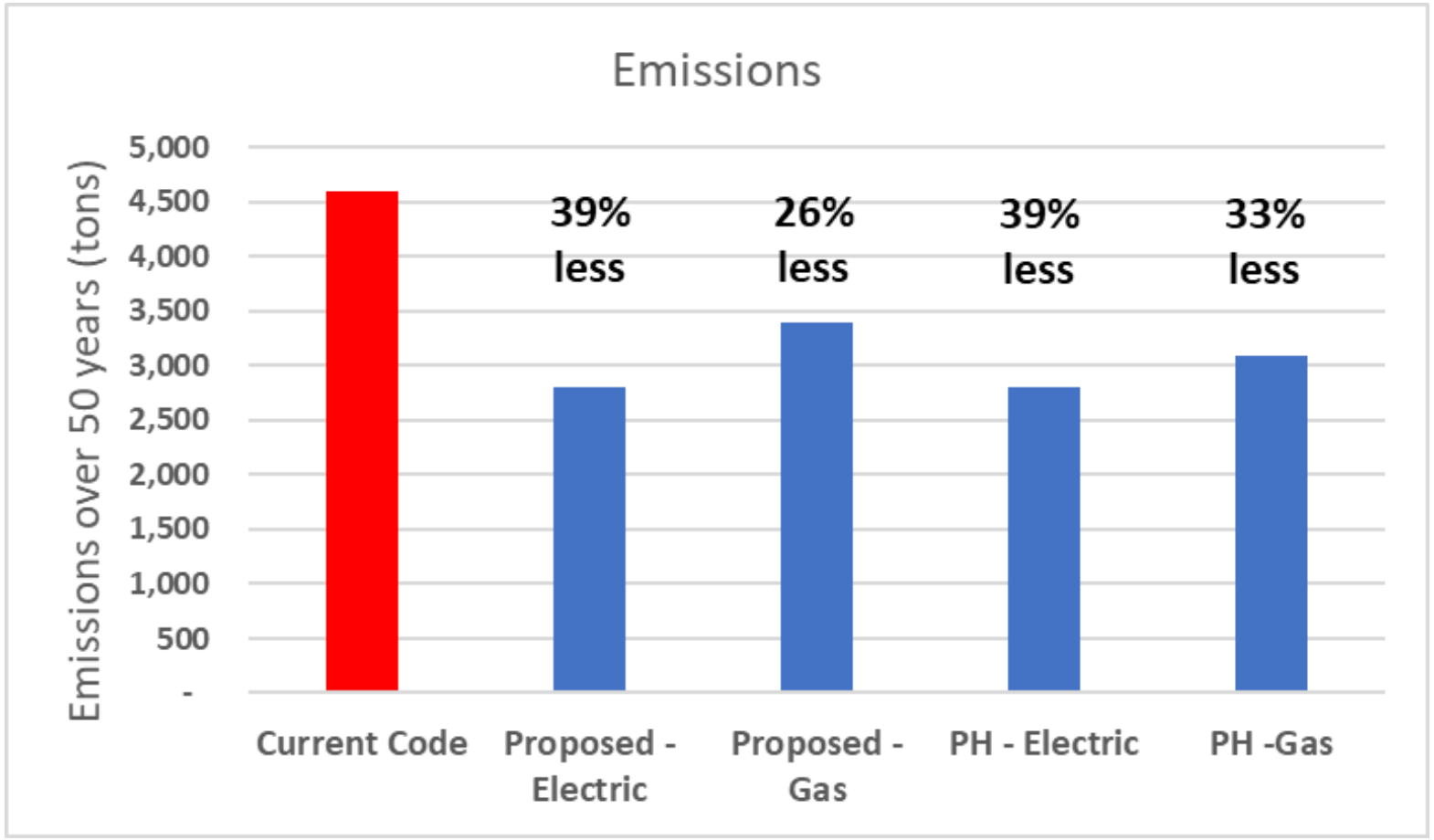
Primary School - Emissions

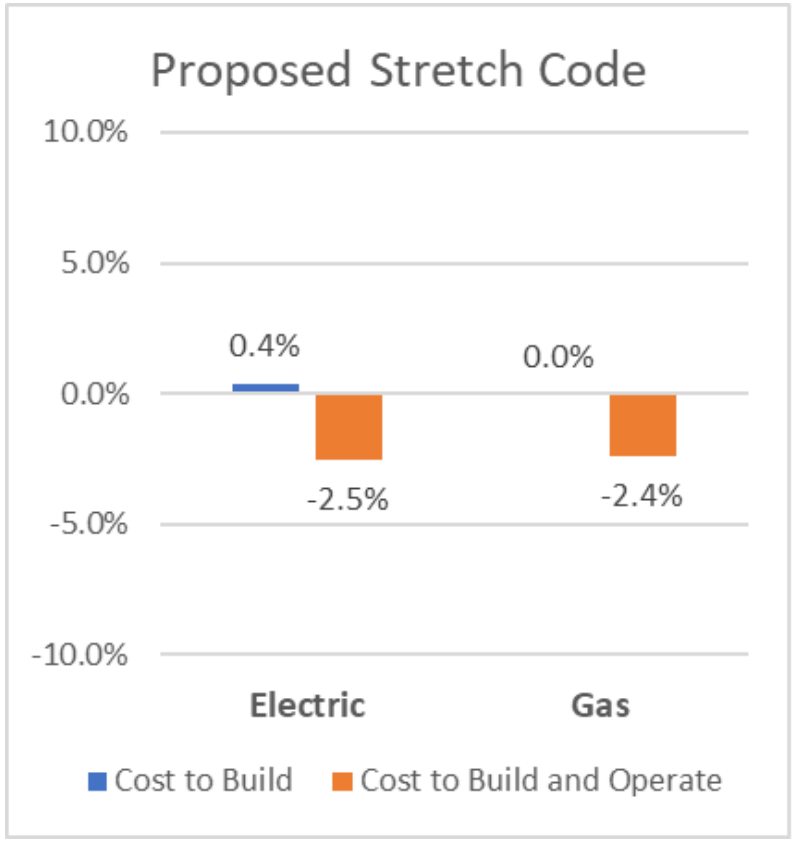
- Emission reduction
  26% to 39%
