BUILDINGENERGY BOSTON

Building Better with What We Have: Balancing Carbon, Cost, and Housing

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SOCOTEC

Curated by Christopher Nielson

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BUILDING BETTER WITH WHAT WE HAVE

Balancing Carbon, Cost, and Housing

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NESEA BuildingEnergy Boston 2026

March 23, 2026 2:30 pm

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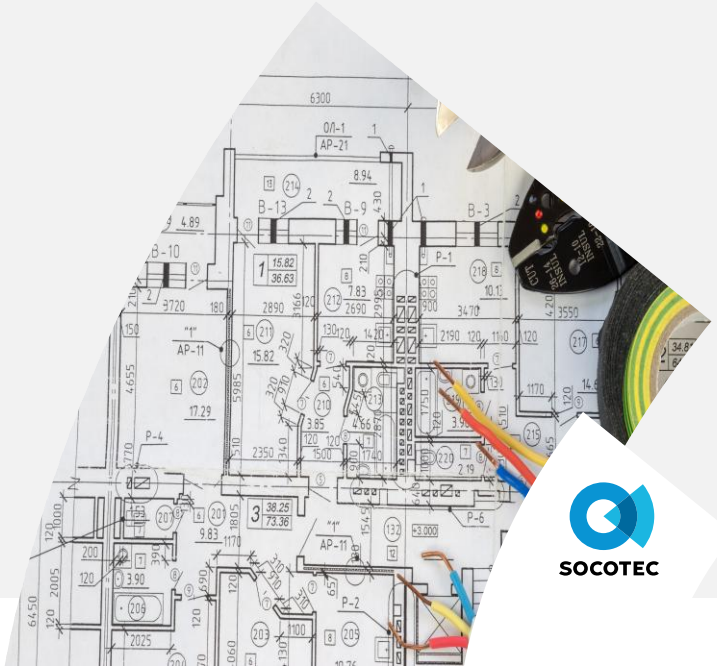
AGENDA

1. Context – housing, climate, and policy
2. Study Design – buildings, typologies, metrics
3. Results
4. Implications – practice, capital planning, policy



LEARNING OBJECTIVES

Abstract: Boston faces twin crises—housing and climate—and must leverage existing buildings in decarbonization efforts. This study evaluates four renovation pathways across multifamily buildings: no renovation, minor renovation, major renovation to new-construction code, and demolition to new construction. With a holistic view of carbon and cost, we identify which interventions deliver the greatest carbon reduction per dollar, using the BERDO database to inform existing conditions of the building stock.

1

Compare the carbon and cost performance of different retrofit strategies, such as envelope upgrades, electrification, and selective versus deep renovations, to identify the most impactful combinations

2

Analyze the trade-offs between upfront construction costs and long-term operational savings in achieving net carbon reductions

3

Apply whole-life carbon thinking to retrofit decision-making processes, integrating embodied carbon considerations into projects that traditionally focus on operational efficiency

4

Inform future policy and design guidance by translating study results into actionable recommendations future code and other housing and sustainability initiatives in the region

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01
CONTEXT

Housing + Climate + Policy

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HOUSING CRISIS + CLIMATE CRISIS

Persistent housing shortage and high costs: Greater Boston remains in a housing crisis, with chronic underbuilding and thousands of already-permitted units stalled, which reinforces the importance of preserving and upgrading existing multifamily stock.

Tight rental market: Vacancy is under 3% in recent reports, making Boston one of the tightest housing markets in the country; losing or displacing existing units through poor retrofit strategies has real equity impacts.

Capital constraints: High construction costs and financing challenges are slowing new construction, which elevates the importance of "retrofit, not rebuild" as a decarbonization and housing strategy.

Climate Concerns: 68% of Boston's total greenhouse gas emissions come from the built environment. Retrofits will be necessary to met the city's goal of net-zero emission by 2050.

1. *https://www.bisnow.com/boston/news/multifamily/bostons-housing-production-slump-could-be-here-to-stay-bu*

POLICY DRIVERS

BERDO 2.0/BEUDO

Building Emissions Reduction and Disclosure Ordinance

Sets requirements for large existing buildings to reduce their greenhouse gas emissions over time.

Building owners subject to BERDO are required to report their buildings' annual energy and water consumption.

Starting in either 2025 or 2030, they will also need to comply with building emissions standards (i.e., emissions limits). These emissions standards decrease over time, with all buildings expected to reach net-zero emissions by 2050.

BERDO covers residential buildings that have 15 or more units

Mass Energy Code

There are three levels of building energy codes in Massachusetts: Base, Stretch, Opt-In Stretch/Specialized

Boston, Cambridge, Sommerville and many more than 50 other communities have adopted the Opt-In Stretch code.

There is a Residential code (not covered in this presentation)

There is a Commercial Code (covered in this presentation).

Under the Opt-In Strech code all new build multifamily buildings must comply via Passive House compliance

Article 37/Article 22

Projects requiring "Large Project Review", buildings greater than 20,000 sf or that have 15+ residential units, and "Planned Development Areas" and "Development Impact Projects" must comply with Article 37/Article 22.

Covered buildings over 50,000 sf must provide a **Life Cycle Assessment (LCA)** of the structure and enclosure of the proposed building.

In addition, all covered new construction buildings require applicable projects to be LEED Gold certifiable under the most appropriate LEED rating system.

Massachusetts: A Home For Everyone

1. **Achieve a state of housing abundance**
2. **Protect existing homes and affordability**
3. Support households
4. Build a stronger safety net
5. Work together for the Commonwealth

Boston Housing Strategy 2025

1. Accelerated Housing Production
2. Affordable Housing Initiatives
3. **Innovative Housing Development**
4. A strong Boston Housing Authority
5. **Housing Stability Support**
6. Home Ownership opportunities
7. **Sustainable Housing**

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1. *https://www.boston.gov/departments/housing/housing-initiatives-under-mayor-michelle-wu* *https://www.mass.gov/a-home-for-everyone-executive-summary*

RETROFIT VS NEW/RE-BUILD DILEMMA

THREE WAY TRADE: MONEY, CARBON, HOUSING STABILITY.

RETROFIT ⟷ **NEW BUILD**

CAPITAL INTENSITY/FINANCE

Lower upfront capex in many cases; can phase work; easier to align with limited funding.

High single-shot capex; larger, cleaner transactions, but harder to fund in today's rate environment.

Question: where do we get the most carbon reduction per dollar, given scarce capital?

WHOLE-LIFE CARBON

Preserves existing structure; much lower embodied carbon; good operational gains with deep retrofit

Very low operational carbon if designed well; large upfront embodied 'spike' from demolition + new materials.

Trade-off: short-term embodied hit vs long-term operational performance

HOUSING CONTINUITY/DISPLACEMENT

Can keep many units online; potential for in-place or phased work; less relocation risk if managed well

Multi-year loss of units; higher risk of permanent displacement and loss of deeply affordable homes

Tension: protect residents and units now vs rebuild 'better' later.

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OBJECTIVES OF THIS STUDY?

- Bridge operational and embodied carbon in decision-making
- Quantify carbon and cost impacts of renovation pathways
- Find the best “carbon per dollar” strategies
- Link project-level choices to policy and codes
- Provide a practical framework for owners and practitioners

02
STUDY DESIGN

Typologies + Metrics

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STUDY DESIGN – 12 ARCHETYPES

Three Multifamily Building Sizes

- **Small** (10,000-25,000SF)
- **Medium** (50,000-75,000SF)
- **Large** (100,000-125,000SF).

Within these three size breakdowns there are 4 vintages:

- **Pre-War (before 1939):** Small, Medium, Large
- **1940-1979:** Small, Medium, Large
- **1979-2006:** Small, Medium, Large
- **2006-Present:** Small, Medium, Large

ENERGY MODELING INPUTS

- Existing Conditions:

	Exterior Wall	Roof	Windows	Lighting and Equipment	Ventilation	Heating	Cooling	DHW
Pre-War	U-0.25	U-0.51	Single pane – clear U-0.93 SHGC-0.86	ASHRAE 90.1- 1999 Lighting Gas Stoves	None	HW 75% Eff	PTAC 7.7 EER	Gas HWH 70% Eff
1940-1979	U-0.142	U-0.094	Single pane – clear U-0.93 SHGC-0.86	ASHRAE 90.1- 1999 Lighting Gas Stoves	None	HW 75% Eff	PTAC 7.7 EER	Gas HWH 70% Eff
1980-2006	U-0.093	U-0.054	double pane – clear U-0.68 SHGC-0.77	Improved LPD Gas Stove	Bathroom/ Kitchen Exhaust	HW 80% Eff	PTAC 7.7 EER	Gas HWH 80% Eff
2006-Present	U-0.055	U-0.042	Double pane – clear U-0.40 SHGC-0.49	ASHRAE 90.1-2010 Lighting Gas Stove	Bathroom/ Kitchen Exhaust	HW 95% Eff	PTAC 7.7 EER	Gas HWH 97% Eff

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ENERGY MODELING INPUTS – RETROFIT LEVELS

MINOR RETROFIT

- Roof Replacement
- Lighting Upgrade + Apt Equipment to EnergyStar all-electric
- SHGC Film on Windows
- R-4 Added to Walls
- DHW-HWH and Boiler tune up

MAJOR RETROFIT

Minor Retrofit Measures Plus:

- Window Replacement
- Over-clad walls
- VRF install for Apartments + DHWHP (1)
- ERV Installed + Kitchen/Toilet Exhaust

FULL DECARBONIZATION

Major Retrofit Measures Plus:

- VRF install for Apartments DHWHP (2) – gas equip. decommissioned

NEW BUILD PASSIVE HOUSE

R-40 Wall • R-60 Roof • High Performance Windows • ERV • DHWHP • Energy Star Equipment • High Performance Lights • VRF/ASHPS

