# Strategic Investments in Residential Energy Efficiency: Insights from NE MARKAL

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# About NESCAUM

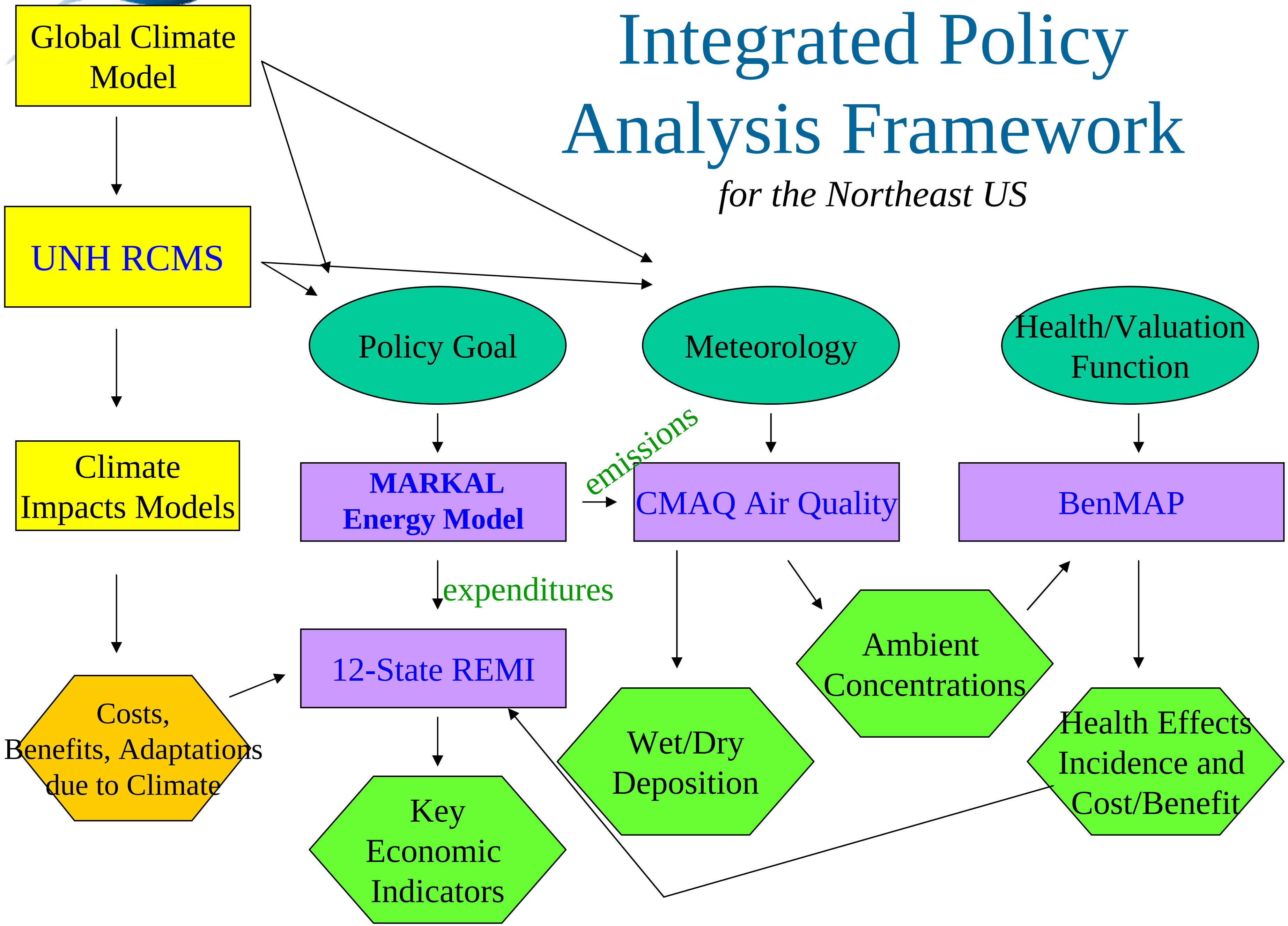
- NESCAUM is a non-profit association of air quality agencies in 8 Northeastern states (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, New Jersey, and New York).

