NATIONAL OILHEAT RESEARCH ALLIANCE

Net Zero Carbon Home
NORA

Providing Renewable Liquid Heating Solutions For a Low Carbon Future

Taking the Carbon out of the Fuel

The first step in decarbonizing a home heating system is transitioning to a low carbon biofuel. The biofuel widely available to the heating market here in the Northeast is biodiesel (ASTM D6751). Relative to petroleum No. 2 fuel, 100% biodiesel (B100) provides a carbon reduction of 75 to 90% with the higher 90% reduction based on the use of waste feed stocks such a used cooking oil.

Bring on the Sun

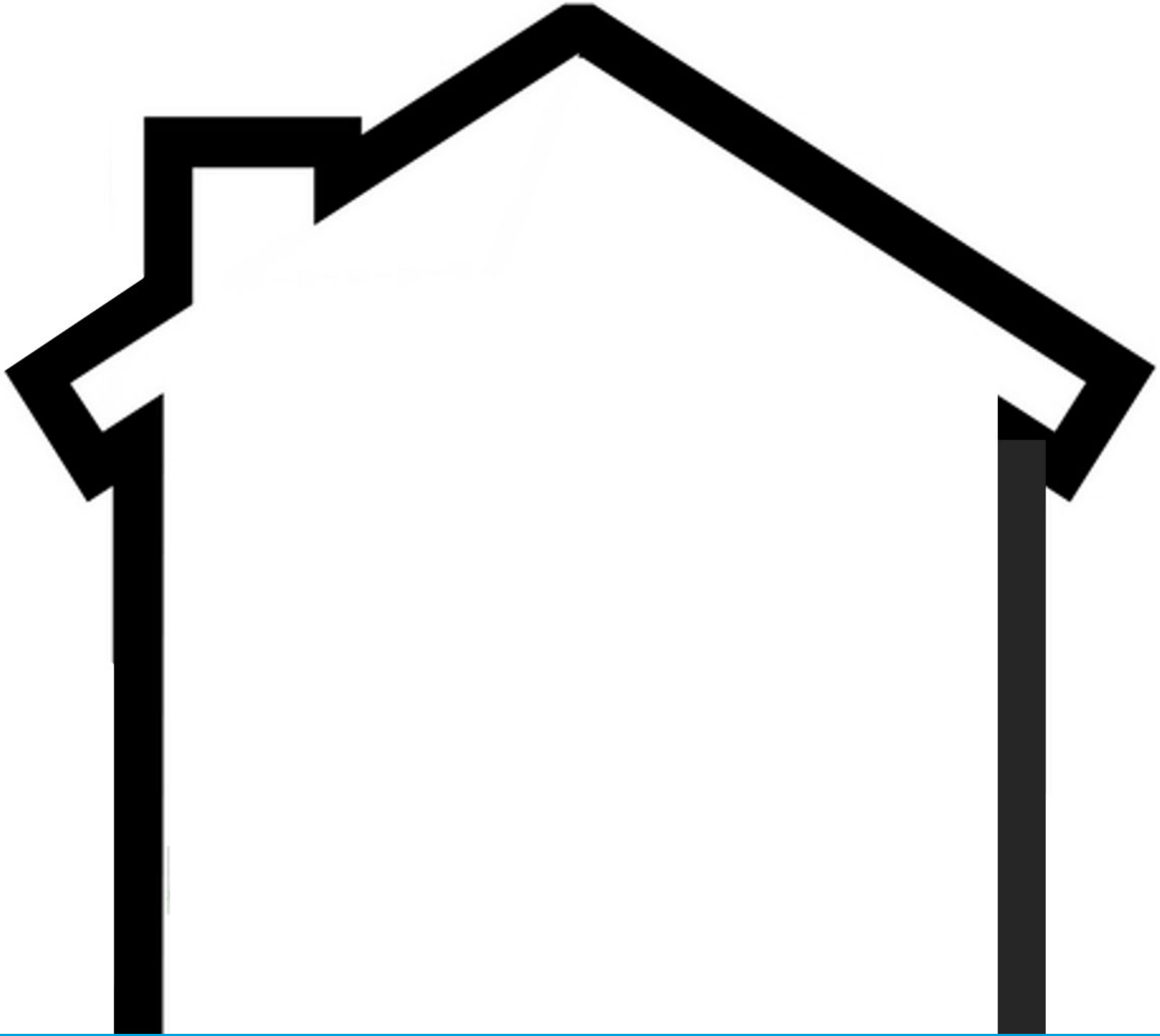
The second step is the addition to add solar panels on the roof of the home. Electric power purchased from the utility is not entirely "clean" as it has significant carbon emissions associated with electricity generation. There is discussion about transitioning electric generation to renewable sources in the future, but this is more a promise than a reality.

Zero-Carbon Home Concept with Biodiesel

- Concept under development to showcase a low cost, heat pump-free zero-carbon home retrofit;
- Conversion of high efficiency boiler to B100 (based on UCO, 90% GHG reduction);
- PV array sized to 120% of annual usage;
- Excess feedback to grid offsets B100 GHG contribution;
- Plan to do short white paper first, followed by actual site conversion;
- First site be located on Long Island.

Decarbonizing that Makes Financial Sense

The solar panel system at Butcher's home was installed by Long Island Power Solutions, in Ronkonkoma, NY. The State and Federal Governments offed financial incentives for installing solar panels making the installation attractive. At the time the installation was planned, the residential power rate was approximately $0.23 per kilowatt hour. At this rate the payback period was calculated at 7 years with an effective annual payback of 14.3%. At the time of this writing, it has risen to $0.28 per kilowatt hour.



NORA MULTIVARIABLE CALCULATOR:

EXAMINING GHG EMISSION REDUCTIONS PATHWAYS FOR OIL HEATED HOMES:

ELECTRIFICATION (HEAT PUMP CONVERSIONS) VERSUS AGGRESSIVE BIOBENDING

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NORA's Multivariable Model

- NORA used the questions above to evaluate different scenarios
  - How cold is the climate, and how will heat pumps perform in that climate
  - Is the electricity in the area coming from hydropower, wind, or coal and natural gas.
  - What is the feedstock source of the biofuels
  - How many oil heated homes will convert to heat pumps
  - How quickly will biodiesel be incorporated into heating oil
  - How efficient is the heating equipment and how quickly will it be replaced
- NORA's model allows all of these factors to be modified so the user can enter any new data points, which makes it a unique and useful tool
  - We used research from the NORA lab in New York
  - And this model was reviewed and approved by a GHG consultant – Earth Shift

Research Study and Multivariable Calculator Development

"Good modeling requires that we have just enough of the "right" transparencies in the map. Of course, the right transparencies depend on the needs of a particular user."

— John H. Miller, Complex Adaptive Systems

- All emissions data are from U.S. DOE (Argonne National Laboratory) GREET Model Calculations, Using December 2020 Version
- All electric heat pump performance curves are from NYSERDA report titled "Development of a Best Practices Guide for Integrated Hydronic and Ductless, Air-source Heat Pump Systems" using 2020 field data.
- The electric grid emissions properly used marginal emission to compare fuel switching and energy efficiency
- Electric heat pump conversion cost estimates are from current HVAC contractors consensus findings.
- This model does not include the impact of water heating