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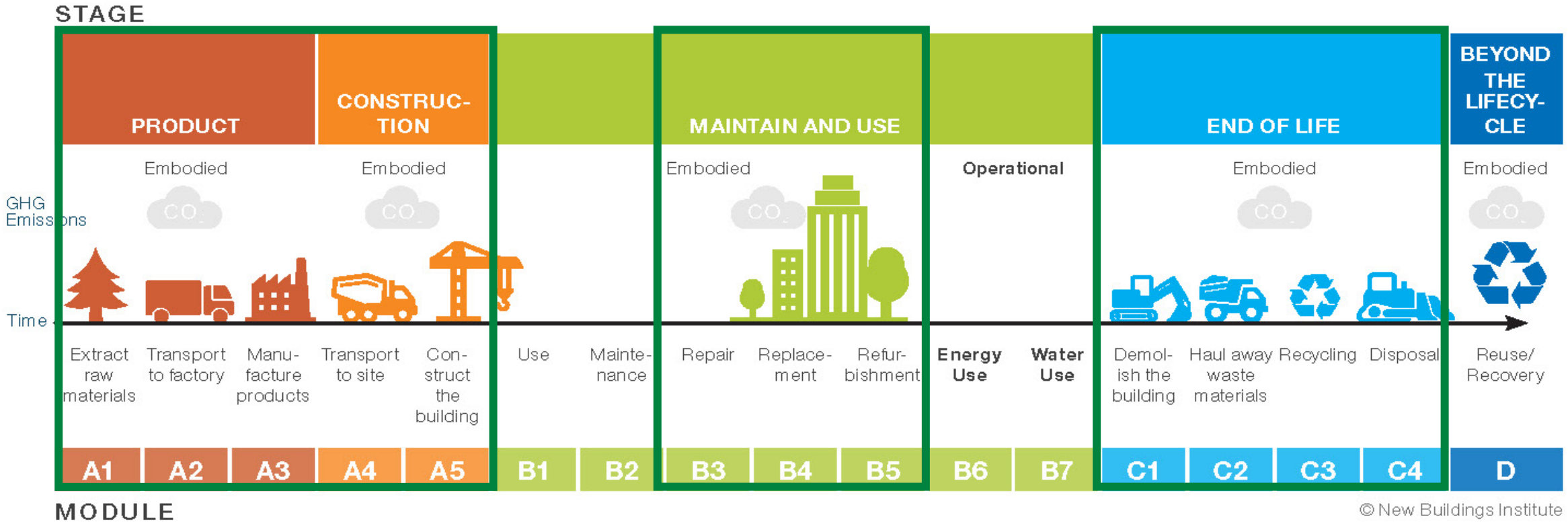
EMBODIED CARBON ANALYSIS SCOPE

The modules below were modeled using OneClick LCA and CIBSE's TM65 tool for MEP equipment and structure and enclosure materials.



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CARBON AND COST METRICS

- **UP FRONT:** Embodied carbon and upfront construction costs ($kgCO_2e$, $)
- **ANNUAL:** Operational energy, operational carbon emissions, and annual energy costs (EUI, CEI, $).
- **FUTURE:** BERDO compliance and penalties

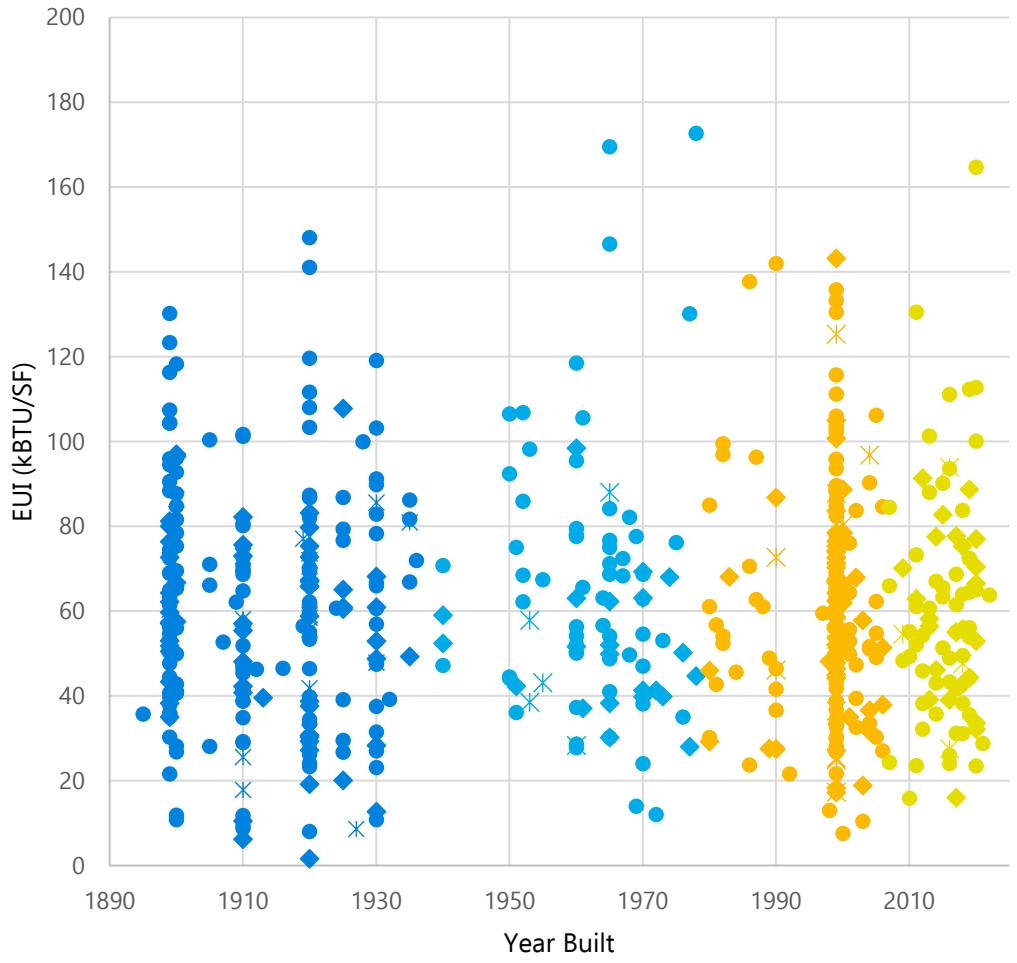
TIME HORIZON & SCENARIOS

- Analysis period looks at 60 years (2025-2085) and 25 years – in alignment with BERDO (2025-2050).
- Boston projects that the grid will be cleaner in the future, per BERDO published documents, those emission rates are captured.
- Energy costs are assumed to hold steady with 2025 rates.