- About 90% less heating demand
- Electric advantage

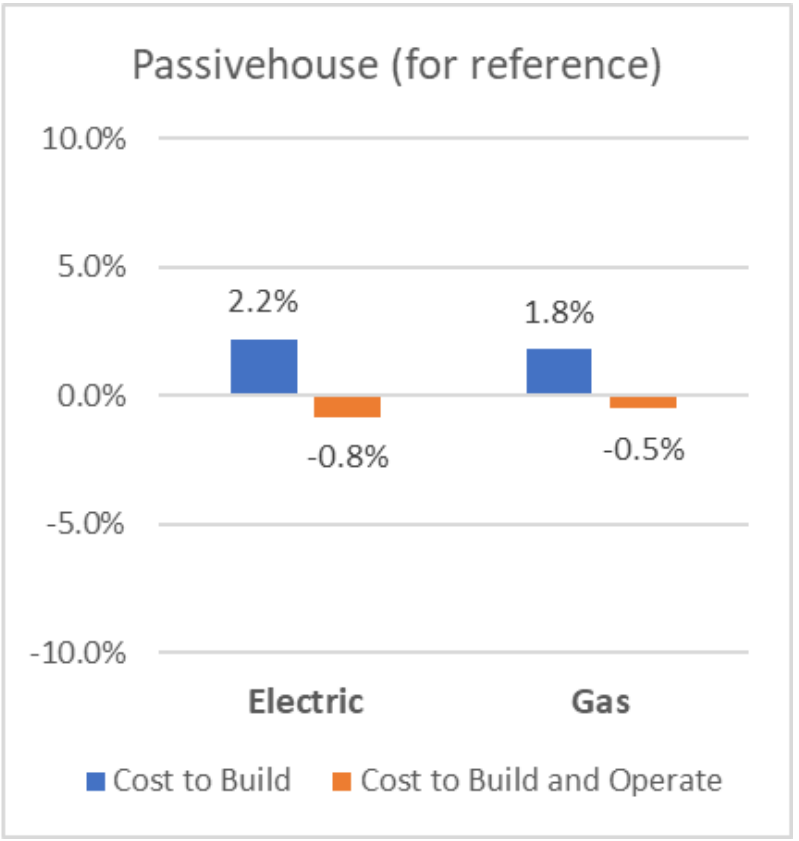


Secondary School – Costs (TEDI path)