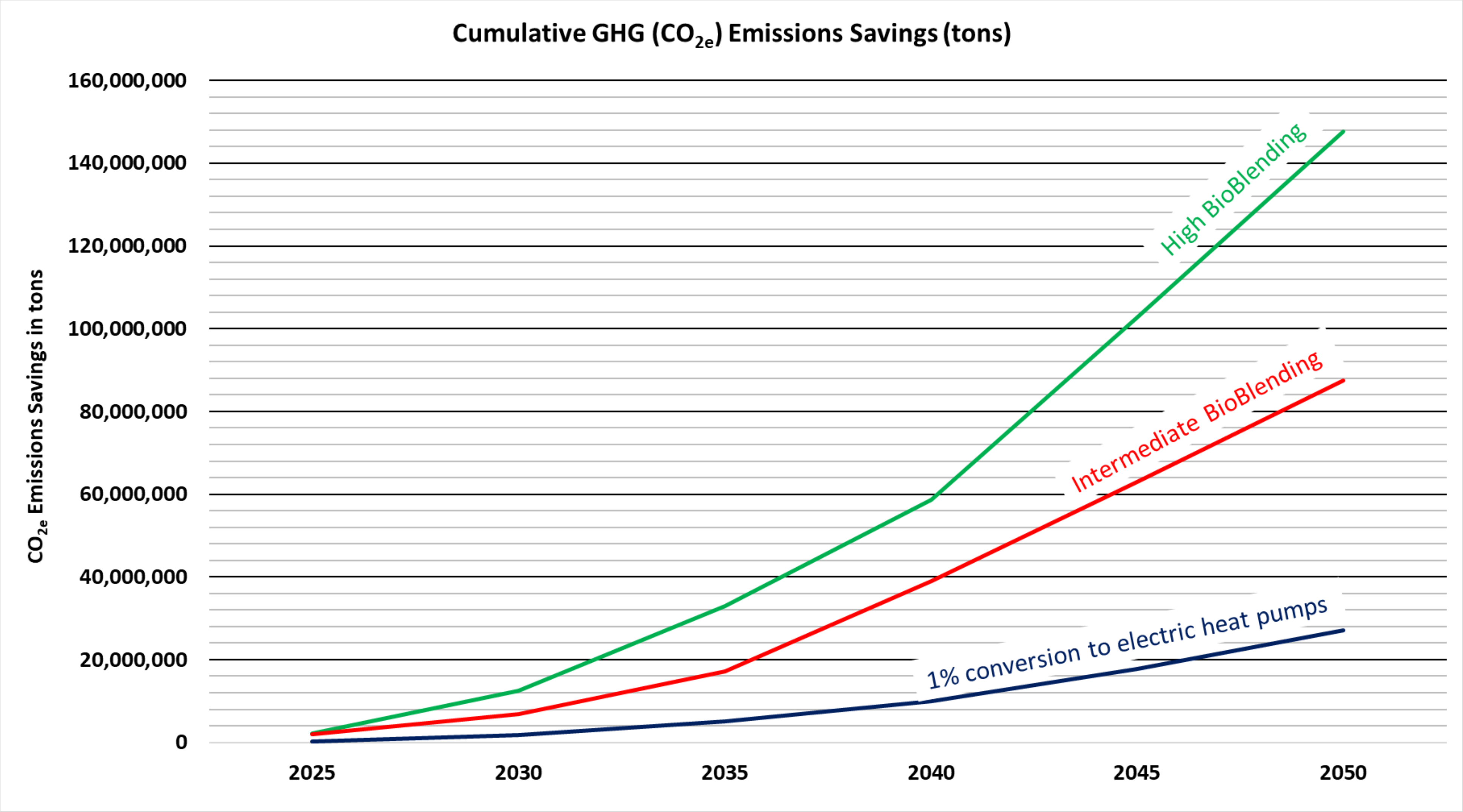
Massachusetts Use Case

Input Table	
City for Weather Data to be Applied to the Homes:	Worcester, MA
Global Warming Atmospheric Lifetime:	100 Year Lifetime-AR5
Biodiesel Feedstock:	Average of Bioblend Feedstocks
Average Liquid Fueled Baseline Efficiency:	78%
Liquid Fueled Non-Condensing Boiler Efficiency:	86%
Liquid Fueled Boiler Retrofits:	5.00%
Select Liquid Fueled Thermal Heat Pump Retrofits:	5.00%
Electric Heat Pump (EHP) Performance Curve:	HP7
Electric Resistance Seasonal Performance Efficiency:	100%
Annual Home Heating Load MMBtu/year:	100
Bioblend Uptake Scenario:	Scenario 2: B5 in 2023, B20 in 2025, B50 in 2030, B100 in 2040
Decarbonization rate over 2021 Baseline for Marginal Electricity and Biofuels:	Scenario 3: 15% in 2025, 25% in 2030, 50% in 2040 & 100% in 2050
Homes to be Assessed (If State Selected, it must agree with City Selected):	Massachusetts
Whole Home Heating Electrification Rate: (HP + electric BU Heating)	646,103
Whole Home Heating Electrificaiton Rate: (HP + electric BU Heating)	5.00%
Annual Heating Electrificaiton Conversions:	32,305
Heat Pump Conversion Cost Estimation Curve:	Low Conversion Cost Scenario 2
Percentage of Load Served by Heat Pump:	100.0%
Average Conversion Cost of One Whole House Heat Pump with Electric Backup:	$25,000

Massachusetts Use Case

Diesel Cost per MMBtu	$22.71
Biodiesel Cost per MMBtu	$26.56
EL Cost per MMBtu	$30.00
Cost of Electricity 2020 EIA Massachusetts ¢/kWh	$0.22
Cost of Electricity 2020 EIA Massachusetts $/MMBtu	$64.4
Assumed constant over period for simplicity	
Low Replacement Cost Non-Condensing Boiler	$5,500
High Replacement Cost Non-Condensing Boiler	$9,500
Low Replacement Cost Condensing Boiler	$10,000
High Replacement Cost Condensing Boiler	$15,000
Low Replacement Cost Thermal Heat Pump	$12,000
High Replacement Cost Thermal Heat Pump	$17,000
Low Conversion Cost for Electric Heat Pump (80% 0f High Cost)	$20,000
High Conversion Cost for Electric Heat Pump	$25,000
Low Replacement Cost for Electric Heat Pump	$12,000
High Replacement Cost for Electric Heat Pump	$14,000
ASHRAE Median Life for boiler is 30 years, ASHRAE Median Life for HP is 15 years	

Massachusetts Use Case Key Finding

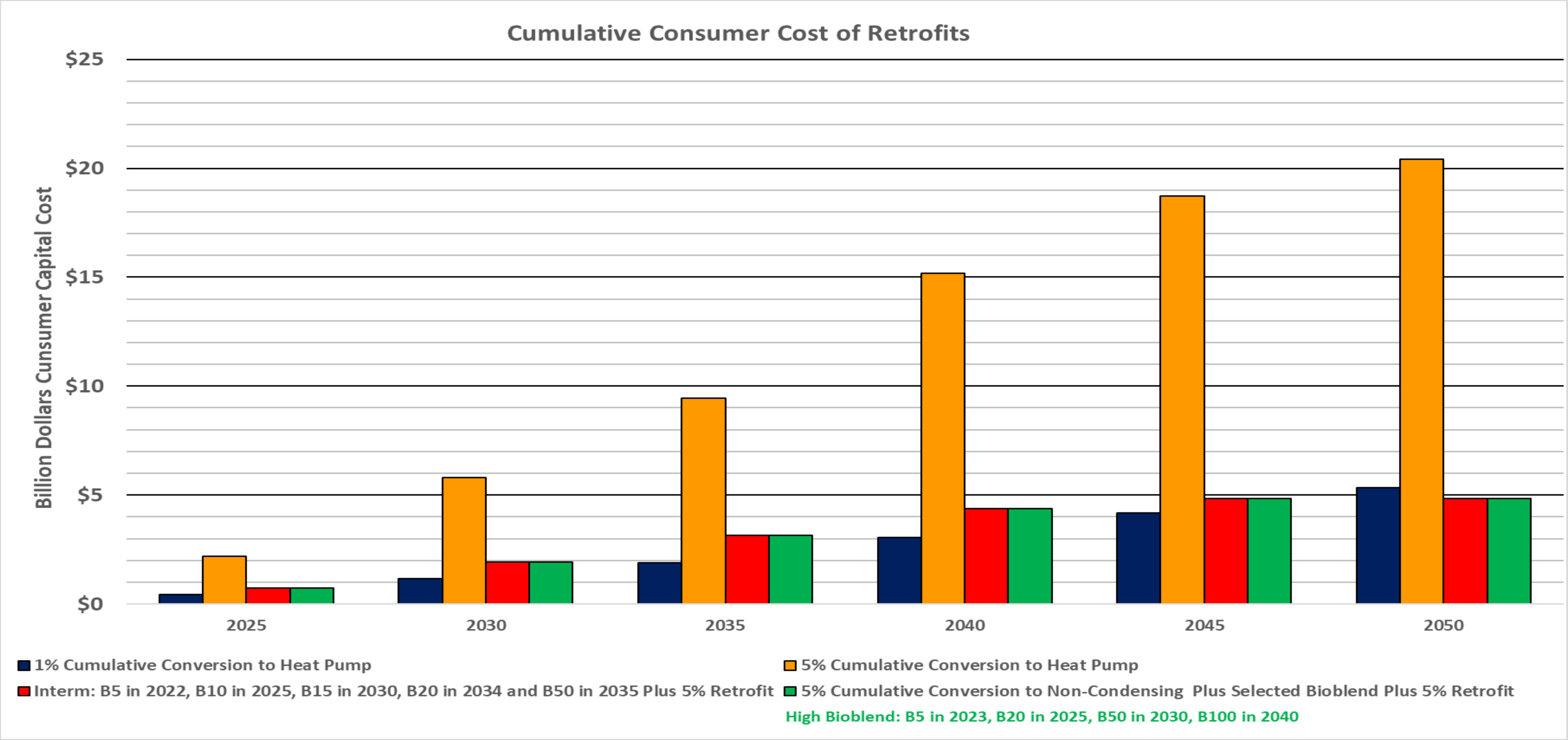


B5 in 2023, B20 in 2025, B50 in 2030 and B100 in 2040 plus normal 5% liquid fuel appliance upgrade