- Staff of thirty scientists, modelers, policy analysts, economists, and communications experts providing technical and policy analysis, outreach, and communications to the NE states on climate, energy, and air quality policies and issues.

- Our integrated modeling framework serves as a platform for much of our air quality, energy, and climate policy work.

# Integrated Policy Analysis Framework

*for the Northeast US*



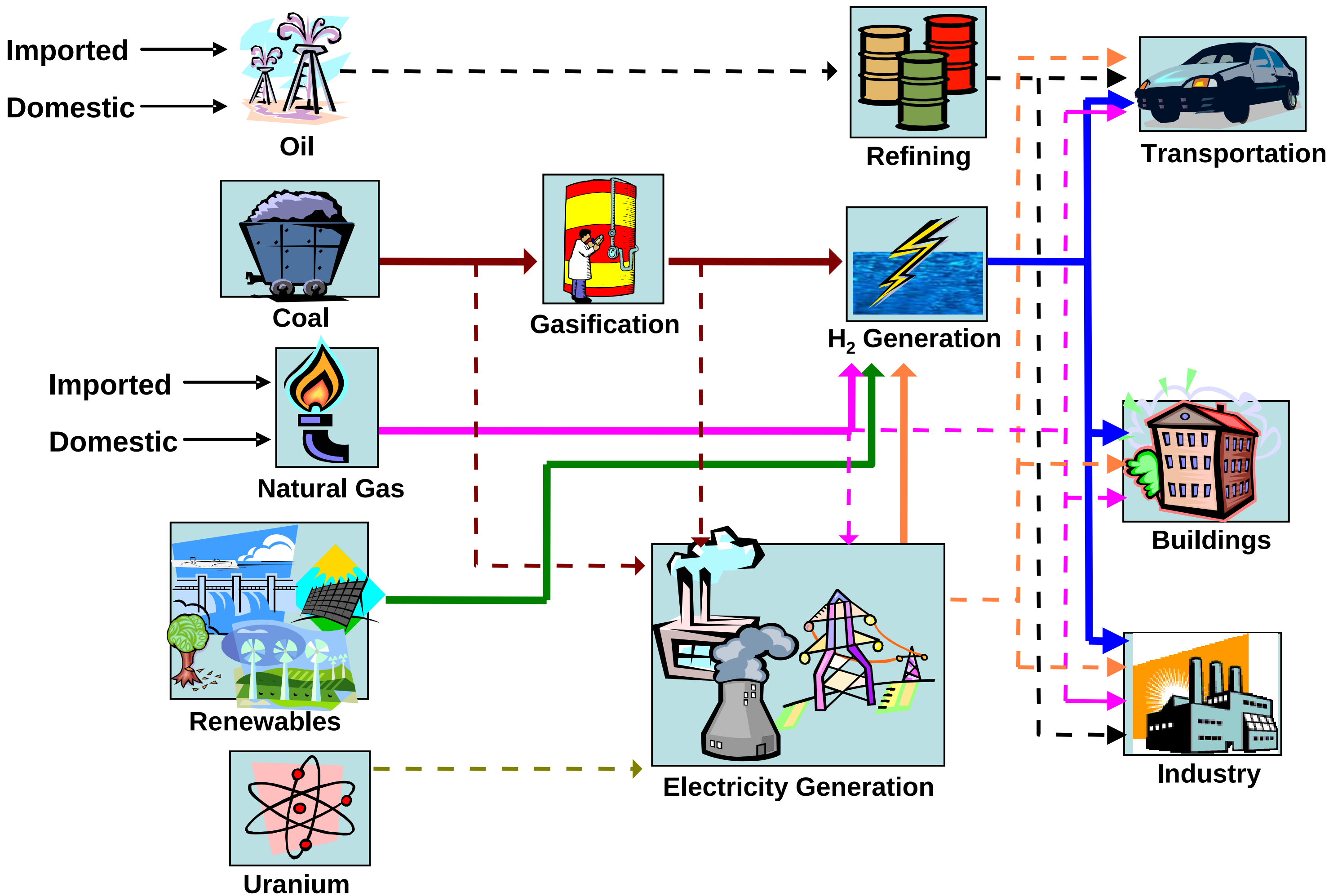
# Northeast Center for Atmospheric Science and Policy (NCASP)