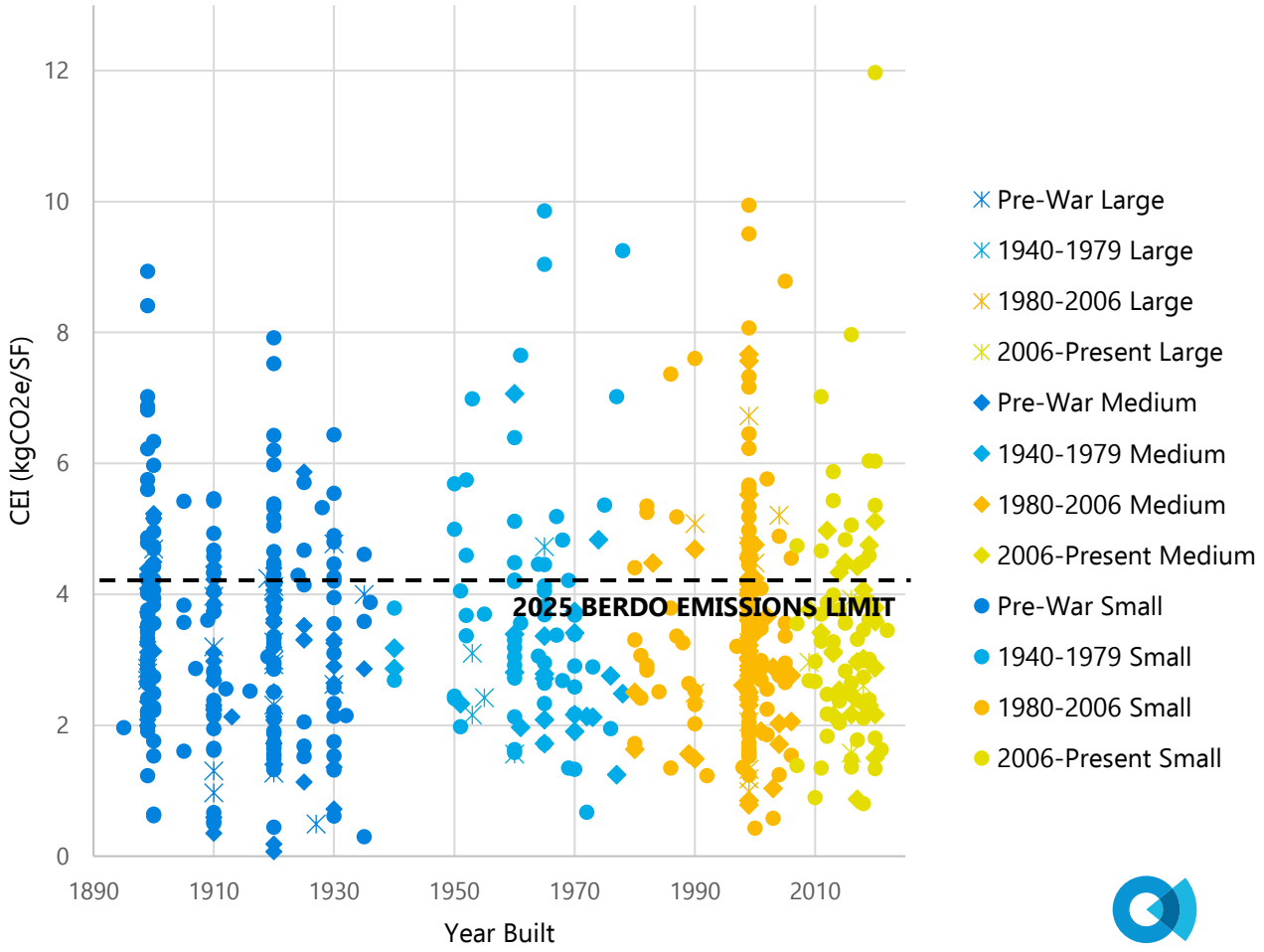
BASELINES: MODELS VS DATA

BERDO DATA

Energy Performance



Carbon Emissions



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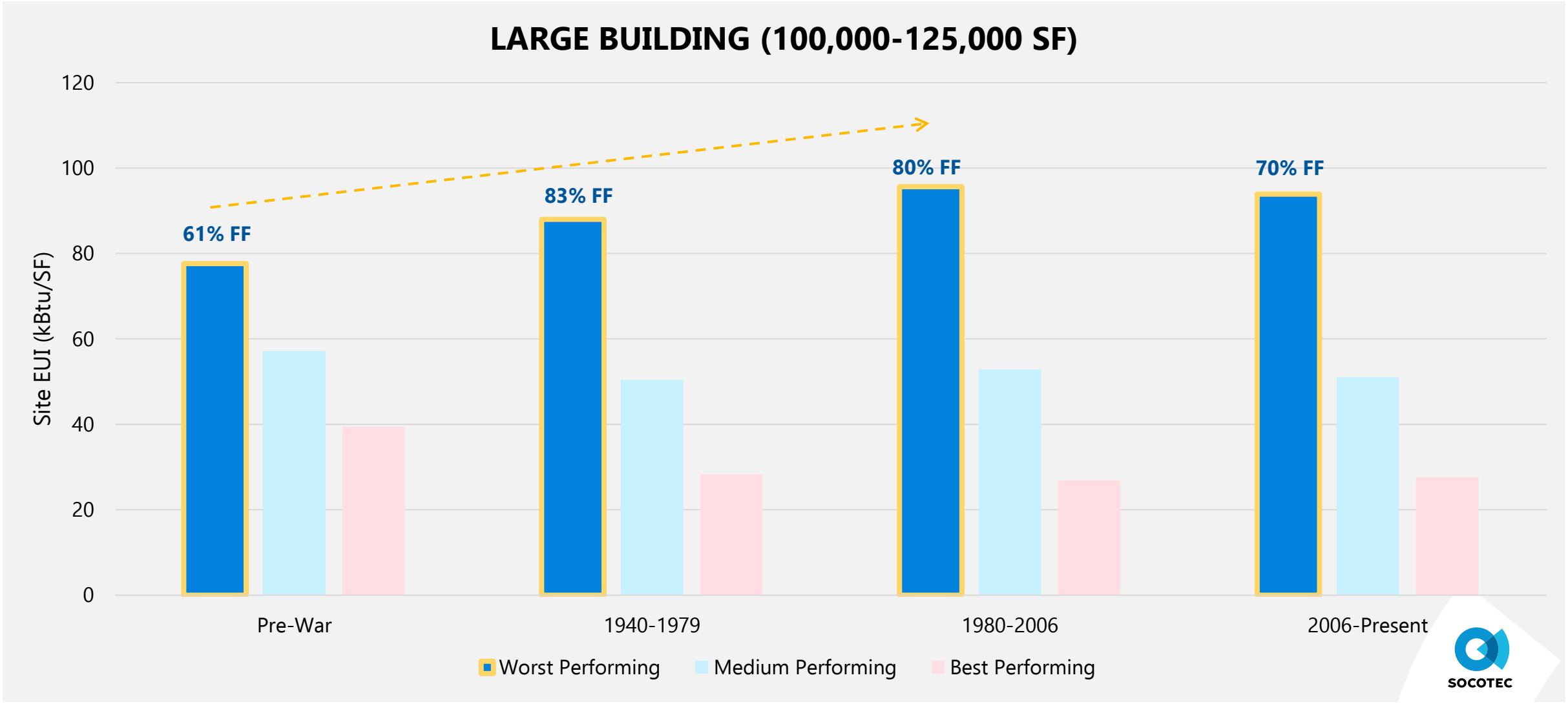
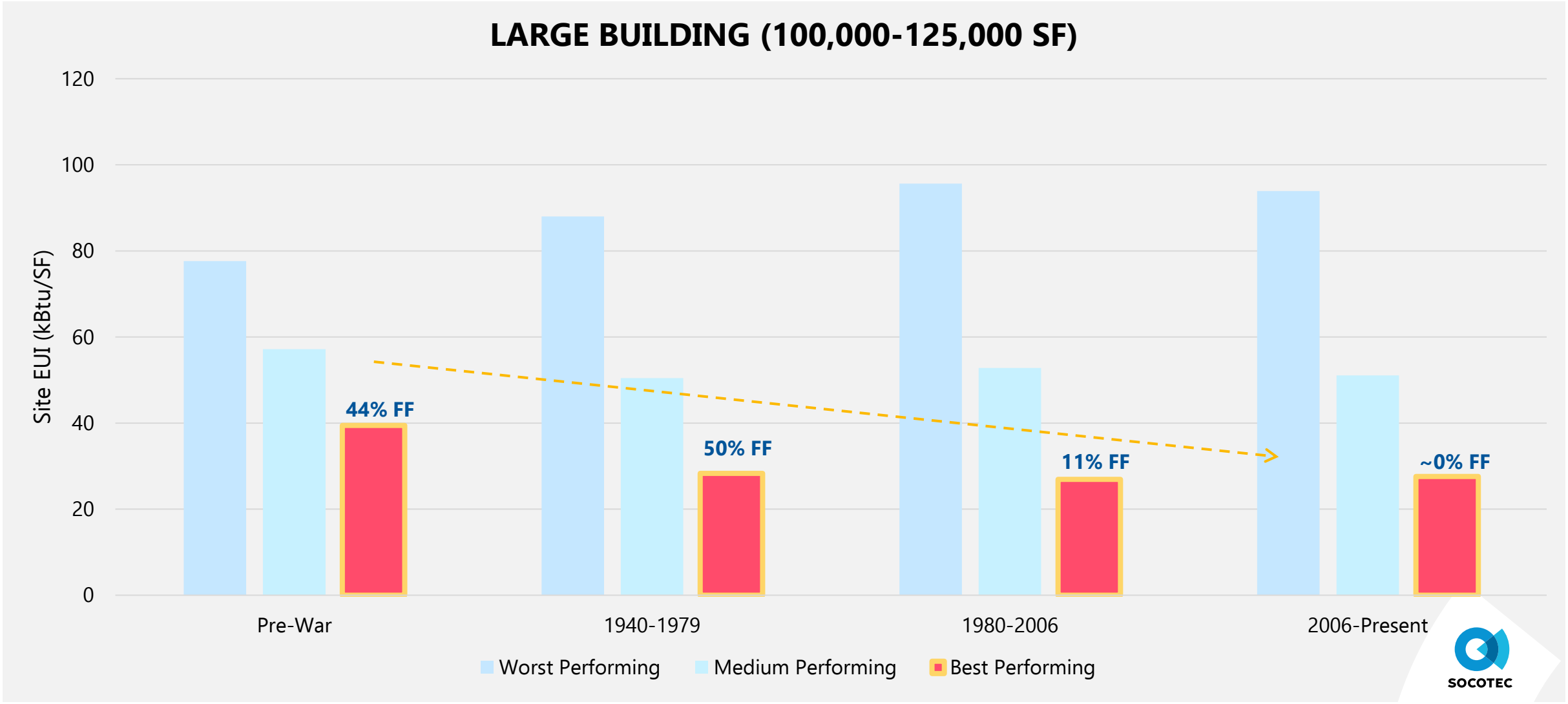
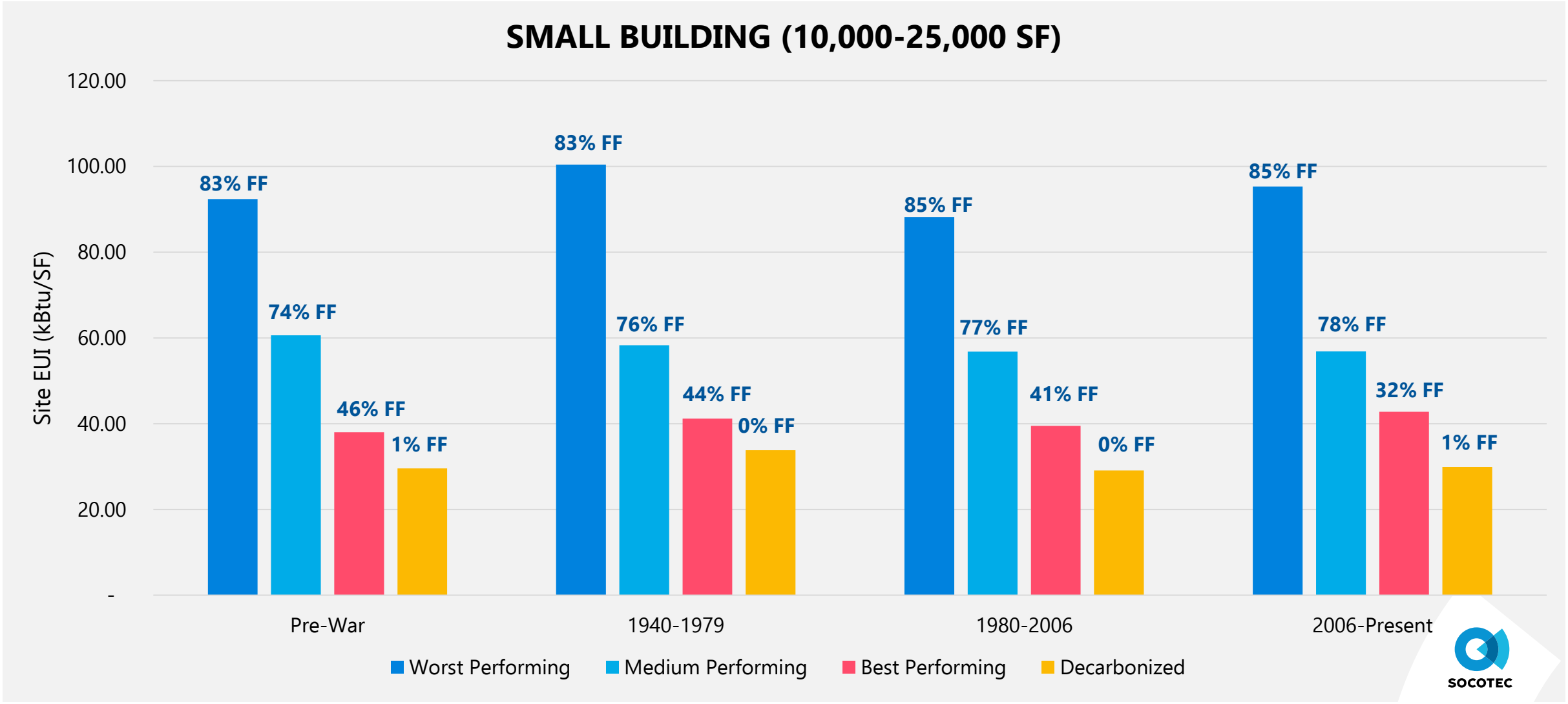
BERDO DATA - LARGE BUILDINGS – WORST PERFORMING