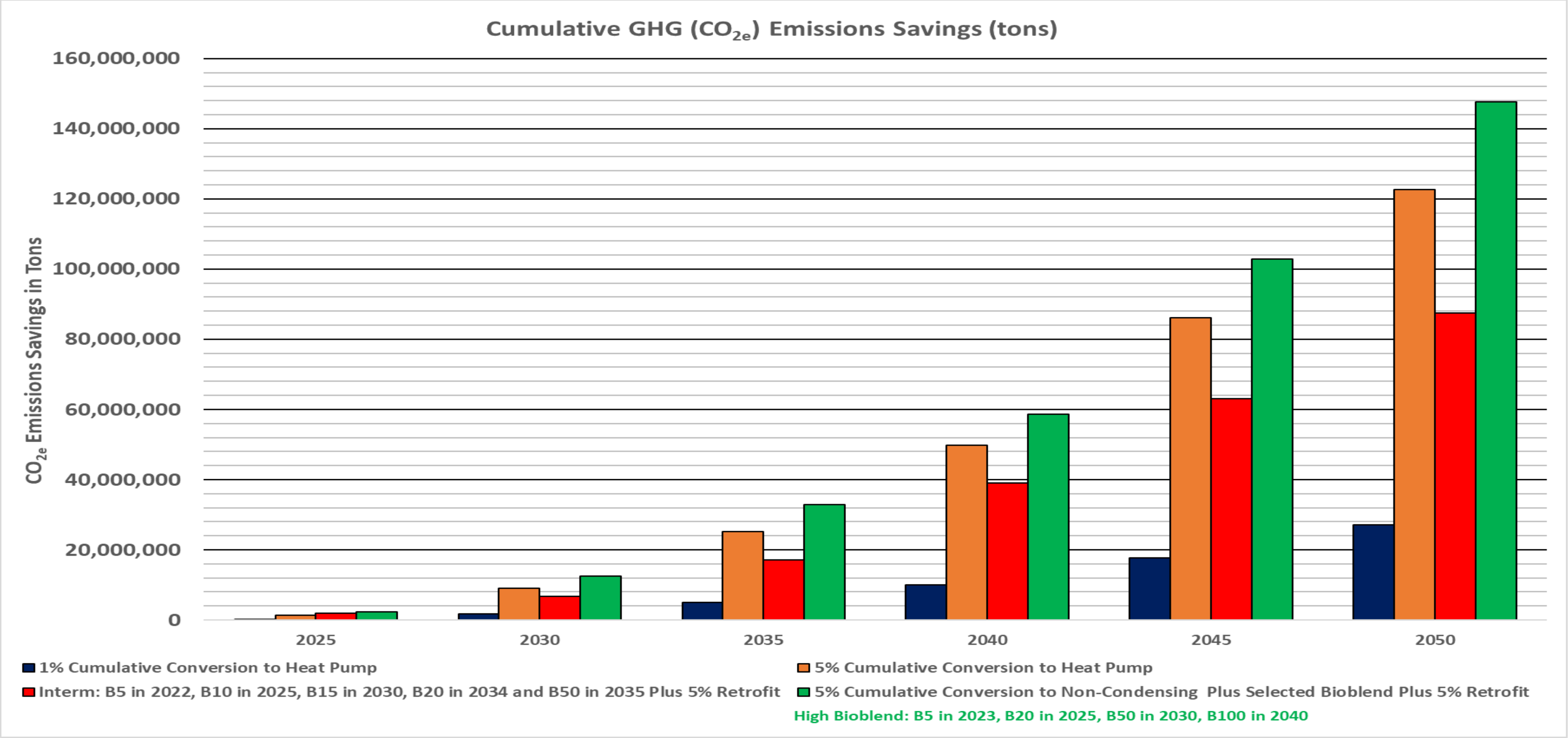
B5 in 2021, B10 in 2023, B20 in 2025, and B50 in 2030 plus normal 5% liquid fuel appliance upgrade

1% conversion to electric heat pumps with electric backup

Massachusetts Customer Capital Cost Over Time



Massachusetts Cumulative GHG Emission Savings Over Time



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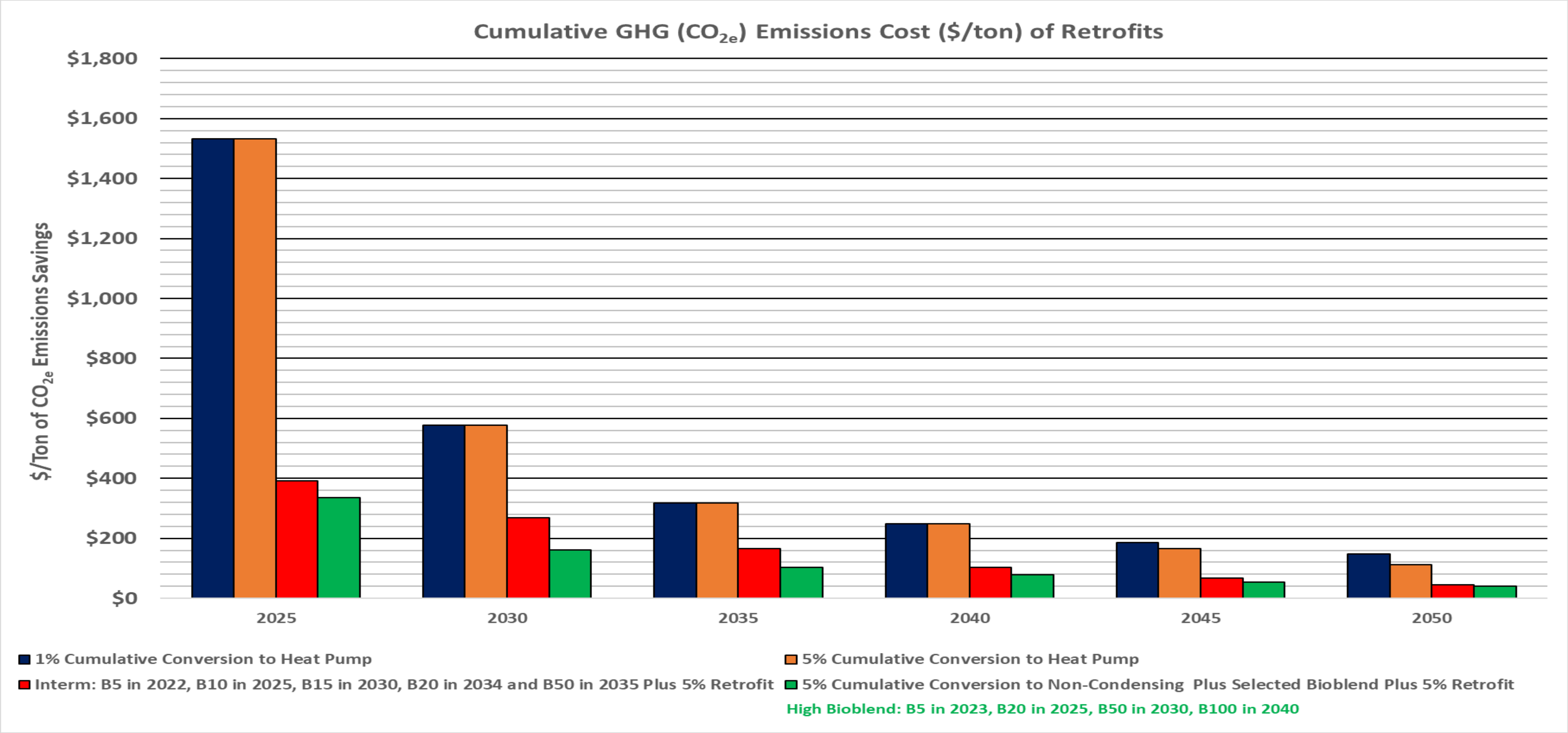
Massachusetts Cumulative Customer GHG Reduction Cost ($/ton GHG Reduced)



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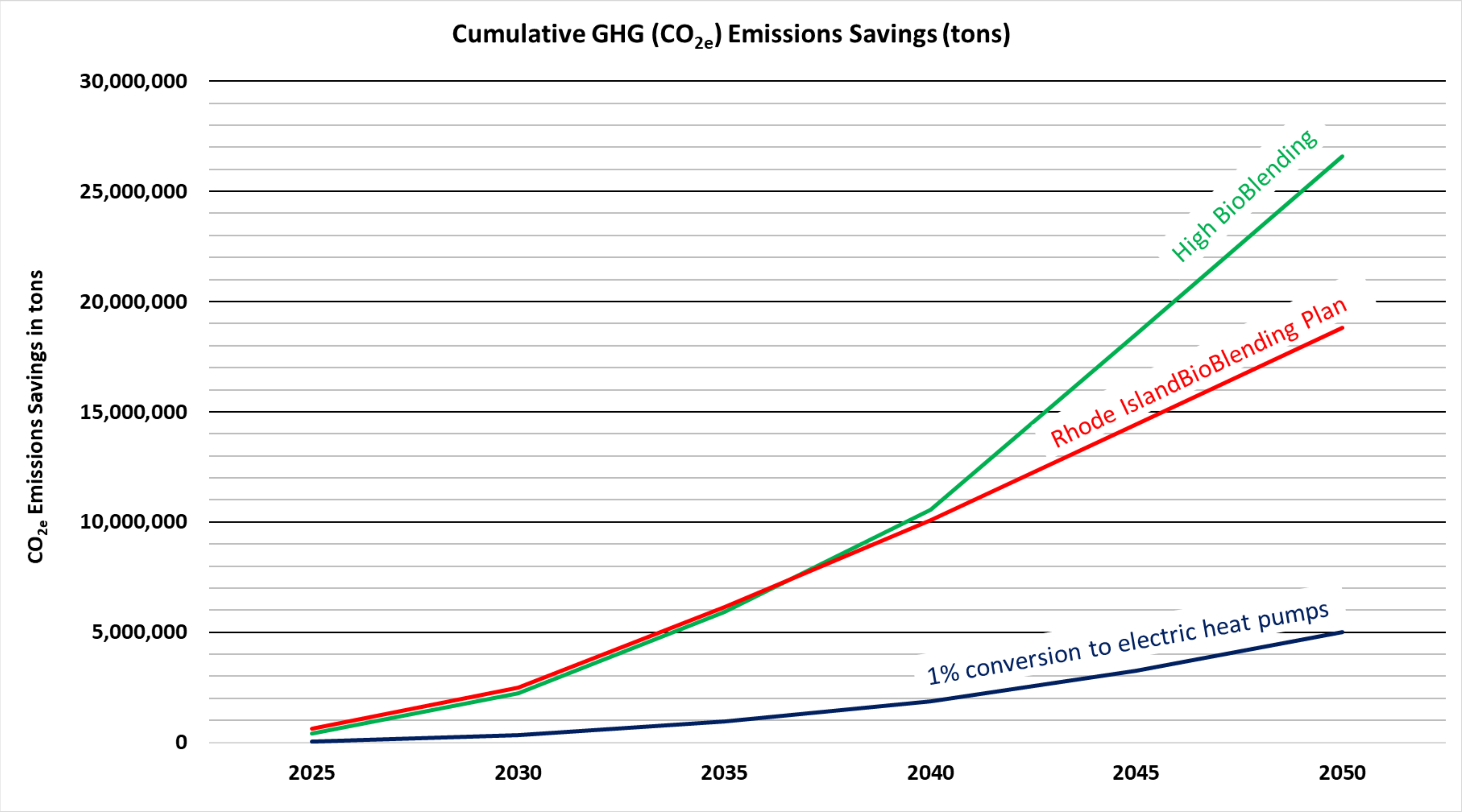
Rhode Island Use Case