- NESCAUM, the University of New Hampshire, and NOAA are collaborating through NCASP to:
  - Link atmospheric science and policy research, and
  - Identify the most effective regional opportunities and initiatives
- We focused on residential heating sector for initial study because:
  - Fossil-intensive sector that represents nearly 15% of New England energy consumption and GHG emissions
  - Underserved by state and utility efficiency programs
- Using the NE MARKAL energy model, we are:
  - Modeling efficiency improvements in residential heating (i.e., upgrading thermal shell)
  - Generating estimates of associated reductions in fuel use, GHGs, and costs

# NE MARKAL
# Energy Model Overview

# MARKAL Modeling of Energy System

## Energy System Interactions



# What NE-MARKAL Is

***(and what it is not!)***

- Excellent tool for long-term policy exploration and analysis ***(not a forecasting tool or dispatch model)***
- Provides big-picture, multi-sectoral overview of regional programs ***(not as detailed for any one sector, e.g., IPM).***
- Optimizes based on lowest-cost patterns of technology deployment over time ***(not predictive of behavior unless motivated by cost)***

# Representing technologies in Bottom-Up Models

- Each technology is characterized in detail by technical and economic parameters.
- Uncertainty about the value of technical parameters (at least in the long term).
- Large degree of uncertainty about some economic parameters (in short term and long term).

# The Problem with “Hurdle Rates”

**Average Hurdle Rates for Energy Efficiency Investments**

| **Study** | **End-Use Type** | **Average rate** |
|---|---|---|
| Arthur D Little (1984) | Thermal shell measures | 32% |
| Cole and Fuller (1990) | Thermal shell measures | 26% |
| Goett (1978) | Space heating system and fuel type | 36% |
| Berkovec, Hausman and Rust (1983) | Space heating system and fuel type | 25% |
| Hausman (1979) | Room air conditioners | 29% |
| Cole and Fuller (1980) | Refrigerators | 61-108% |
| Gately (1980) | Refrigerators | 45-300% |
| Meier and Whittier (1983) | Refrigerators | 34-58% |
| Goett (1983) | Cooking and water heating | 36% |
| Goett and McFadden (1982) | Water heating fuel type | 67% |
| **Source(s): Sandstad *et al.* (1995); Train (1985).** | | |

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# Uncertainties about impacts of MARKAL's "legacy" hurdle rates for residential heating technologies motivated this study.

Vintage technologies were collapsed into one technology where key parameters evolve over time. (Examples)