No MassSave or MSBA or other incentives included

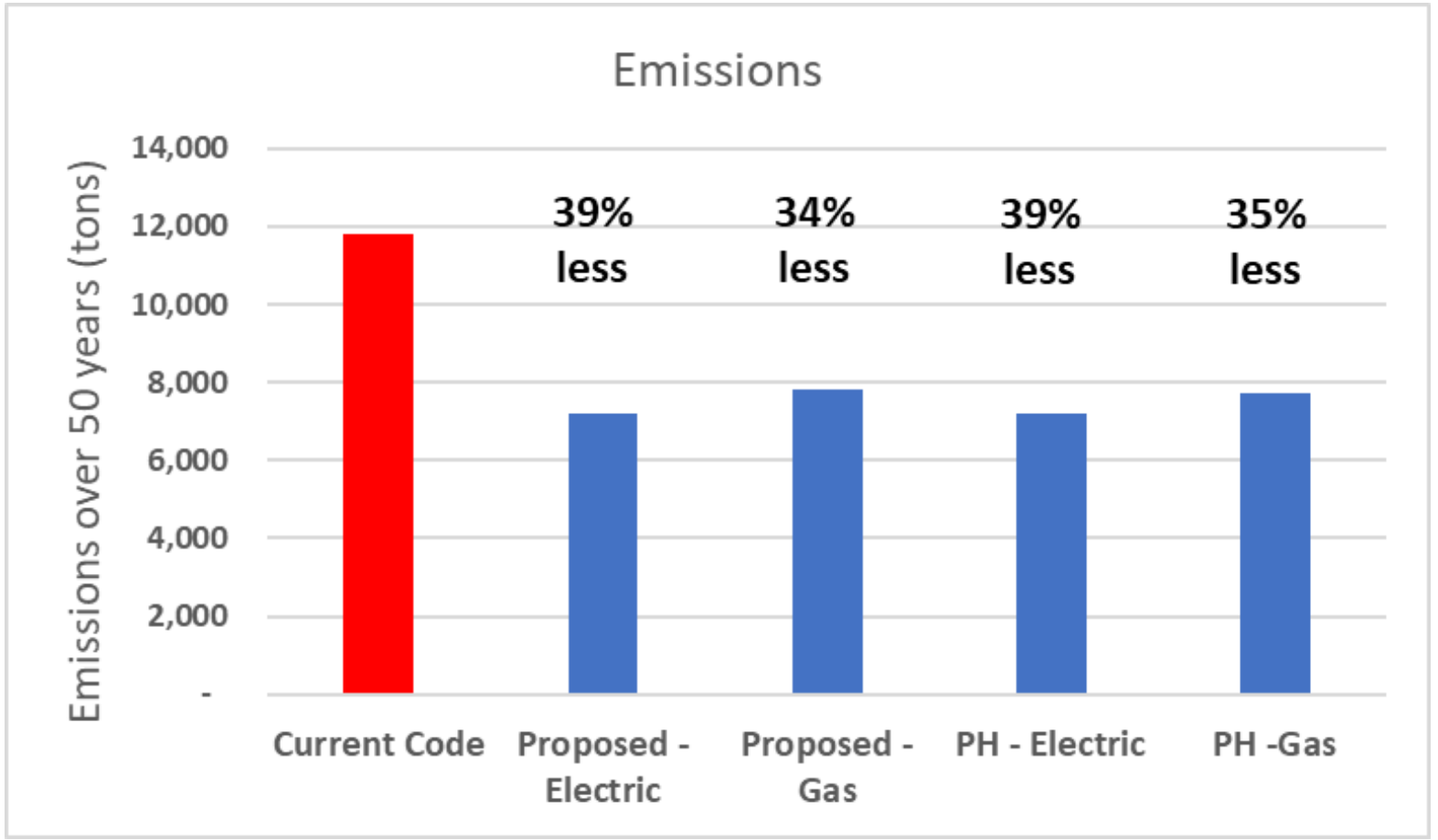
- Cost to Build
  0% to 0.4% more
- Cost to Building and Operate (50 yr)
  2.4% to 2.5% less





Secondary School - Emissions

- Emission reduction
  34% to 39%
- About 90% less heating demand
- Electric advantage