Input Table	
City for Weather Data to be Applied to the Homes:	Providence, RI
Global Warming Atmospheric Lifetime:	100 Year Lifetime-AR5
Biodiesel Feedstock:	Average of Bioblend Feedstocks
Average Liquid Fueled Baseline Efficiency:	78%
Liquid Fueled Non-Condensing Boiler Efficiency:	86%
Liquid Fueled Boiler Retrofits:	5.00%
Select Liquid Fueled Thermal Heat Pump Retrofits:	5.00%
Electric Heat Pump (EHP) Performance Curve:	HP7
Electric Resistance Seasonal Performance Efficiency:	100%
Annual Home Heating Load MMBtu/year:	100
Bioblend Uptake Scenario:	Scenario 2: B5 in 2023, B20 in 2025, B50 in 2030, B100 in 2040
Decarbonization rate over 2021 Baseline for Marginal Electricity and Biofuels:	Scenario 3: 15% in 2025, 25% in 2030, 50% in 2040 & 100% in 2050
Homes to be Assessed (If State Selected, it must agree with City Selected):	Rhode Island
Whole Home Heating Electrification Rate: (HP + electric BU Heating)	116,413
Whole Home Heating Electrificaiton Rate: (HP + electric BU Heating)	5.00%
Annual Heating Electrificaiton Conversions:	5,821
Heat Pump Conversion Cost Estimation Curve:	Low Conversion Cost Scenario 2
Percentage of Load Served by Heat Pump:	100.0%
Average Conversion Cost of One Whole House Heat Pump with Electric Backup:	$25,000

Rhode Island Use Case

Diesel Cost per MMBtu	$22.71
Biodiesel Cost per MMBtu	$26.56
EL Cost per MMBtu	$30.00
Cost of Electricity 2020 EIA Rhode Island ¢/kWh	$0.22
Cost of Electricity 2020 EIA Rhode Island $/MMBtu	$64.5
Assumed constant over period for simplicity	
Low Replacement Cost Non-Condensing Boiler	$5,500
High Replacement Cost Non-Condensing Boiler	$9,500
Low Replacement Cost Condensing Boiler	$10,000
High Replacement Cost Condensing Boiler	$15,000
Low Replacement Cost Thermal Heat Pump	$12,000
High Replacement Cost Thermal Heat Pump	$17,000
Low Conversion Cost for Electric Heat Pump (80% 0f High Cost)	$20,000
High Conversion Cost for Electric Heat Pump	$25,000
Low Replacement Cost for Electric Heat Pump	$12,000
High Replacement Cost for Electric Heat Pump	$14,000
ASHRAE Median Life for boiler is 30 years, ASHRAE Median Life for HP is 15 years	

Rhode Island Use Case Key Finding

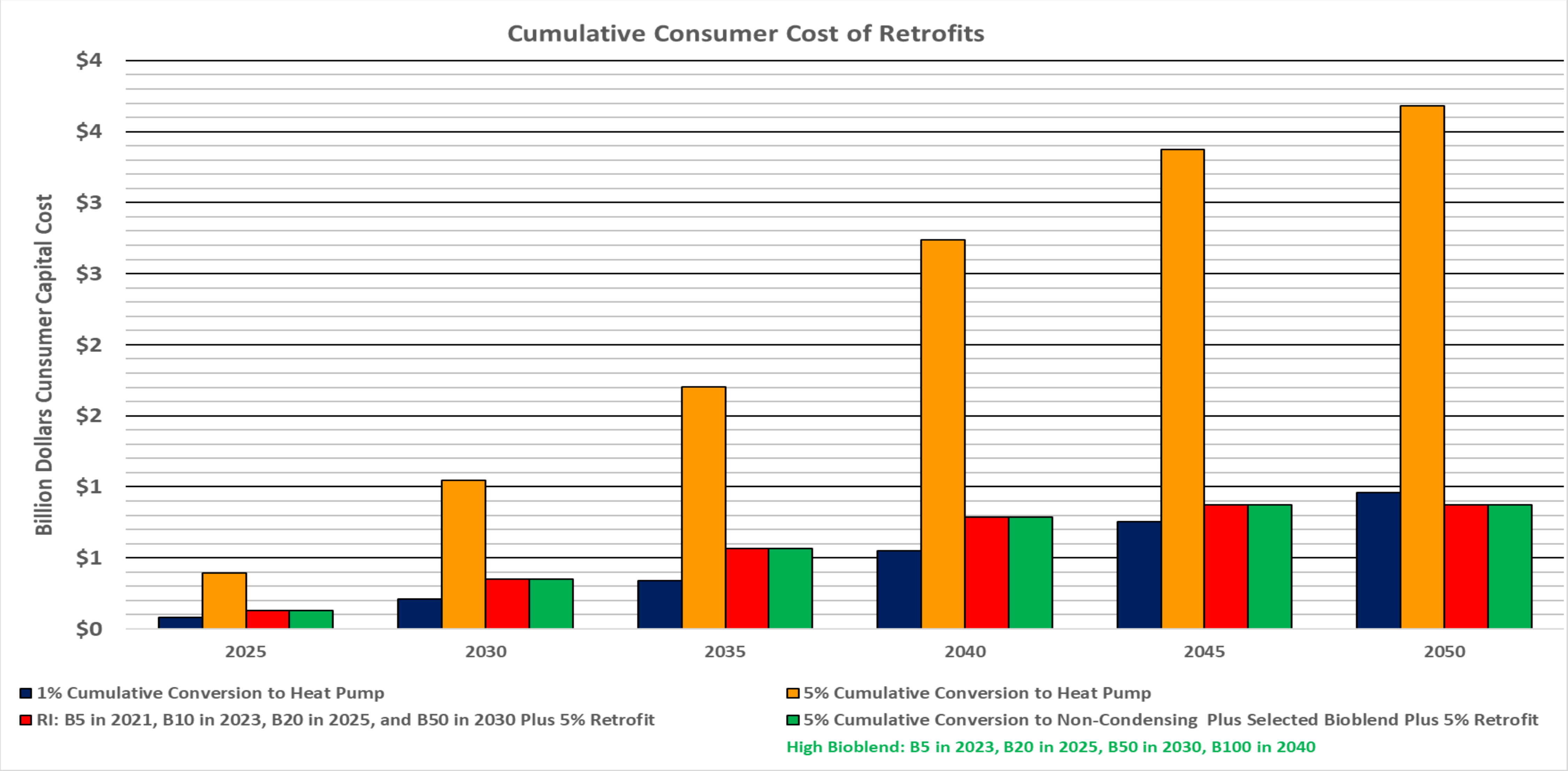


B5 in 2023, B20 in 2025, B50 in 2030 and B100 in 2040 plus normal 5% liquid fuel appliance upgrade

B5 in 2022, B10 in 2025, B15 in 2030, B20 in 2034 and B50 in 2035 plus normal 5% liquid fuel appliance upgrade

1% conversion to electric heat pumps with electric backup

Rhode Island Customer Capital Cost Over Time



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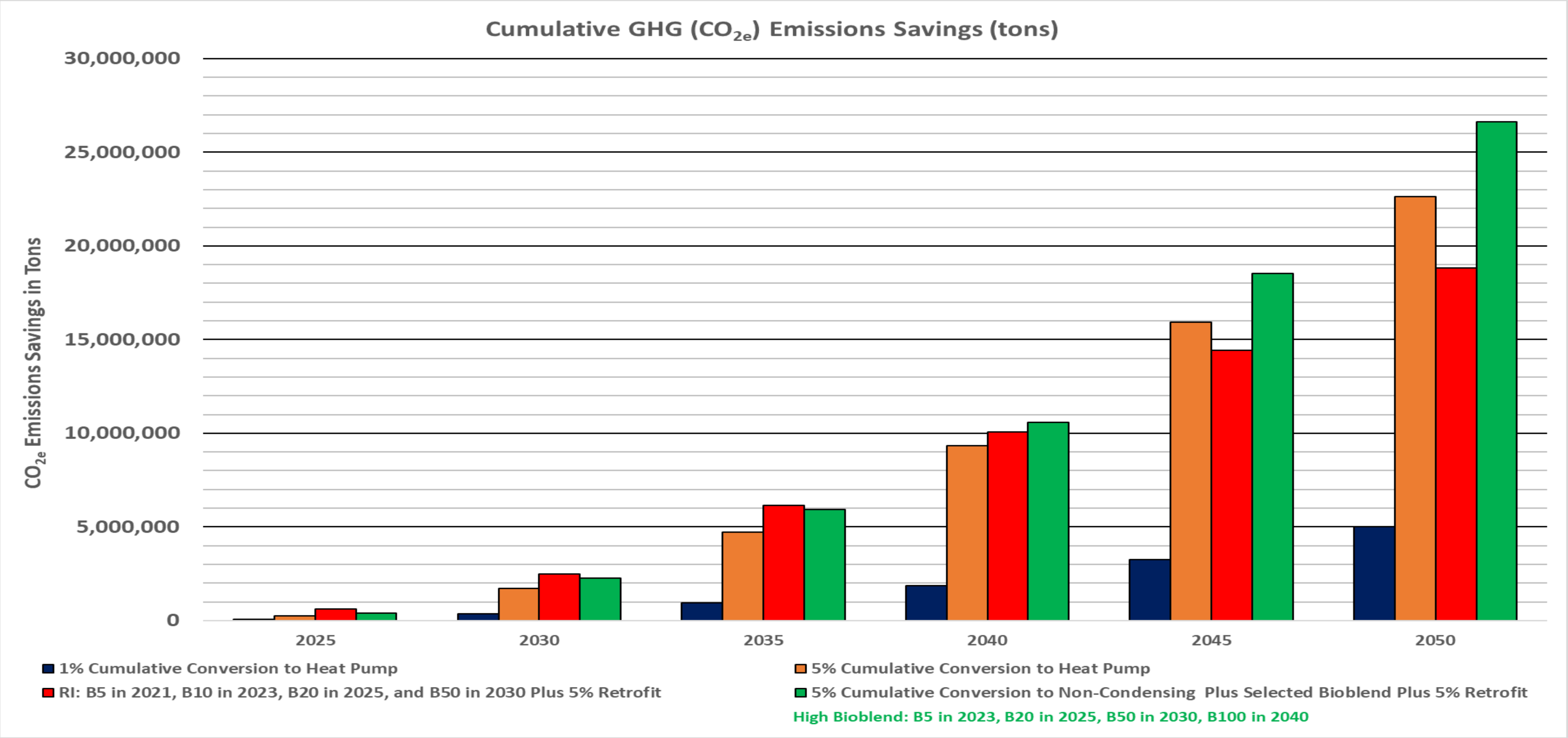
Rhode Island Cumulative GHG Emission Savings Over Time