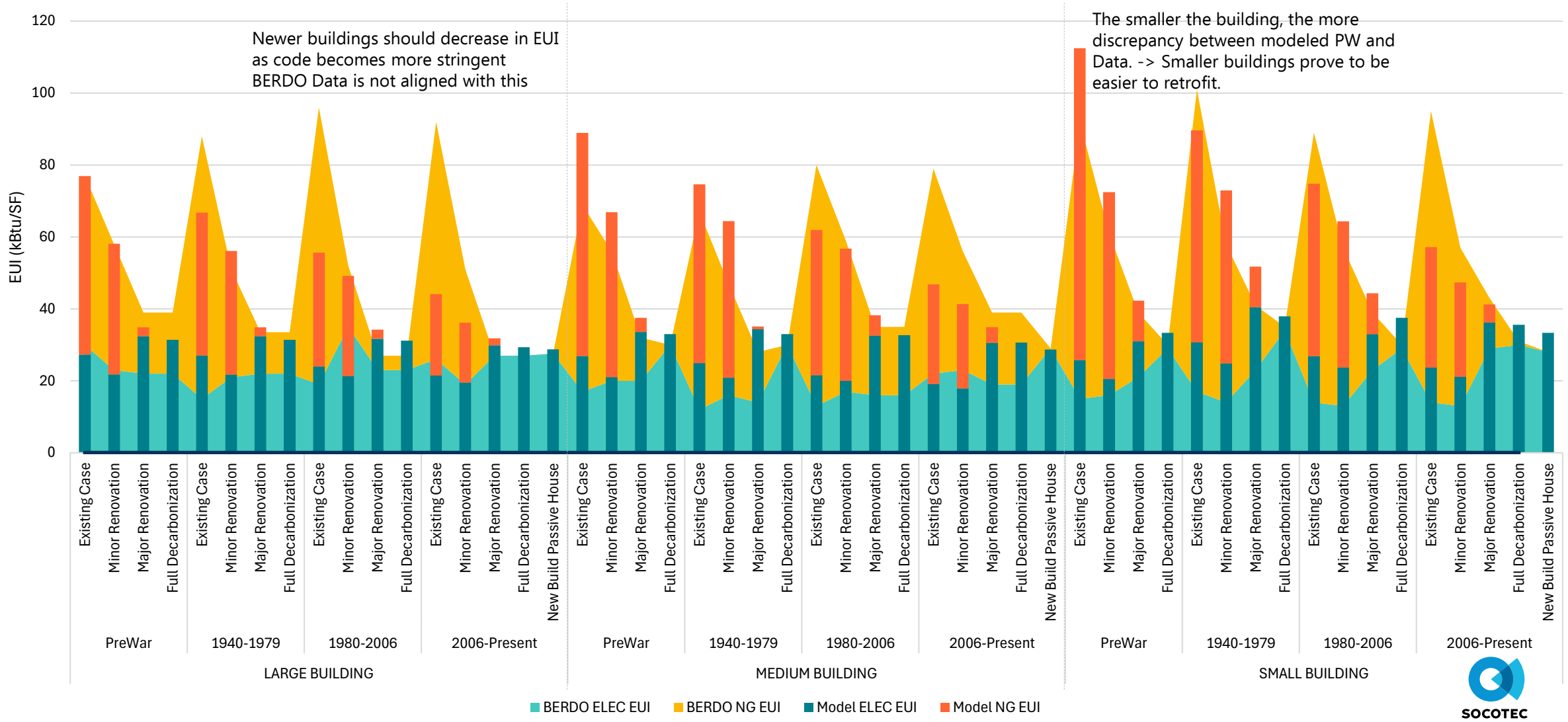
BERDO DATA - LARGE BUILDINGS – BEST PERFORMING



BERDO DATA - SMALL BUILDINGS



MODELED PERFORMANCE VS BERDO REPORTED DATA



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WHAT DOES THE BERDO DATA TELL US AND HOW SHOULD THAT INFORM OUR READ OF THE RESULTS

KEY INSIGHT: CODE MINIMUMS DON'T LIFT ALL BOATS
TARGET BUILDINGS FOR RETROFIT BY POOR-PERFORMANCE NOT AGE

1

WORST PERFORMERS: the worst performing new buildings use more energy and emits more carbon than the worst performing old buildings.

Why? Deferred maintenance + partial retrofits lock in inefficiency + continuously improving code doesn't necessarily mean the building operates correctly/efficiently. New buildings provide more base building services (ventilation etc.)

2

MEDIUM PERFORMERS: medium performers across all vintages and all sizes perform similarly with EUI, however have a wide range of % Fossil Fuel Consumption.

What does this mean? Energy efficiency is not necessarily indicative of emissions

3

BEST PERFORMERS: Best performers are well aligned with predicted EUIs. Mix of Fossil Fuel and All-electric best performers.

What does this mean? We know what works, the solutions are proven out. Complete Decarbonization is not required to lower EUI.

03 RESULTS

Carbon + Energy

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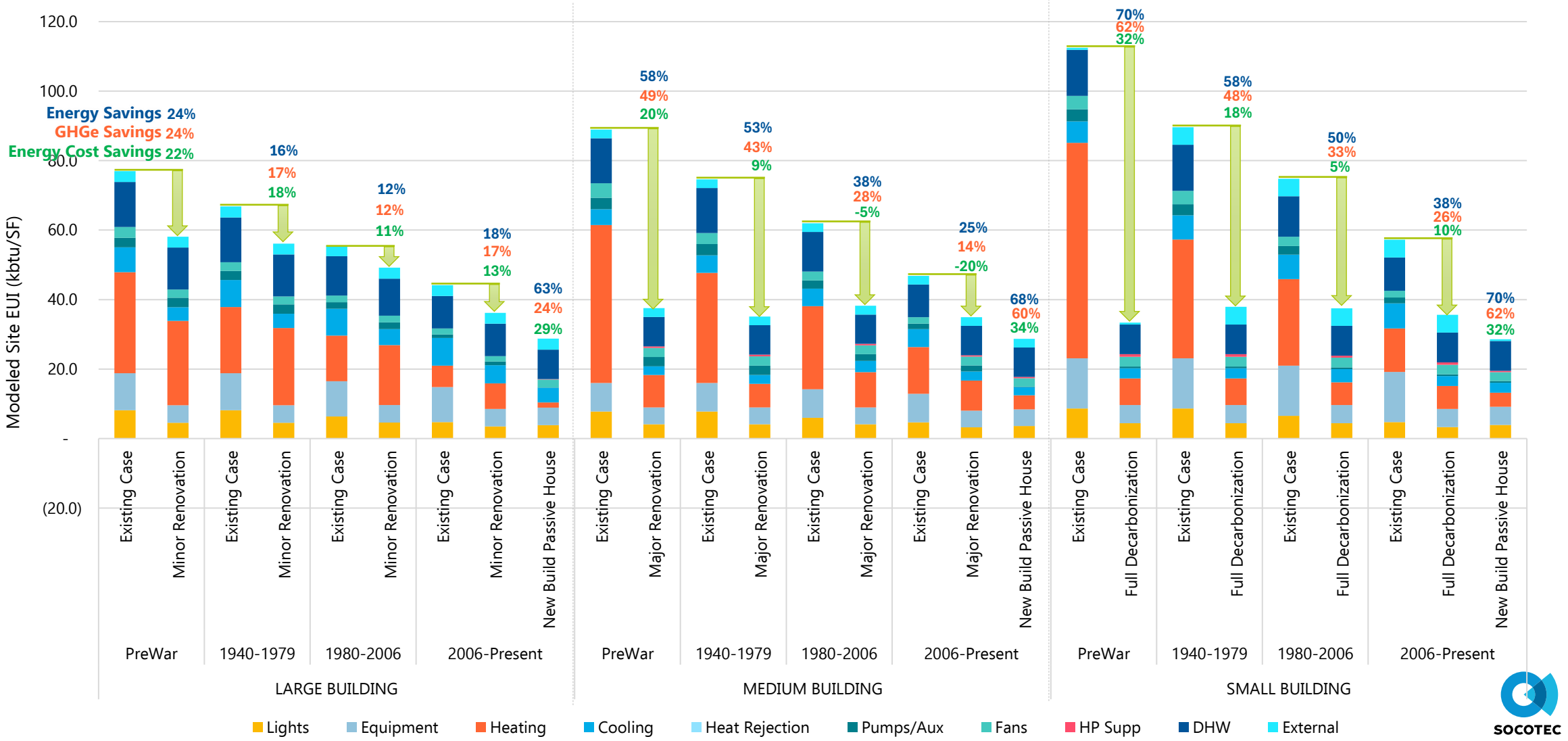
MODELED ENERGY PERFORMANCE– SAMPLES