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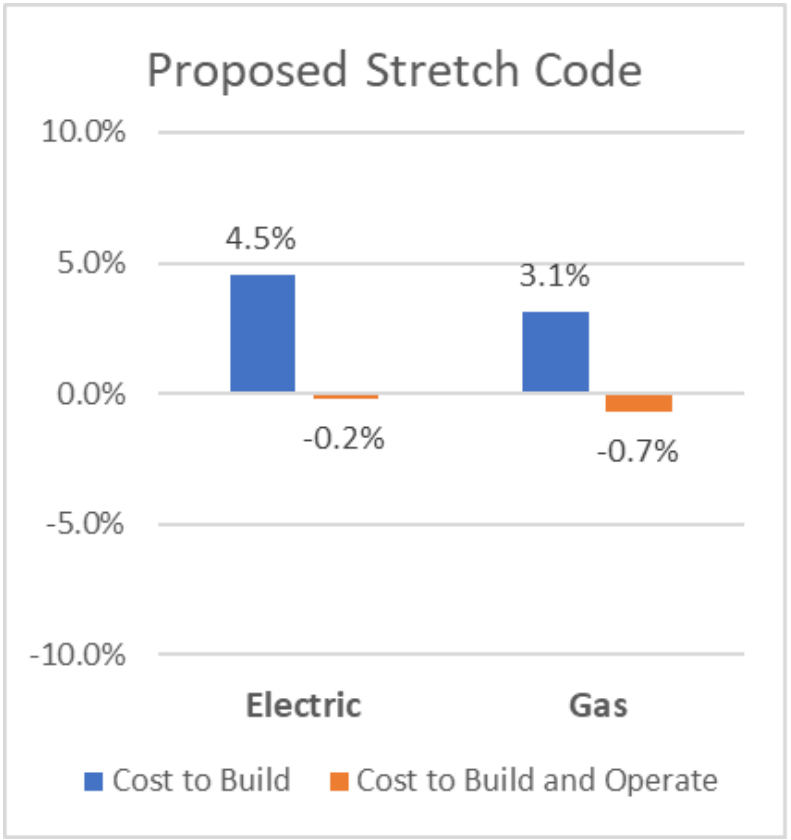
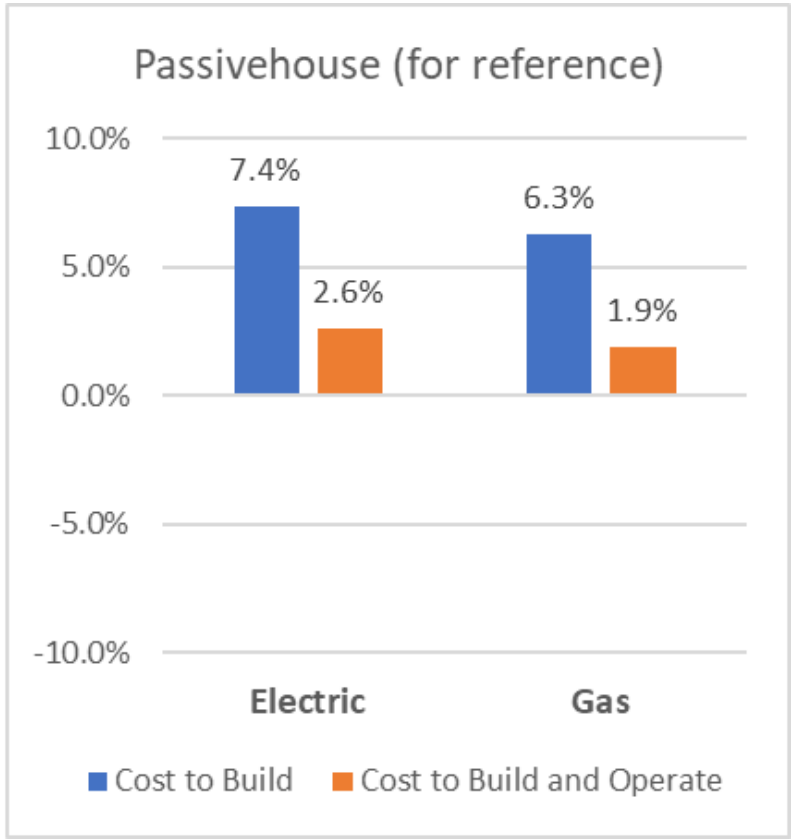
Small Office – Costs (TEDI path)