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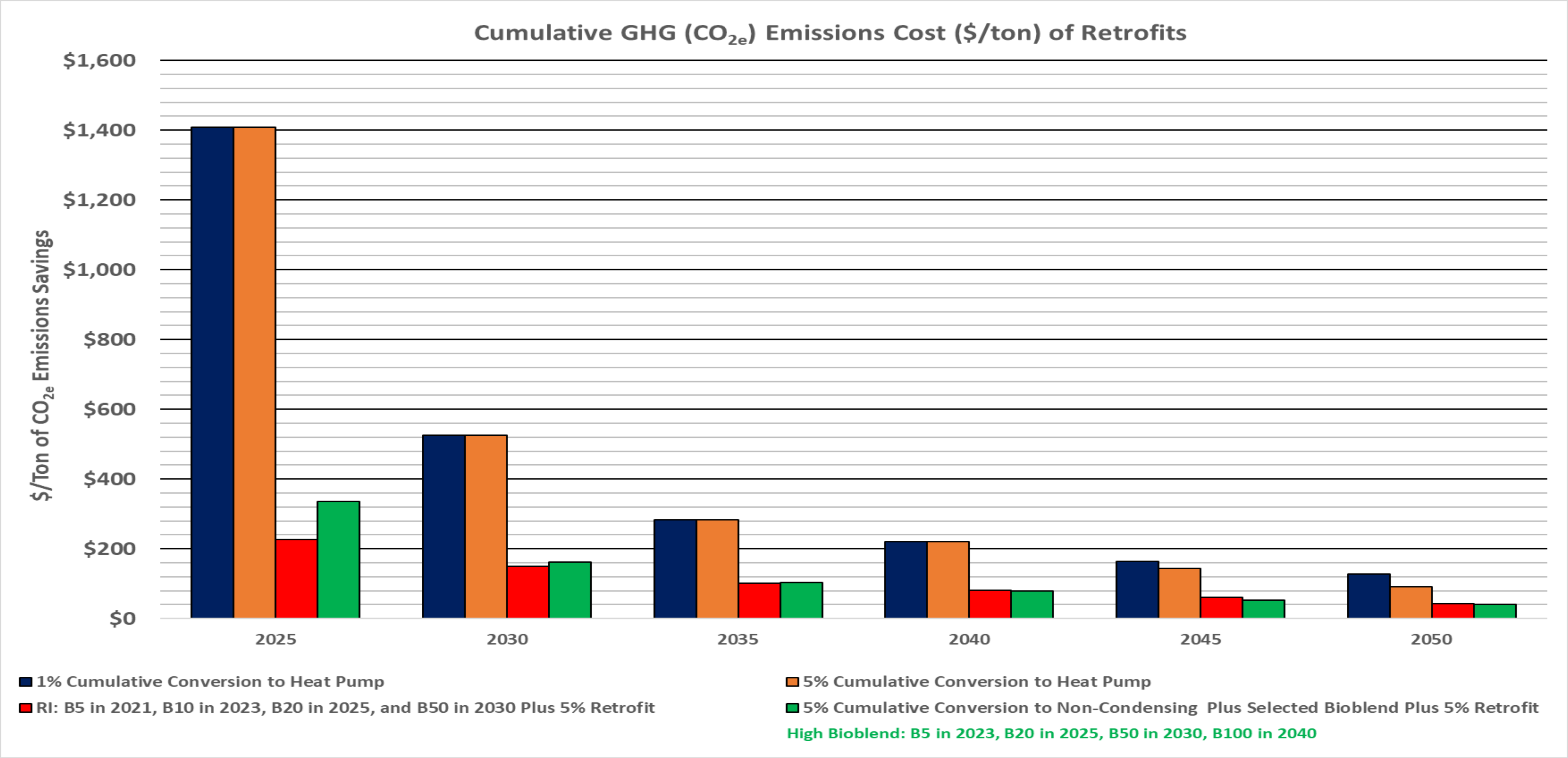
Rhode Island Cumulative Customer GHG Reduction Cost ($/ton GHG Reduced)



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Connecticut Use Case

Input Table	
City for Weather Data to be Applied to the Homes:	Hartford, CT
Global Warming Atmospheric Lifetime:	100 Year Lifetime-AR5
Biodiesel Feedstock:	Average of Bioblend Feedstocks
Average Liquid Fueled Baseline Efficiency:	78%
Liquid Fueled Non-Condensing Boiler Efficiency:	86%
Liquid Fueled Boiler Retrofits:	5.00%
Select Liquid Fueled Thermal Heat Pump Retrofits:	5.00%
Electric Heat Pump (EHP) Performance Curve:	HP7
Electric Resistance Seasonal Performance Efficiency:	100%
Annual Home Heating Load MMBtu/year:	100
Bioblend Uptake Scenario:	Scenario 2: B5 in 2023, B20 in 2025, B50 in 2030, B100 in 2040
Decarbonization rate over 2021 Baseline for Marginal Electricity and Biofuels:	Scenario 3: 15% in 2025, 25% in 2030, 50% in 2040 & 100% in 2050
Homes to be Assessed (If State Selected, it must agree with City Selected):	Connecticut
Whole Home Heating Electrification Rate: (HP + electric BU Heating)	535,420
Whole Home Heating Electrificaiton Rate: (HP + electric BU Heating)	5.00%
Annual Heating Electrificaiton Conversions:	26,771
Heat Pump Conversion Cost Estimation Curve:	Low Conversion Cost Scenario 2
Percentage of Load Served by Heat Pump:	100.0%
Average Conversion Cost of One Whole House Heat Pump with Electric Backup:	$25,000

Connecticut Use Case

Diesel Cost per MMBtu	$22.71
Biodiesel Cost per MMBtu	$26.56
EL Cost per MMBtu	$30.00
Cost of Electricity 2020 EIA Connecticut ¢/kWh	$0.23
Cost of Electricity 2020 EIA Connecticut $/MMBtu	$66.6
Assumed constant over period for simplicity	
Low Replacement Cost Non-Condensing Boiler	$5,500
High Replacement Cost Non-Condensing Boiler	$9,500
Low Replacement Cost Condensing Boiler	$10,000
High Replacement Cost Condensing Boiler	$15,000
Low Replacement Cost Thermal Heat Pump	$12,000
High Replacement Cost Thermal Heat Pump	$17,000
Low Conversion Cost for Electric Heat Pump (80% 0f High Cost)	$20,000
High Conversion Cost for Electric Heat Pump	$25,000
Low Replacement Cost for Electric Heat Pump	$12,000
High Replacement Cost for Electric Heat Pump	$14,000
ASHRAE Median Life for boiler is 30 years, ASHRAE Median Life for HP is 15 years	