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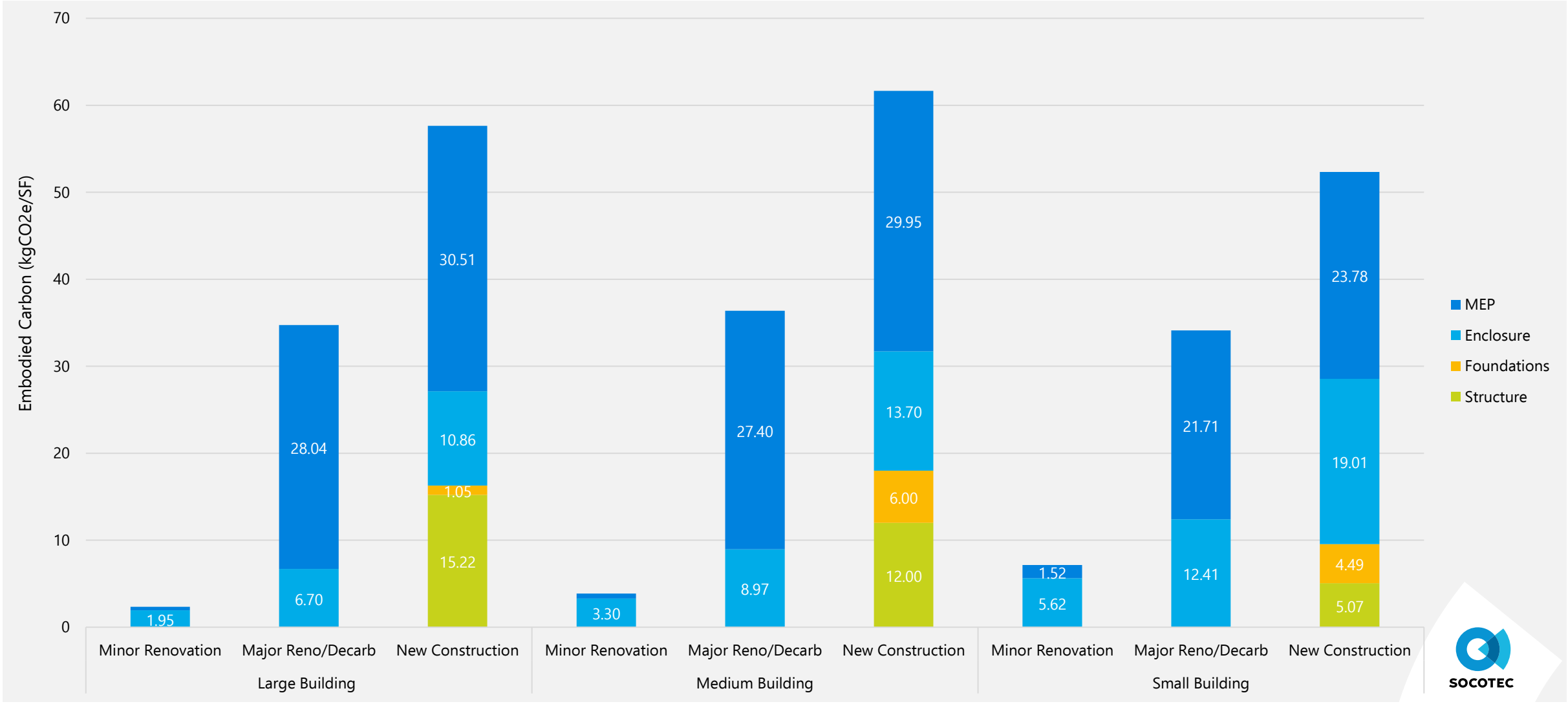
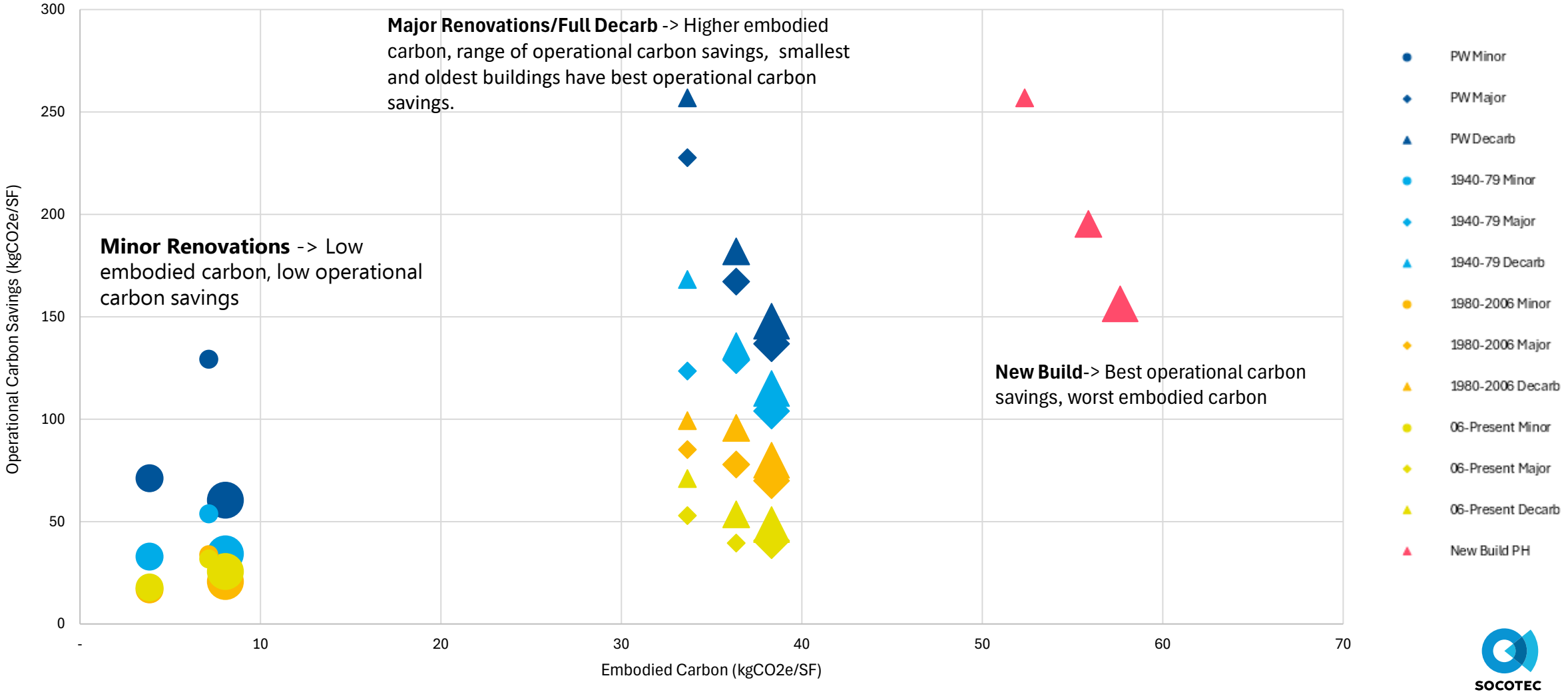
EMBODIED CARBON RESULTS

Whole-Life View

EMBODIED CARBON OF RETROFIT SCOPES ACROSS ALL SIZES (60 YEAR)



OPERATIONAL CARBON SAVINGS VS EMBODIED CARBON (60 YRS)



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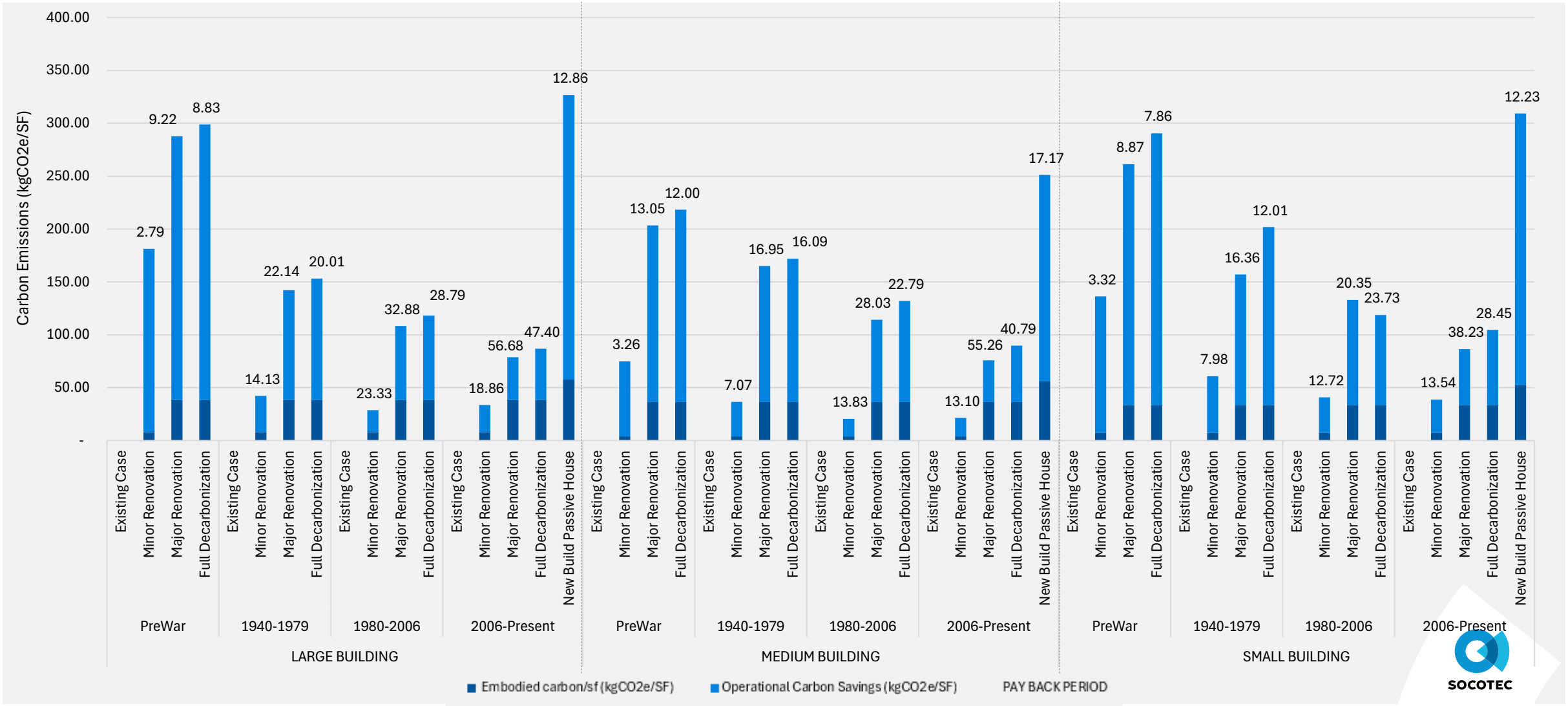
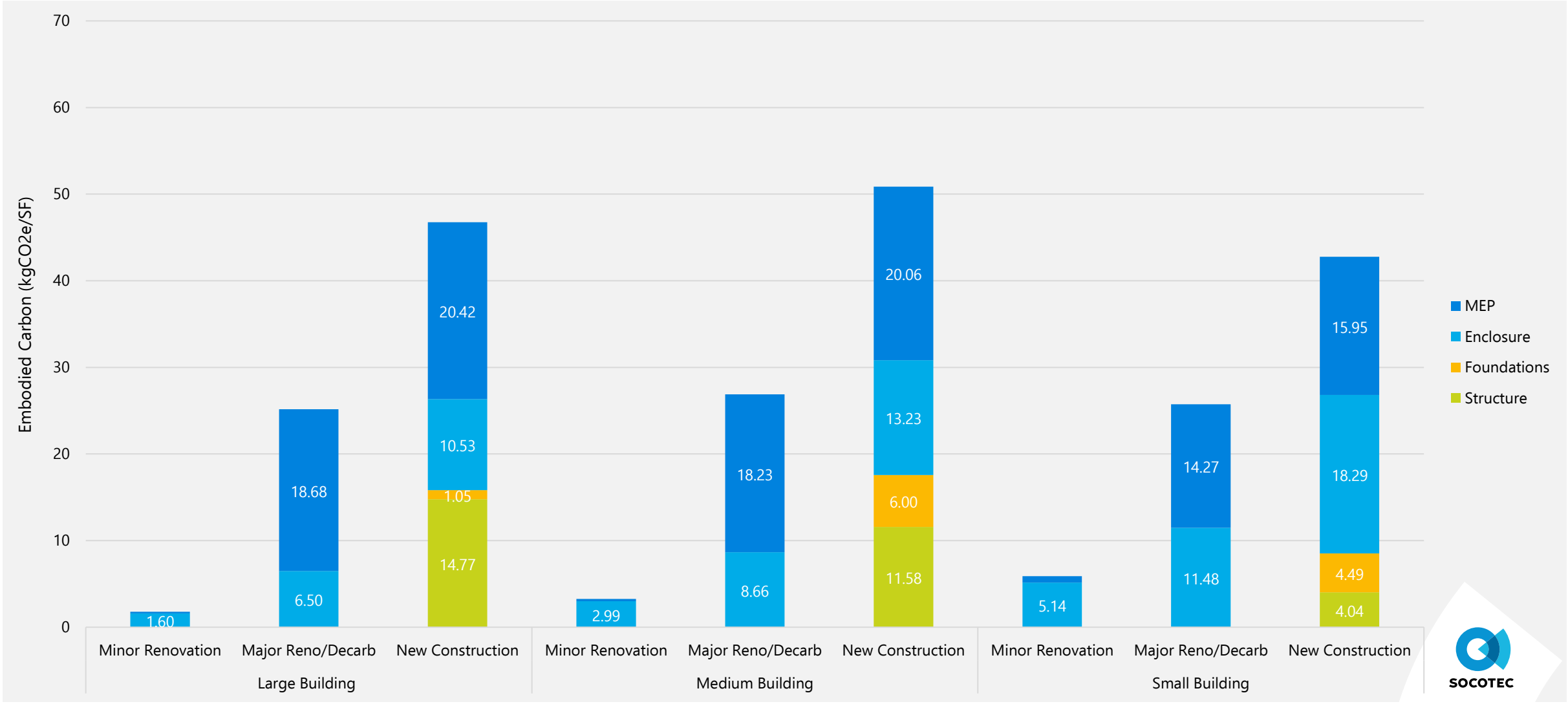
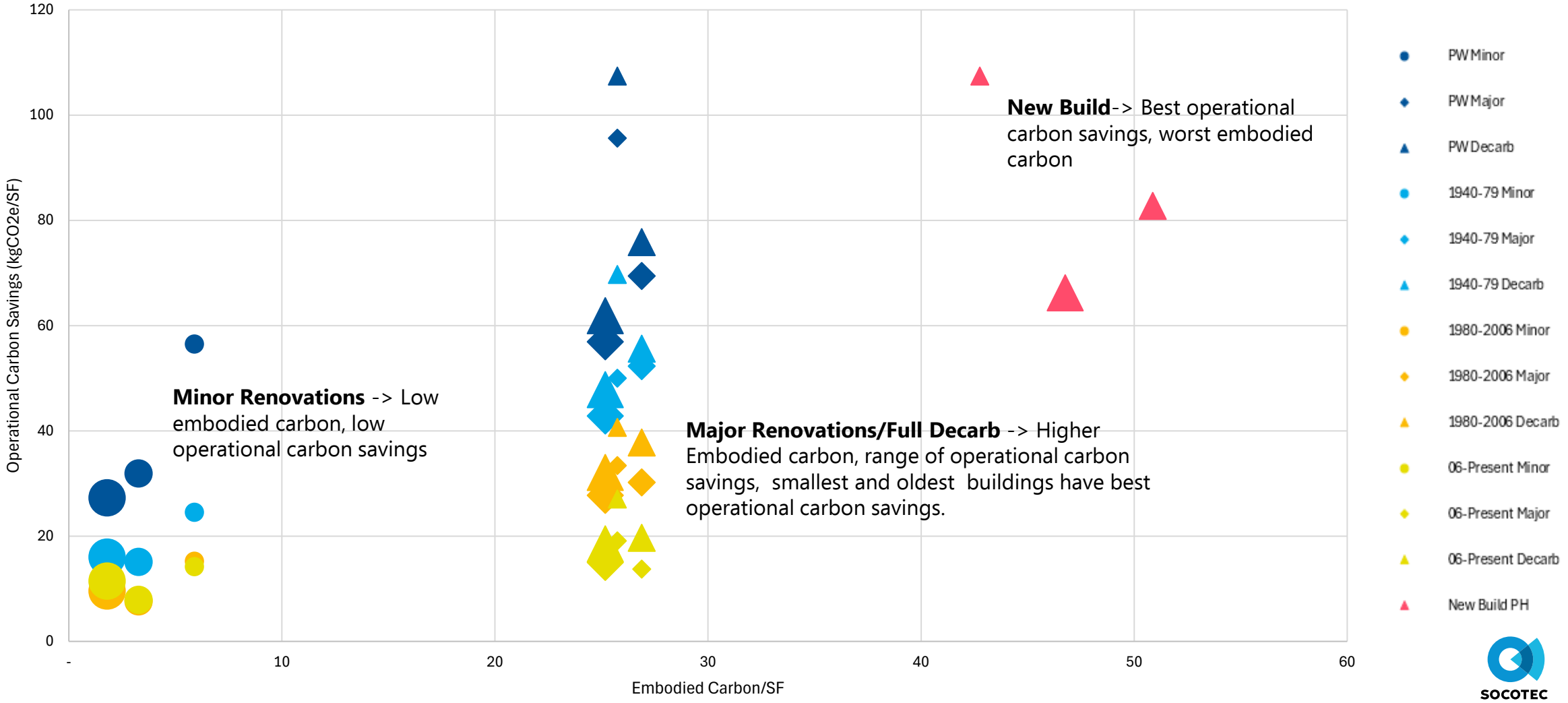
OPERATIONAL CARBON VS EMBODIED CARBON (60 YR)