No MassSave or other incentives included

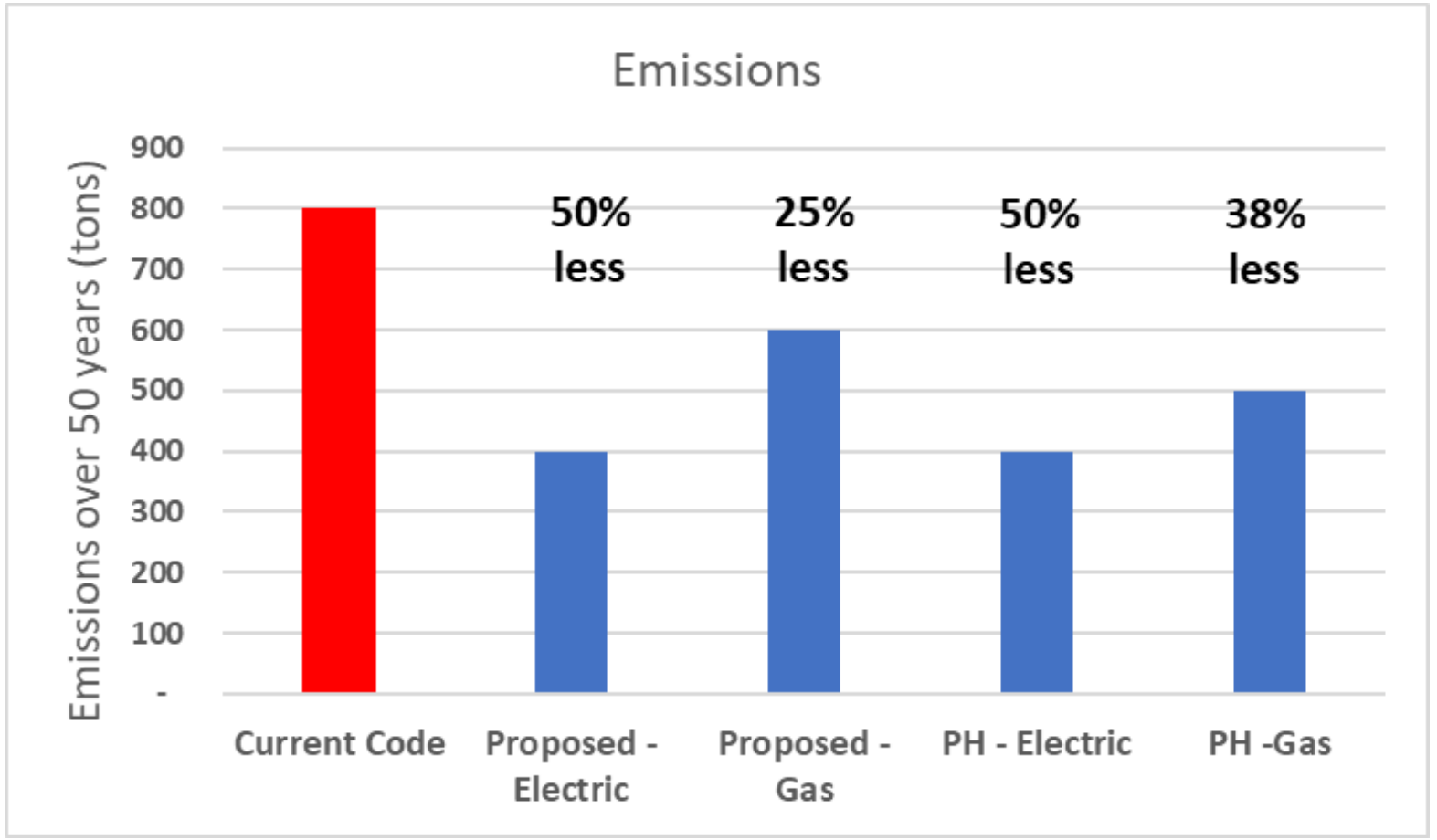
- Cost to Build
  3.1% to 4.5% more
- Cost to Build and Operate (50 yr)
  0.2% to 0.7% less





Small Office - Emissions

- Emission reduction
  25% to 50%
- About 90% less heating demand
- Big electric advantage