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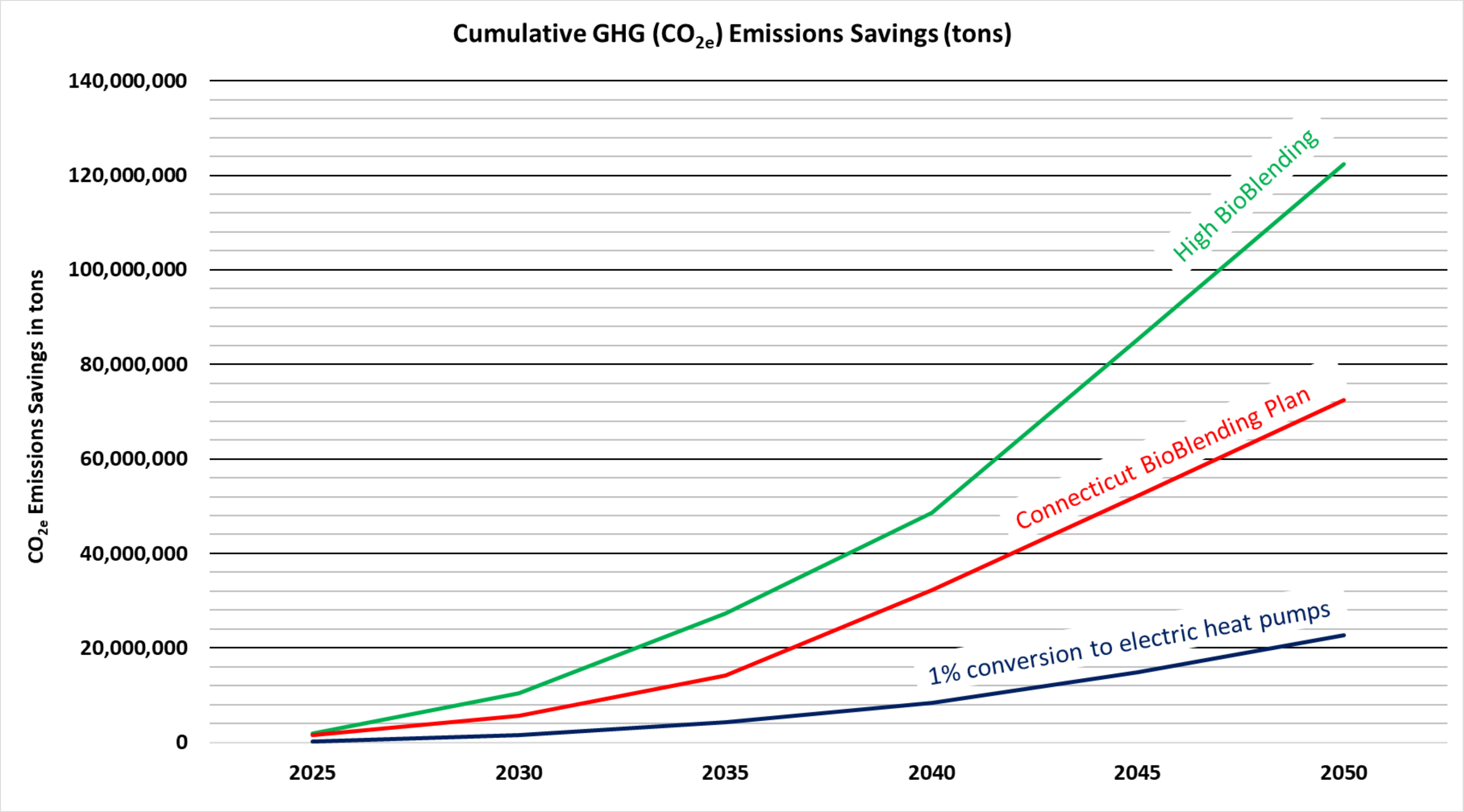
Connecticut Use Case Key Finding



B5 in 2023, B20 in 2025, B50 in 2030 and B100 in 2040 plus normal 5% liquid fuel appliance upgrade

B5 in 2022, B10 in 2025, B15 in 2030, B20 in 2034 and B50 in 2035 plus normal 5% liquid fuel appliance upgrade

1% conversion to electric heat pumps with electric backup

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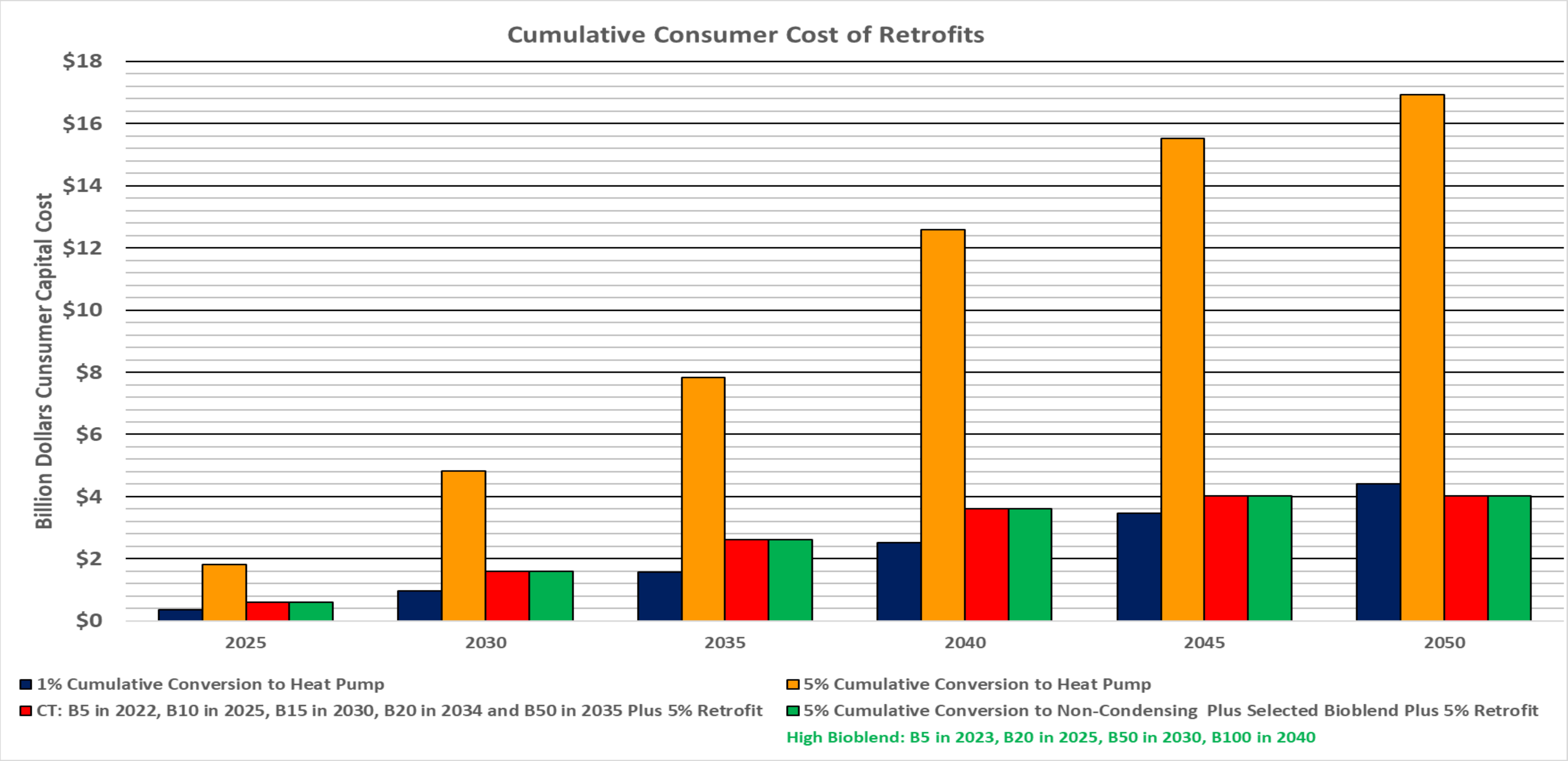
Connecticut Customer Capital Cost Over Time



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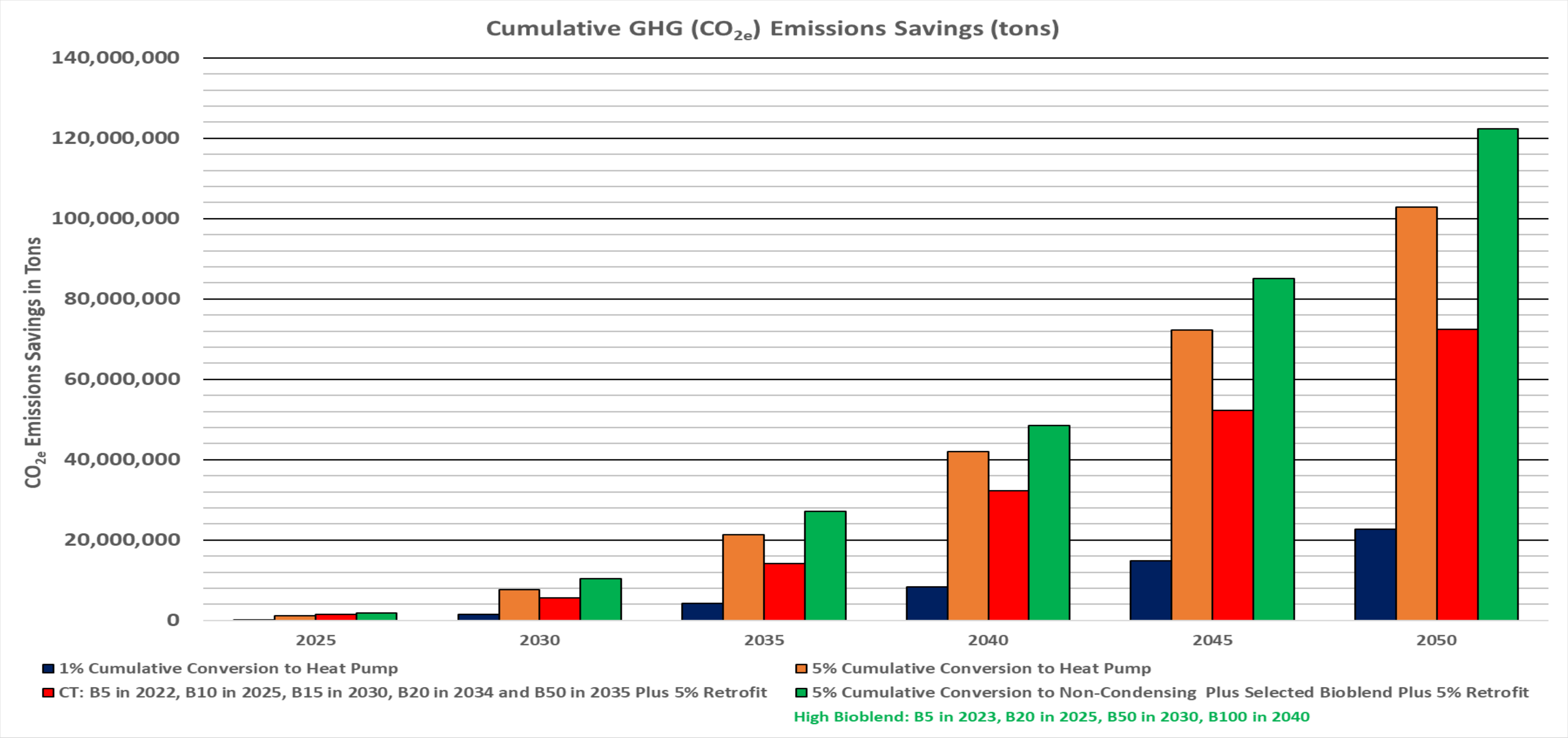
Connecticut Cumulative GHG Emission Savings Over Time