EMBODIED CARBON OF RETROFIT SCOPES ACROSS ALL SIZES (25 YEAR)



OPERATIONAL CARBON SAVINGS VS EMBODIED CARBON (25 YRS)



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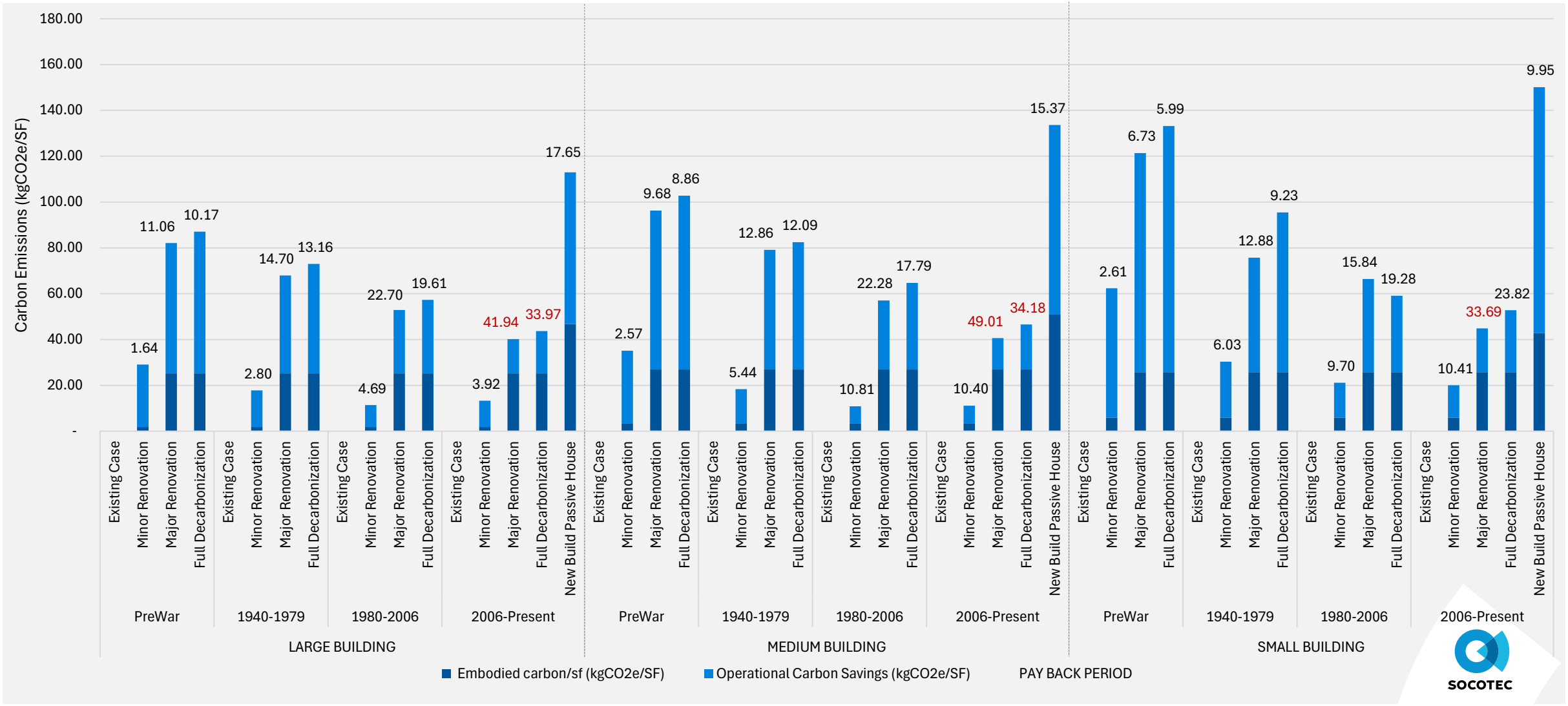
OPERATIONAL CARBON VS EMBODIED CARBON (25 YR)



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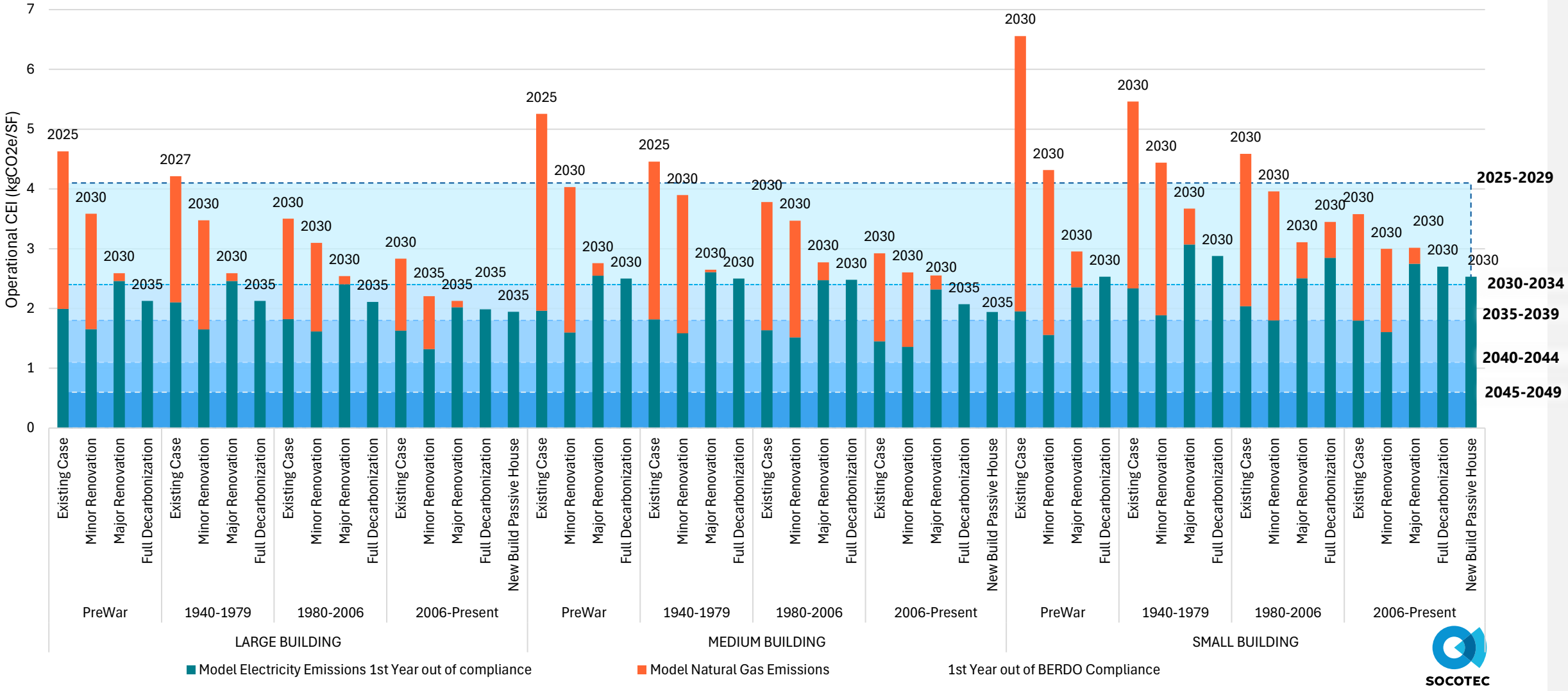
CARBON PER DOLLAR AND BERDO COMPLIANCE