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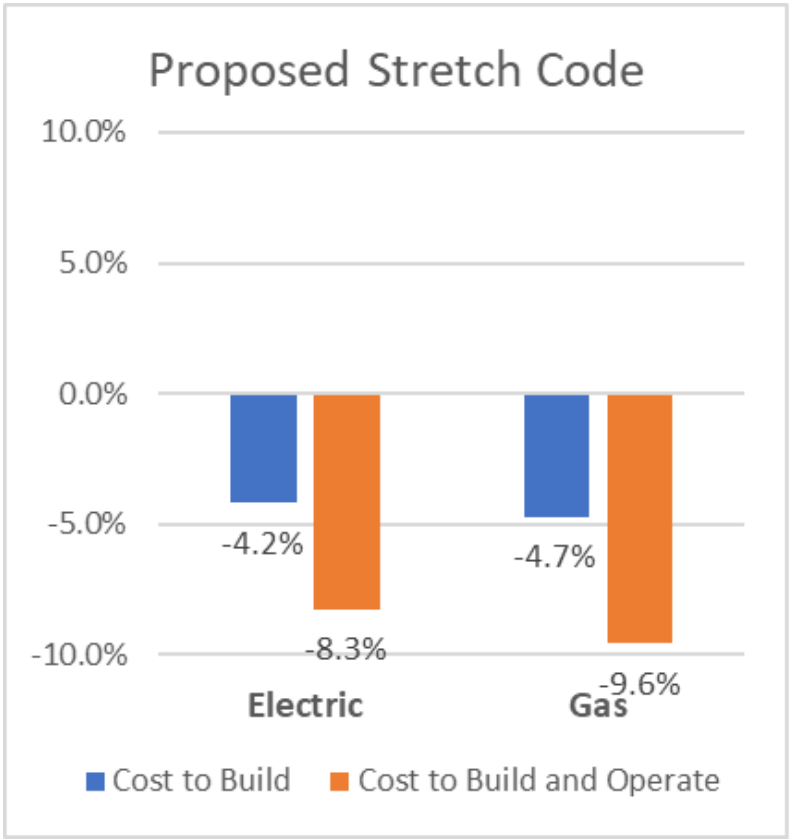
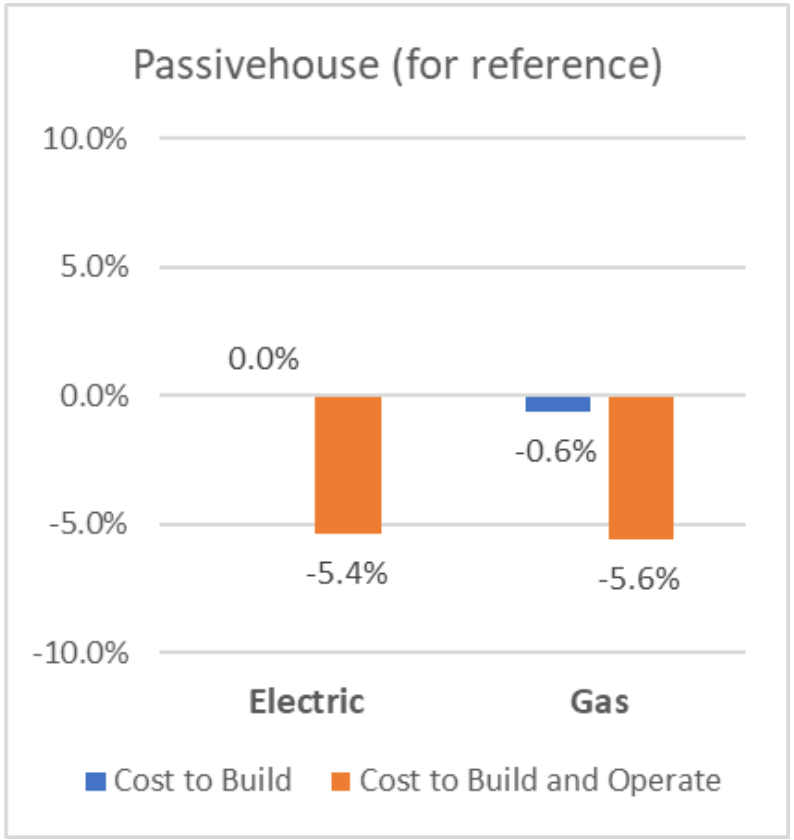
Large Office – Costs (TEDI path)

No MassSave or other incentives included

- Cost to Build
  - 4.2% to 4.7% less
- Cost to Build and Operate (50 yr)
  - 8.3% to 9.6% less
- Envelope
  - All curtain wall
  - 50% window