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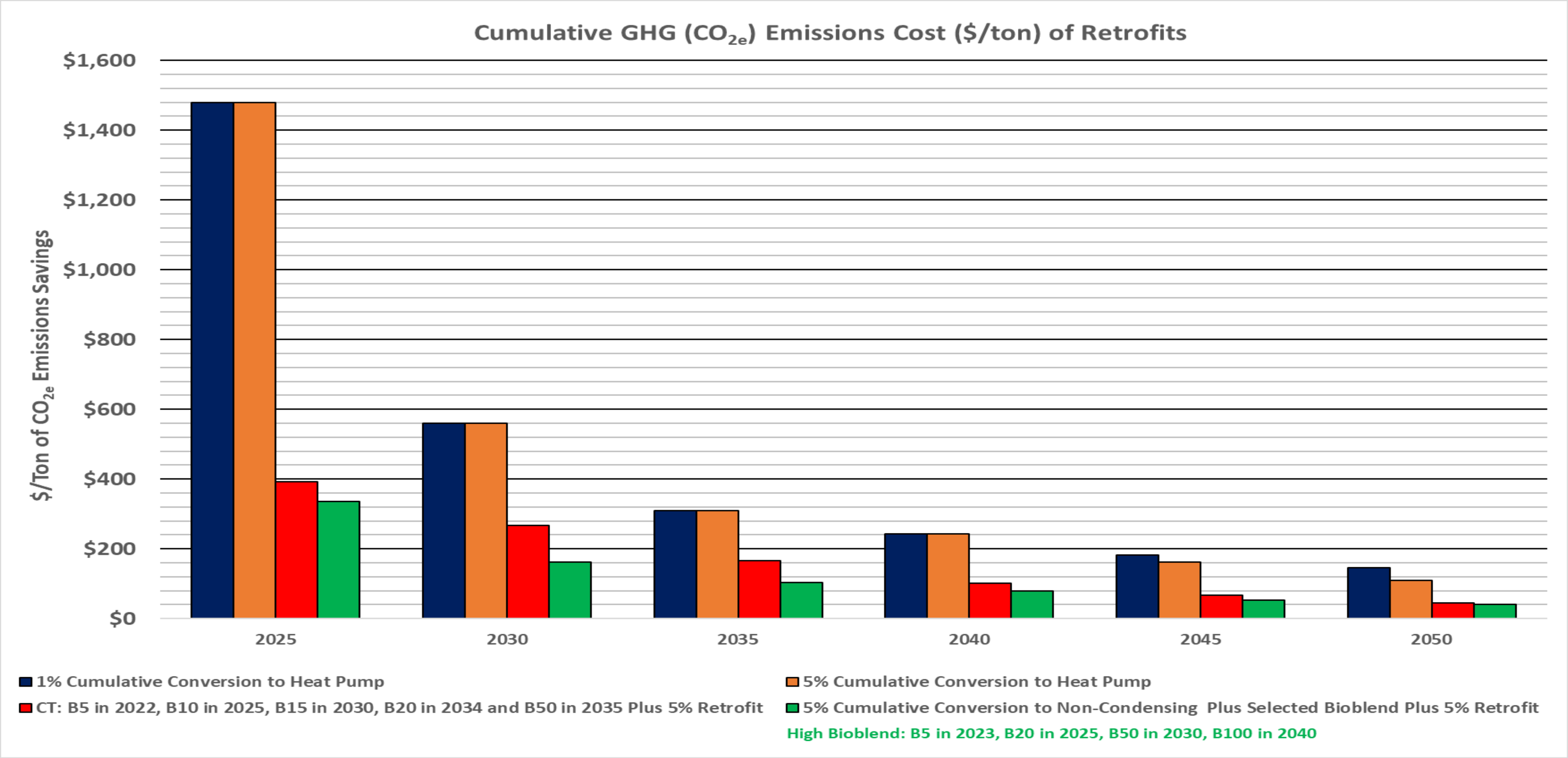
Connecticut Cumulative Customer GHG Reduction Cost ($/ton GHG Reduced)



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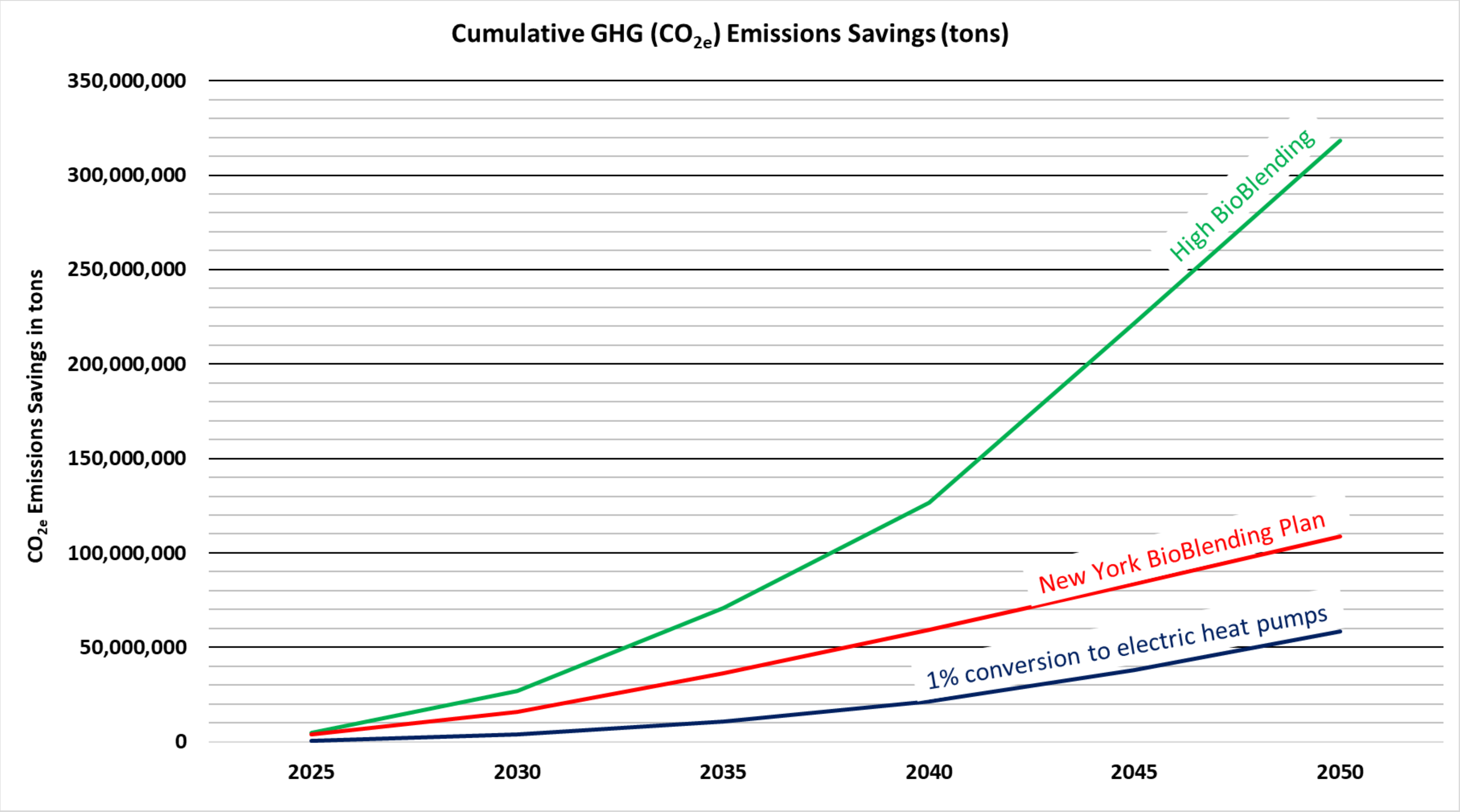
New York Use Case

Input Table	
City for Weather Data to be Applied to the Homes:	Albany, NY
Global Warming Atmospheric Lifetime:	100 Year Lifetime-AR5
Biodiesel Feedstock:	Average of Bioblend Feedstocks
Average Liquid Fueled Baseline Efficiency:	78%
Liquid Fueled Non-Condensing Boiler Efficiency:	86%
Liquid Fueled Boiler Retrofits:	5.00%
Select Liquid Fueled Thermal Heat Pump Retrofits:	5.00%
Electric Heat Pump (EHP) Performance Curve:	HP7
Electric Resistance Seasonal Performance Efficiency:	100%
Annual Home Heating Load MMBtu/year:	100
Bioblend Uptake Scenario:	Scenario 2: B5 in 2023, B20 in 2025, B50 in 2030, B100 in 2040
Decarbonization rate over 2021 Baseline for Marginal Electricity and Biofuels:	Scenario 3: 15% in 2025, 25% in 2030, 50% in 2040 & 100% in 2050
Homes to be Assessed (If State Selected, it must agree with City Selected):	New York
Whole Home Heating Electrification Rate: (HP + electric BU Heating)	1,393,560
Whole Home Heating Electrificaiton Rate: (HP + electric BU Heating)	5.00%
Annual Heating Electrificaiton Conversions:	69,678
Heat Pump Conversion Cost Estimation Curve:	Low Conversion Cost Scenario 2
Percentage of Load Served by Heat Pump:	100.0%
Average Conversion Cost of One Whole House Heat Pump with Electric Backup:	$25,000