GREEN HOUSE GAS EMISSIONS VS BERDO LIMITS (YEAR OF NON-COMPLIANCE)



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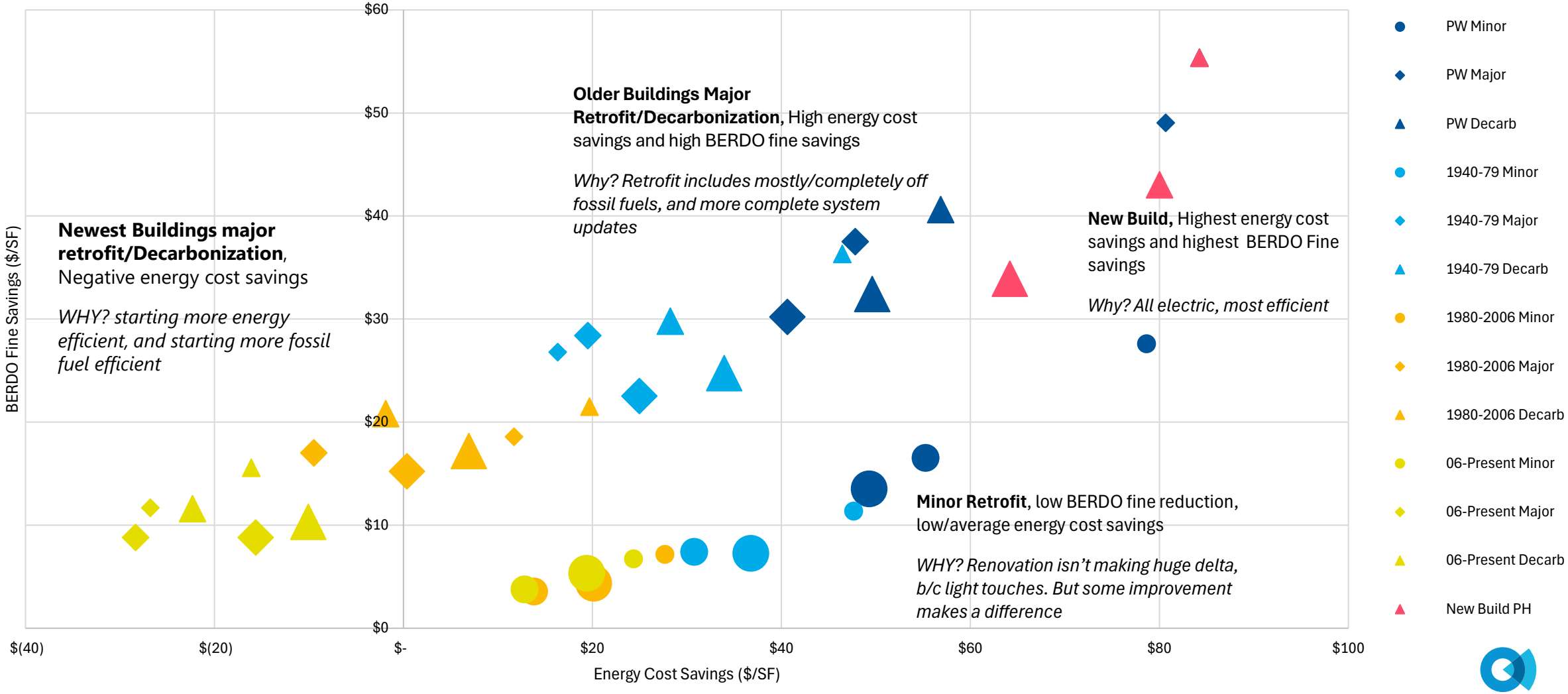
BERDO SAVINGS VS OPERATIONAL COST SAVINGS (2025-2085)



1. *https://www.eia.gov/dnav/ng/ng_pri_sum_a_epg0_prs_dmcf_a.htm https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a*

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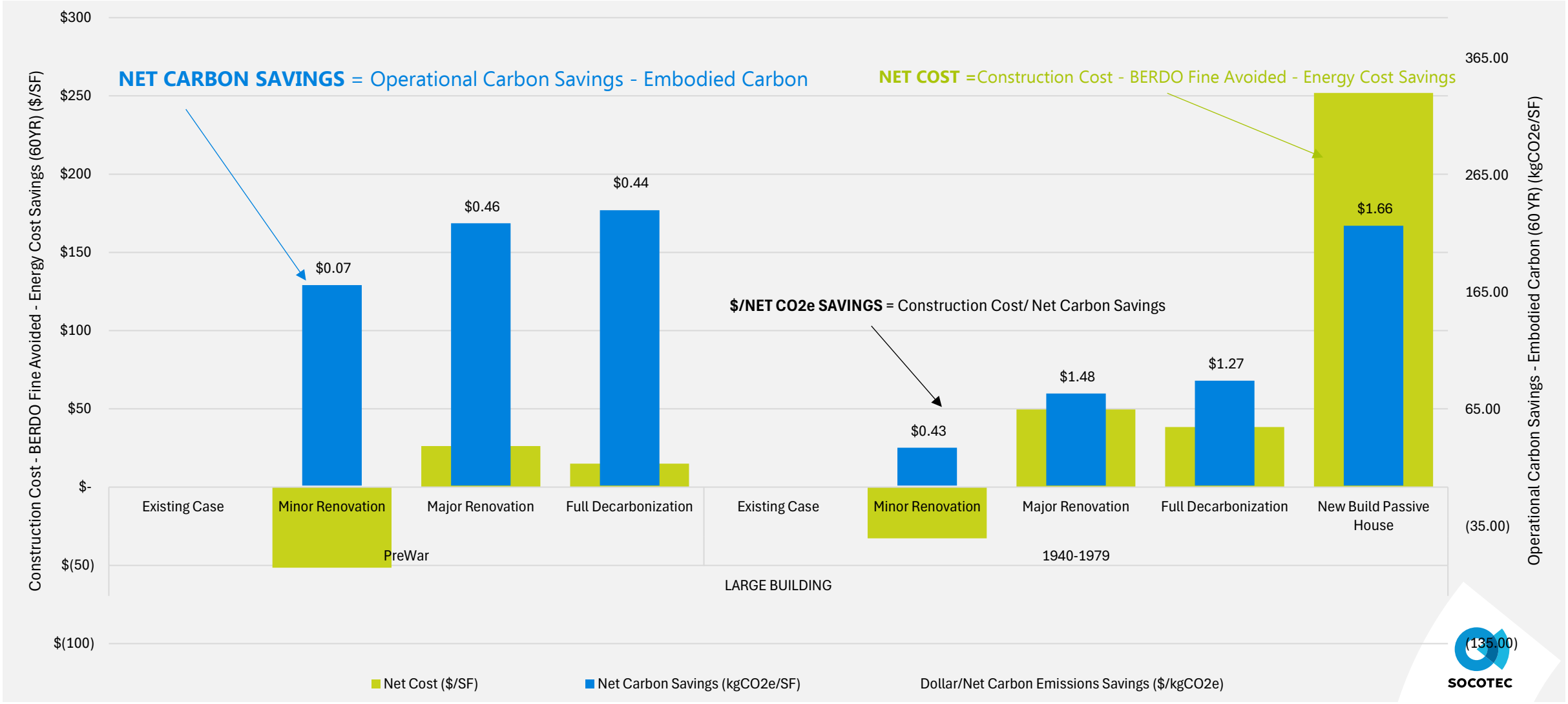
CONSTRUCTION COSTS

MINOR RENOVATION		SMALL BUILDING	MEDIUM BUILDING	LARGE BUILDING
LOW-E/SHGC REDUCTION WINDOW FILM	$8-$12/SF_{WINDOW}	$ 20,400	$ 67,000	$ 139,500
COOKING ELECTRIFICATION:	$1,500-$2,000/UNIT	$ 26,000	$ 140,000	$ 232,000
BOILER/DHW TUNE UP:	$500/BOILER	$ 2,000	$ 2,000	$ 2,000
ROOF REPLACEMENT (R-30)	$10-$14/SF_{ROOF}	$ 58,850	$ 155,400	$ 125,600
R-4 WALL INSULATION	$3-$6/SF_{WALL}	$ 75,200	$ 231,600	$ 296,600
LIGHTING UPGRADE TO LED	$2-$4/GFA	$ 67,400	$ 272,500	$ 438,300
TOTAL		**$ 249,900**	**$ 868,500**	**$ 1,234,050**