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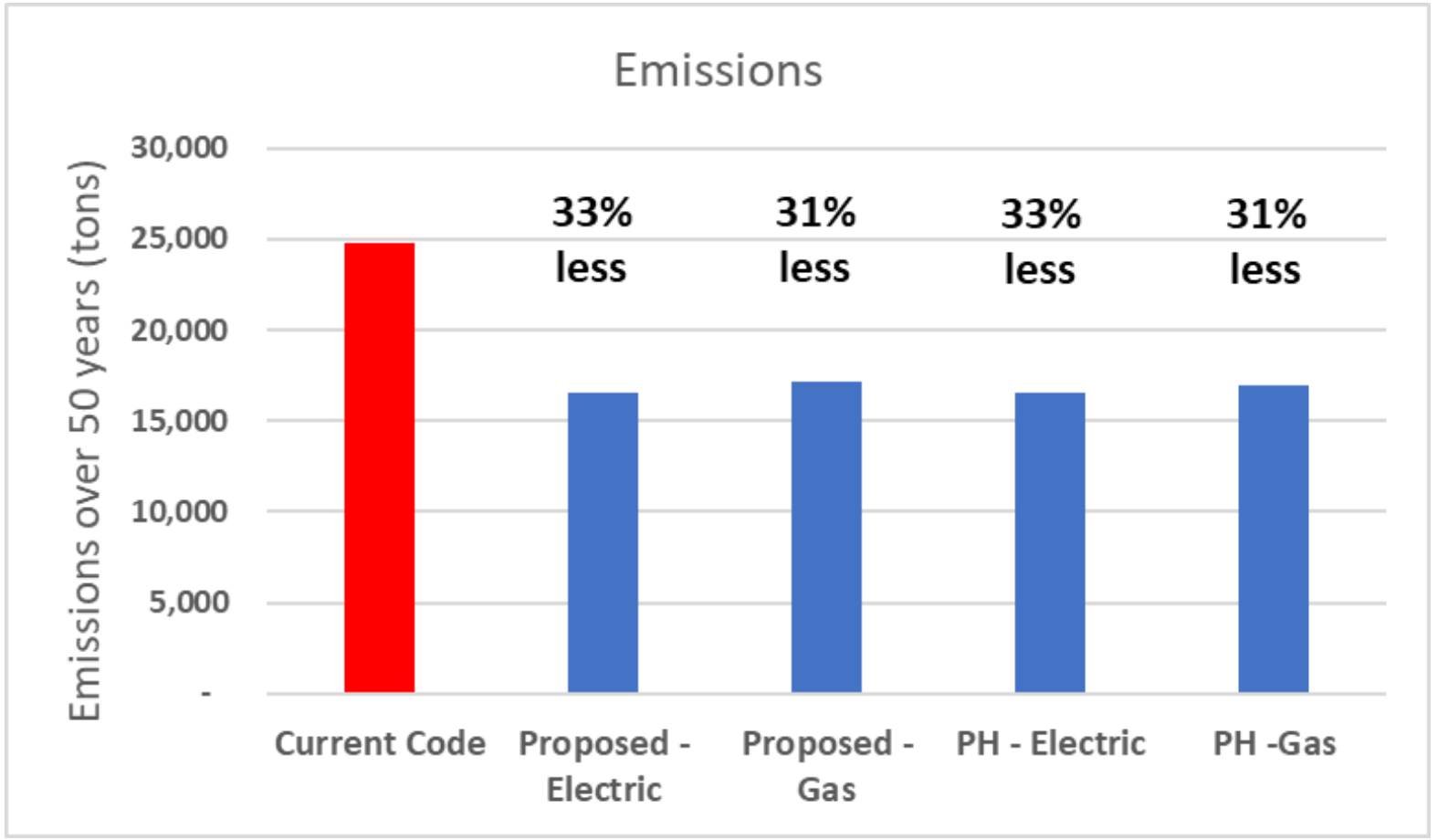
Large Office - Emissions

- Emission reduction
  31% to 33%
- About 90% less heating demand
- Electric advantage