New York Use Case

Diesel Cost per MMBtu	$22.71
Biodiesel Cost per MMBtu	$26.56
EL Cost per MMBtu	$30.00
Cost of Electricity 2020 EIA New York ¢/kWh	$0.18
Cost of Electricity 2020 EIA New York $/MMBtu	$53.8
Assumed constant over period for simplicity	
Low Replacement Cost Non-Condensing Boiler	$5,500
High Replacement Cost Non-Condensing Boiler	$9,500
Low Replacement Cost Condensing Boiler	$10,000
High Replacement Cost Condensing Boiler	$15,000
Low Replacement Cost Thermal Heat Pump	$12,000
High Replacement Cost Thermal Heat Pump	$17,000
Low Conversion Cost for Electric Heat Pump (80% 0f High Cost)	$20,000
High Conversion Cost for Electric Heat Pump	$25,000
Low Replacement Cost for Electric Heat Pump	$12,000
High Replacement Cost for Electric Heat Pump	$14,000
ASHRAE Median Life for boiler is 30 years, ASHRAE Median Life for HP is 15 years	

New York Use Case Key Finding

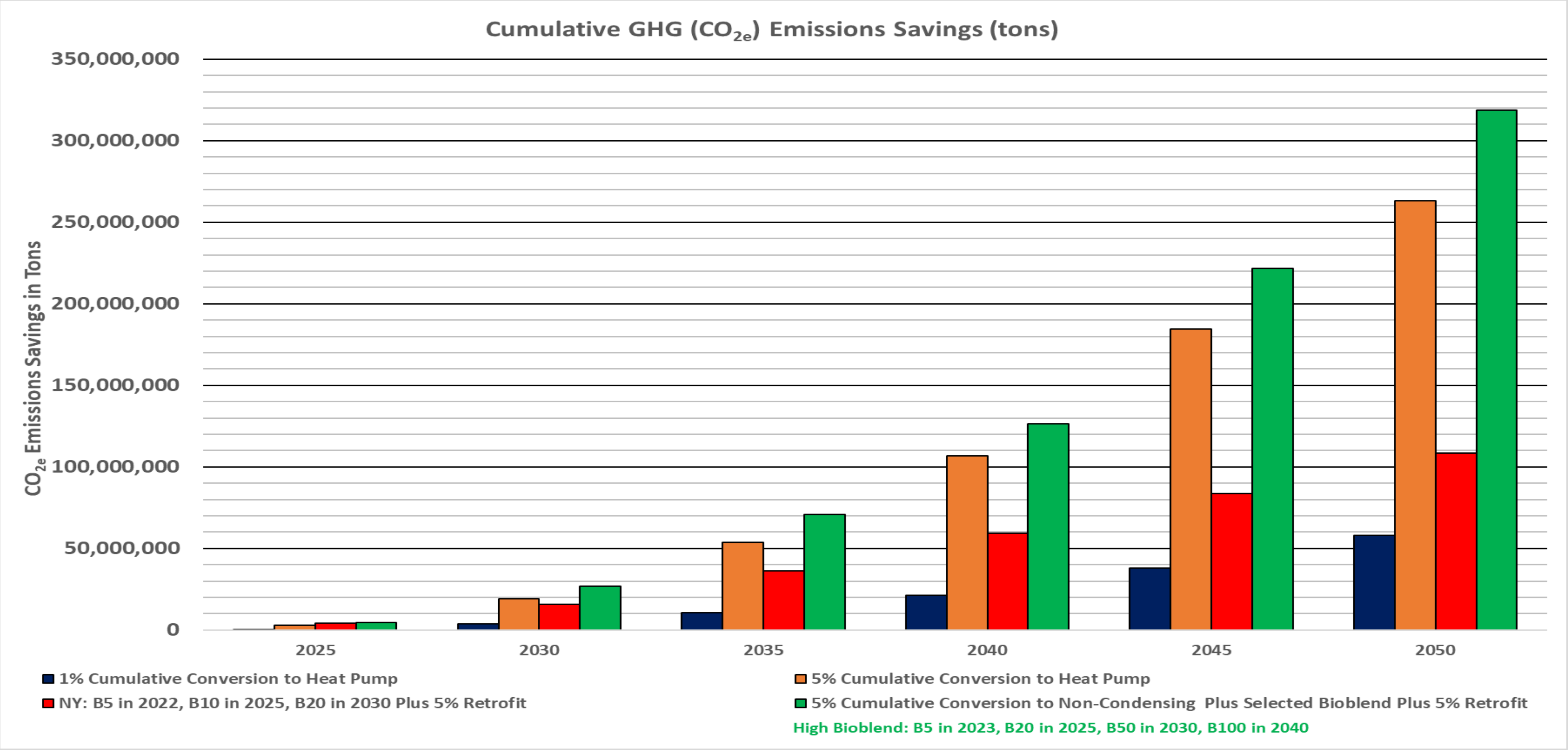


B5 in 2023, B20 in 2025, B50 in 2030 and B100 in 2040 plus normal 5% liquid fuel appliance upgrade

B5 in 2022, B10 in 2025, B20 in 2030 plus normal 5% liquid fuel appliance upgrade

1% conversion to electric heat pumps with electric backup

New York Cumulative GHG Emission Savings Over Time



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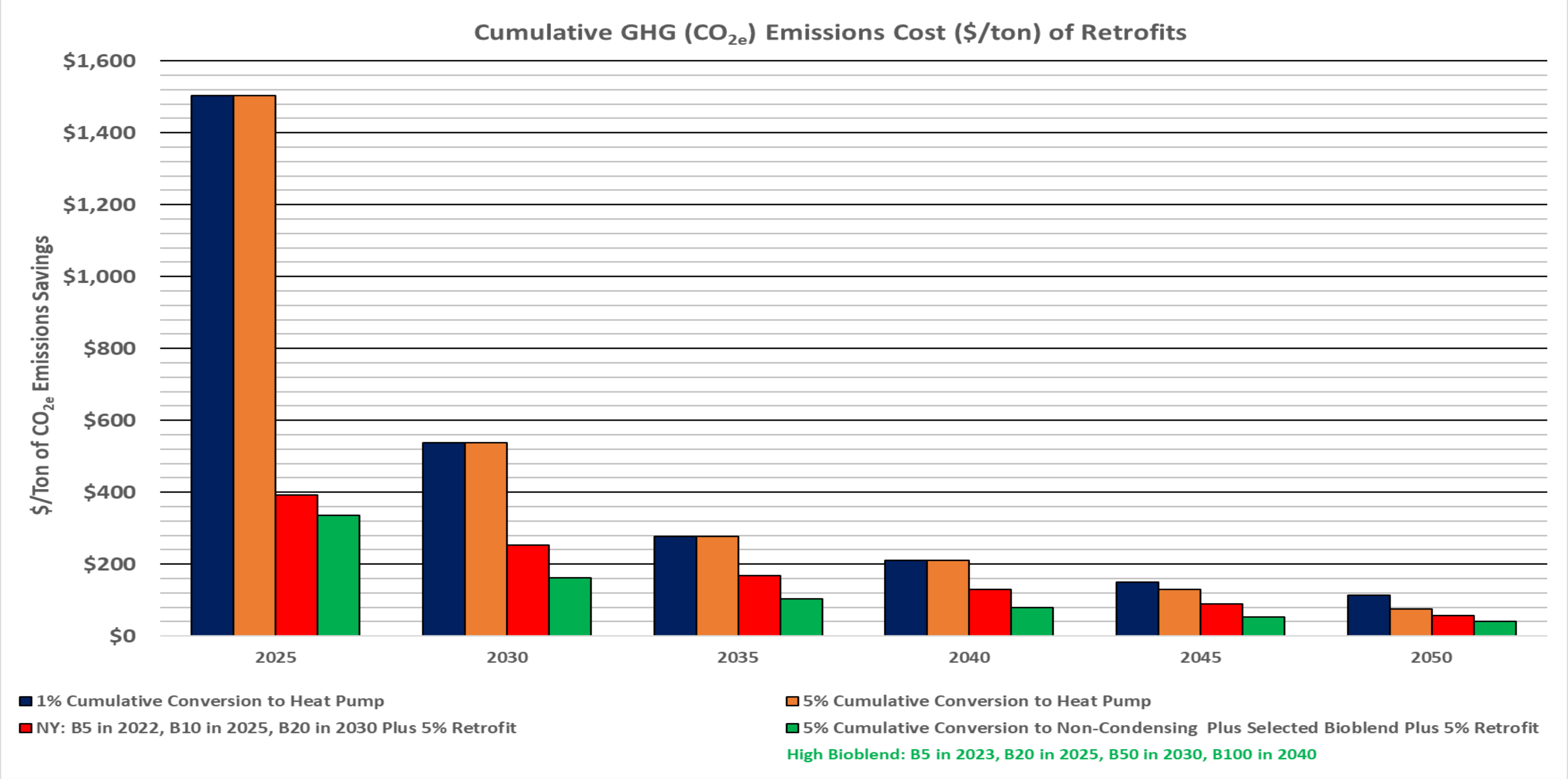
New York Cumulative Customer GHG Reduction Cost ($/ton GHG Reduced)



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Increases and expands IRS Section 25C tax credits for home efficiency improvements through 2031 (Sec. 13301

- The consumer would receive $600 dollars if the unit is placed into service after December 31, 2022, and before January 1, 2027, meets or exceeds 2021 *Energy Star* efficiency criteria, and is rated by the OEM for use with at least 20% biofuel blends

- The consumer would receive $600 dollars if the unit is placed into service after December 31, 2026, achieves at least 90 AFUE, and is rated by the OEM for use with at least 50% biofuel blends

Thank you!

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703-340-1660