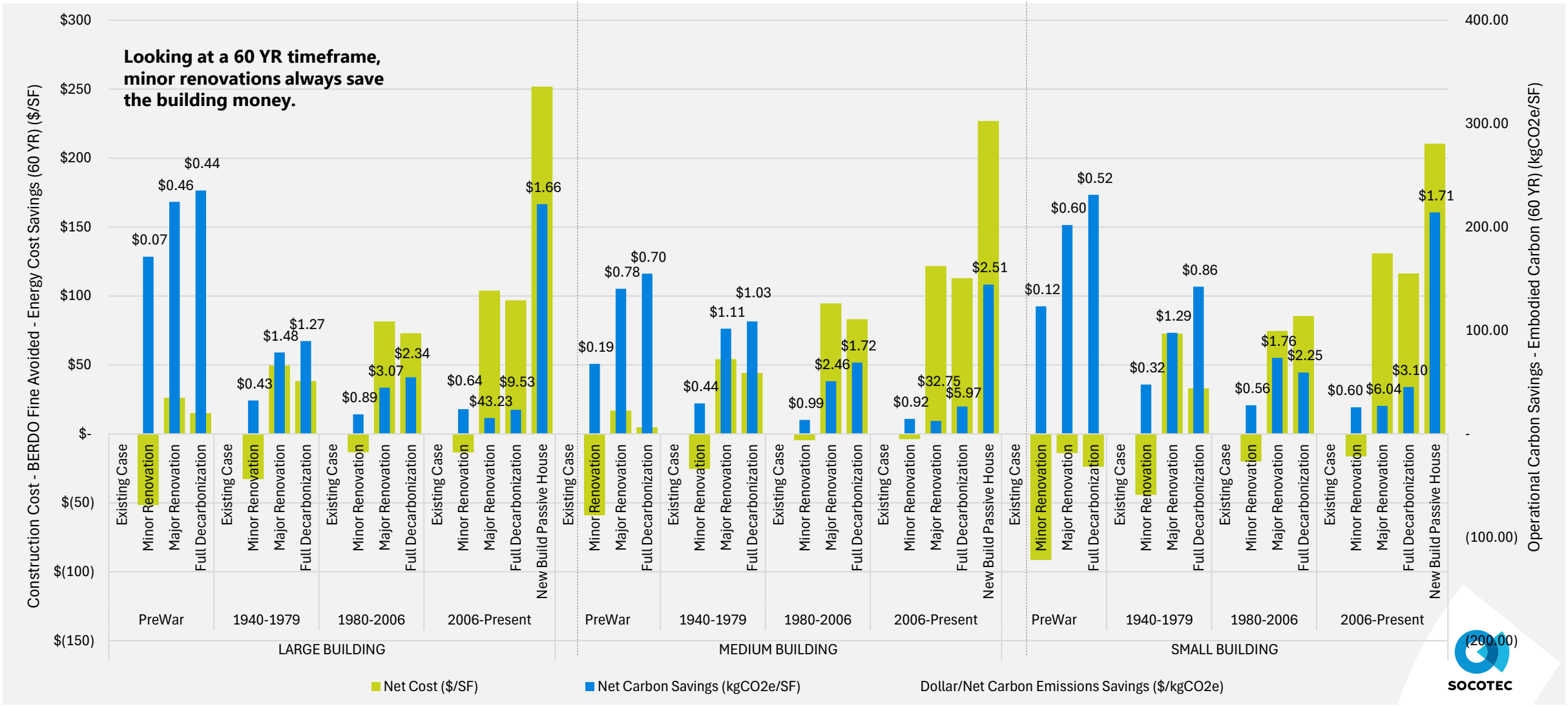
MAJOR RENOVATION/DECARBONIZATION		SMALL BUILDING	MEDIUM BUILDING	LARGE BUILDING
OVERCLAD WALLS	$30-$60/SF_{WALL}	$ 752, 000	$ 2,316,100	$ 2,965,900
ROOF REPLACEMENT (R-30)	$10-$14/SF_{ROOF}	$ 58,900	$ 155,400	$ 125,600
WINDOW REPLACEMENT	$60-$120/SF_{WINDOW}	$ 203,700	$ 670,100	$ 1,395,300
LIGHTING UPGRADE TO LED	$2-$4/GFA	$ 67,400	$ 272,500	$ 438,300
COOKING ELECTRIFICATION:	$1,500-$2,000/UNIT	$ 26,000	$ 140,000	$ 232,000
BOILER/DHW TUNE UP:	$500/BOILER	$ 1,000	$ 1,000	$ 1,000
DHWHP	$5-10/GFA	$ 168,600	$ 681,200	$ 1,095,800
VRF/ASHP + SELECTIVE PLANT DEMO	$10-25/GFA	$ 421,500	$ 1,703,000	$ 2,739,530
ERV	$5-15/GFA	$ 252,900	$ 1,021,800	$ 1,643,700
TOTAL		**$ 1,951,971**	**$ 6,961,100**	**$ 10,637,200**

NEW BUILD – PASSIVE HOUSE		LOW END	HIGH END
SMALL BUILDING	$150-$250/GFA	$ 5,901,000	$ 7,587,000
MEDIUM BUILDING	$80-$130/GFA	$ 23,842,500	$ 30,654,600
LARGE BUILDING	$90-$150/GFA	$ 38,353,400	$ 49,311,500

CONSTRUCTION COST VS CARBON (60 YR) – *HOW TO READ CHART*



CONSTRUCTION COST VS CARBON (60 YR)



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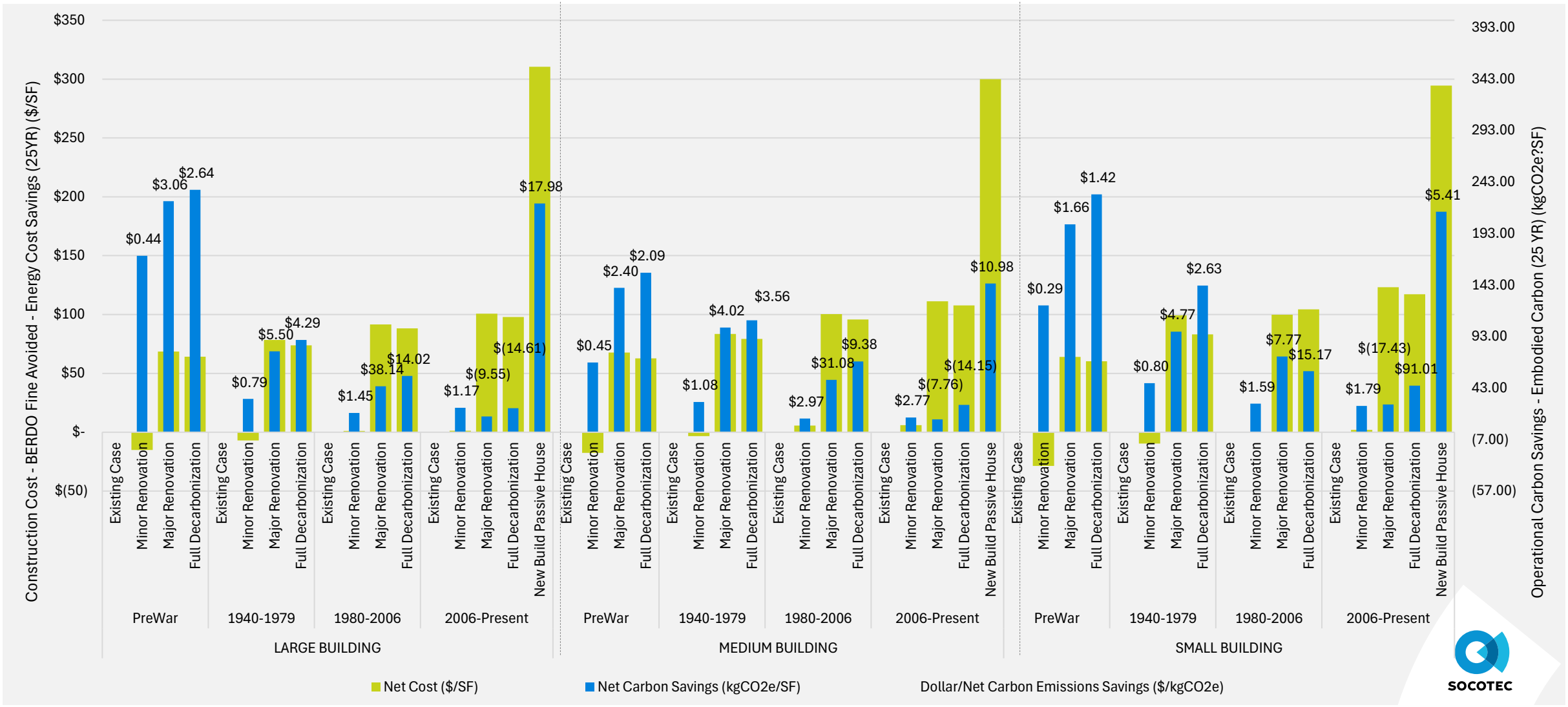
CONSTRUCTION COST VS CARBON (25 YR)



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04
IMPLICATIONS

Practice + Capital Planning + Policy

WHAT THE STUDY TELLS US

- **Performance, not age, should drive action.**
  - Newer buildings can perform just as badly as older ones when maintenance is deferred, buildings are not operated as designed, have additional base building loads, etc. Best performers exist across all vintages.
- **Look at minor retrofits first.**
  - Light, low-embodied-carbon scopes (lighting, controls, selective envelope and electrification) deliver low-cost, low-disruption improvements with meaningful operational savings and BERDO fine mitigation.
- **Deep retrofits pay off in the right places, especially when you look at it on a longer time scale.**
  - Major/decarbonization retrofits on smaller and older multifamily buildings produce the biggest operational carbon savings and strongest carbon-per-dollar results over BERDO timeframes.
- **When possible, retrofit existing assets.**
  - Demolition-to-new Passive House is great. It wins on operational emissions but carries the highest embodied carbon, capital cost, and housing disruption (when from existing building).
- **The optimal path balances looks at the whole picture.**
  - The “right” strategy is the one that optimizes whole-life carbon, net cost (capex while also considering energy savings and penalty mitigation), and housing continuity—not any single metric in isolation.

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WHAT THIS MEANS FOR POLICY AND INCENTIVES

- **Reinforces the importance of BERDO**
  - Metered data can be used to prioritize worst performers and high fossil-fuel users from building stock, and give best performers a clear glide path to stay compliant.
- **Incentivize retro-commissioning and low lift measures first**
  - Any improvement in carbon emissions is a step in the right direction. Deep energy retrofit is not the only viable option.
  - Pair any demolition/new-build design with strict criteria on housing replacement, embodied carbon limits, and demonstrated infeasibility of retrofit pathways.
- **Make whole-life carbon a key metric.**
  - Integrate operational and embodied carbon comparisons into decision making.
  - For IECC Chapter 4 and 5 -> add a path that shows whole life carbon instead of energy performance/cost
- **Invest in grid decarbonization and onsite renewables.**
  - No matter how efficient and low emitting a building is, if the grid is still dirty, they will be out of compliance with BERDO.
- **Invest in the workforce development.**
  - Continue to fund technical assistance and owner education on decarbonization and retrofits.
  - Support and partner with groups focusing on embodied carbon – such as circularity groups, etc.

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WHAT'S NEXT?

- Investigate Design Practices
- Office to Multifamily Conversions
- Order of Staged Retrofits
- Impact of Financial Incentives
- New Markets
- Circularity and Sustainable Materials

THANK YOU!

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Please fill out an evaluation for this session

or: *nesea.org/eval*

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