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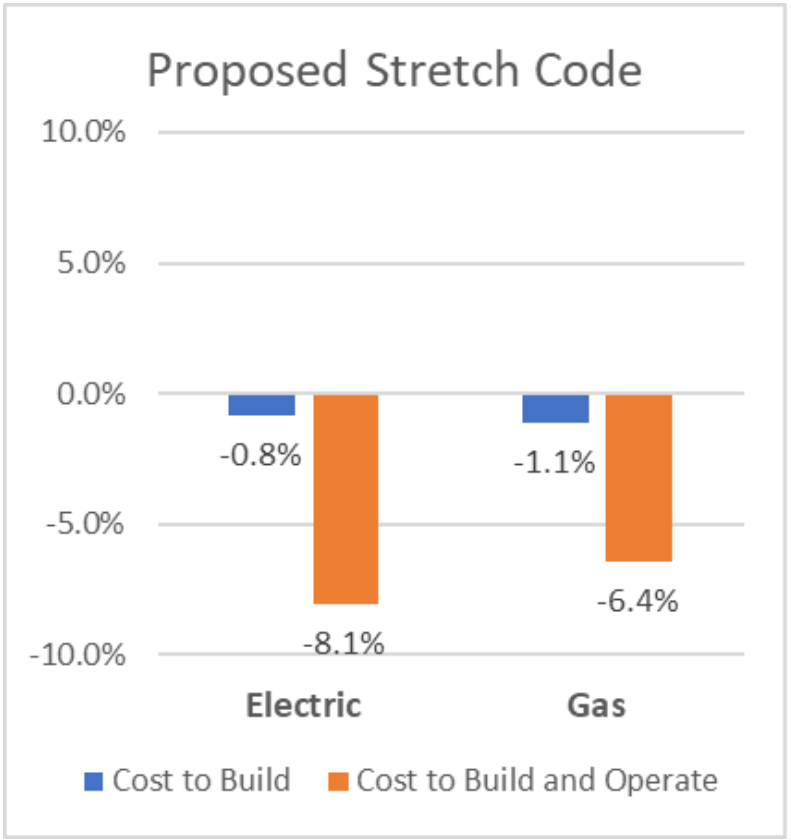
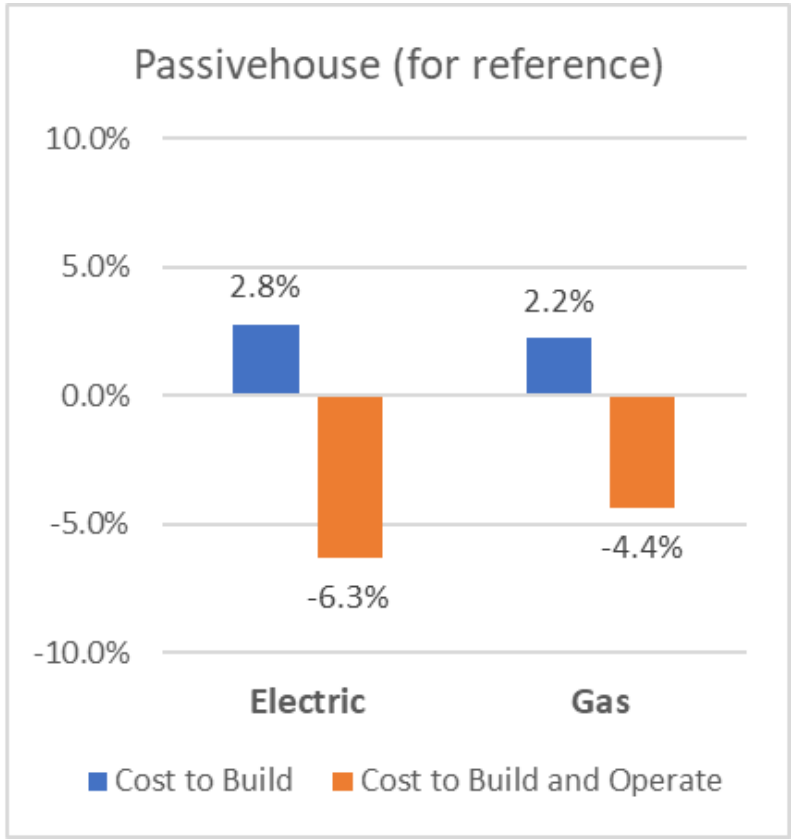
Office/Lab – Costs (MA ASHRAE path)

No MassSave or other incentives included

- Cost to Build
  - 0.8% to 1.1% less
- Cost to Building and Operate (50 yr)
  - 6.4 to 8.1% less
- Envelope
  - All curtain wall
  - 50% window





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Office/Lab - Emissions

- Emission reduction
  29% to 67%
- About 60% less heating demand
- Electric advantage