| Technology | Drate | Eff | Fixom | Invcost | Start |
|---|---|---|---|---|---|
| Electric Air Source Heat Pump #1 | 0.18 | 1.99 | 0.48 | 5.96 | 2002 |
| Electric Air Source Heat Pump #1 | 0.18 | 2.20 | 0.57 | 7.12 | 2011 |
| Electric Air Source Heat Pump #2 | 0.44 | 2.38 | 0.63 | 7.83 | 2011 |
| Electric Air Source Heat Pump #2 | 0.44 | 2.46 | 0.63 | 7.89 | 2020 |
| Electric Furnace #0 | 0.18 | 1.01 | 0.21 | 2.62 | 2002 |
| Electric Furnace #0 | 0.44 | 1.05 | 0.23 | 2.89 | 2011 |
| Electric Furnace #1 | 0.18 | 1.00 | 0.24 | 2.95 | 2002 |
| Electric Furnace #1 | 0.6 | 1.10 | 0.25 | 3.15 | 2011 |
| Electric Ground Source Heat Pump #1 | 0.8 | 3.40 | 1.63 | 20.40 | 2002 |
| Electric Ground Source Heat Pump #1 | 0.8 | 3.40 | 1.64 | 20.52 | 2005 |
| Electric Ground Source Heat Pump #1 | 0.8 | 3.80 | 1.64 | 20.52 | 2020 |
| Kerosene Furnace N | 0.18 | 0.78 | 0.59 | 7.37 | 2002 |
| Natural Gas Furnace #1 | 0.18 | 0.78 | 0.21 | 2.62 | 2002 |
| Natural Gas Furnace #2 | 0.44 | 0.80 | 0.23 | 2.84 | 2002 |
| Natural Gas Furnace #3 | 0.44 | 0.82 | 0.24 | 3.06 | 2002 |
| Natural Gas Furnace #4 | 0.44 | 0.92 | 0.33 | 4.15 | 2002 |
| Natural Gas Furnace #4 | 0.44 | 0.92 | 0.31 | 3.93 | 2005 |
| Natural Gas Furnace #4 | 0.44 | 0.92 | 0.30 | 3.72 | 2011 |
| Natural Gas Furnace #4 | 0.44 | 0.92 | 0.28 | 3.50 | 2020 |
| Natural Gas Furnace N | 0.18 | 0.76 | 0.18 | 2.23 | 2002 |
| Natural Gas Heat Pump #0 | 0.18 | 1.40 | 1.06 | 13.22 | 2002 |
| Natural Gas Heat Pump #0 | 0.18 | 1.50 | 1.06 | 13.22 | 2020 |
| Natural Gas Radior #1 | 0.24 | 0.80 | 0.43 | 5.42 | 2002 |
| Natural Gas Radior #2 | 0.44 | 0.87 | 0.54 | 6.70 | 2002 |
| Natural Gas Radior #2 | 0.44 | 0.89 | 0.54 | 6.70 | 2011 |
| Natural Gas Radior N | 0.18 | 0.72 | 0.40 | 5.04 | 2002 |
| Oil Furnace #1 | 0.24 | 0.80 | 0.23 | 2.84 | 2002 |
| Oil Furnace #2 | 0.44 | 0.82 | 0.24 | 3.06 | 2002 |
| Oil Furnace #3 | 0.44 | 0.87 | 0.33 | 4.15 | 2002 |
| Oil Furnace N | 0.18 | 0.78 | 0.22 | 2.76 | 2002 |
| Oil Radiator #1 | 0.24 | 0.76 | 0.43 | 5.42 | 2002 |
| Oil Radiator #2 | 0.44 | 0.82 | 0.54 | 6.70 | 2002 |
| Oil Radiator #2 | 0.44 | 0.89 | 0.54 | 6.70 | 2011 |
| Oil Radiator N | 0.18 | 0.72 | 0.42 | 5.26 | 2002 |
| Propane Furnace #1 | 0.18 | 0.78 | 0.21 | 2.62 | 2002 |
| Propane Furnace #2 | 0.44 | 0.80 | 0.23 | 2.84 | 2002 |
| Propane Furnace N | 0.18 | 0.76 | 0.21 | 2.57 | 2002 |

# Assessing the effect of “Hurdle Rate” Assumptions in NE-MARKAL

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# Objectives of Hurdle Rate Exercise

- How sensitive are key model results to uniform changes in the hurdle rate?
  - Fuel Use
  - Emissions
  - Investment patterns
  - System Cost
- How would key model results change if we use policy to drive hurdle rates down for energy-efficient technologies?
- If policy can influence hurdle rates, what should the policy goal be?

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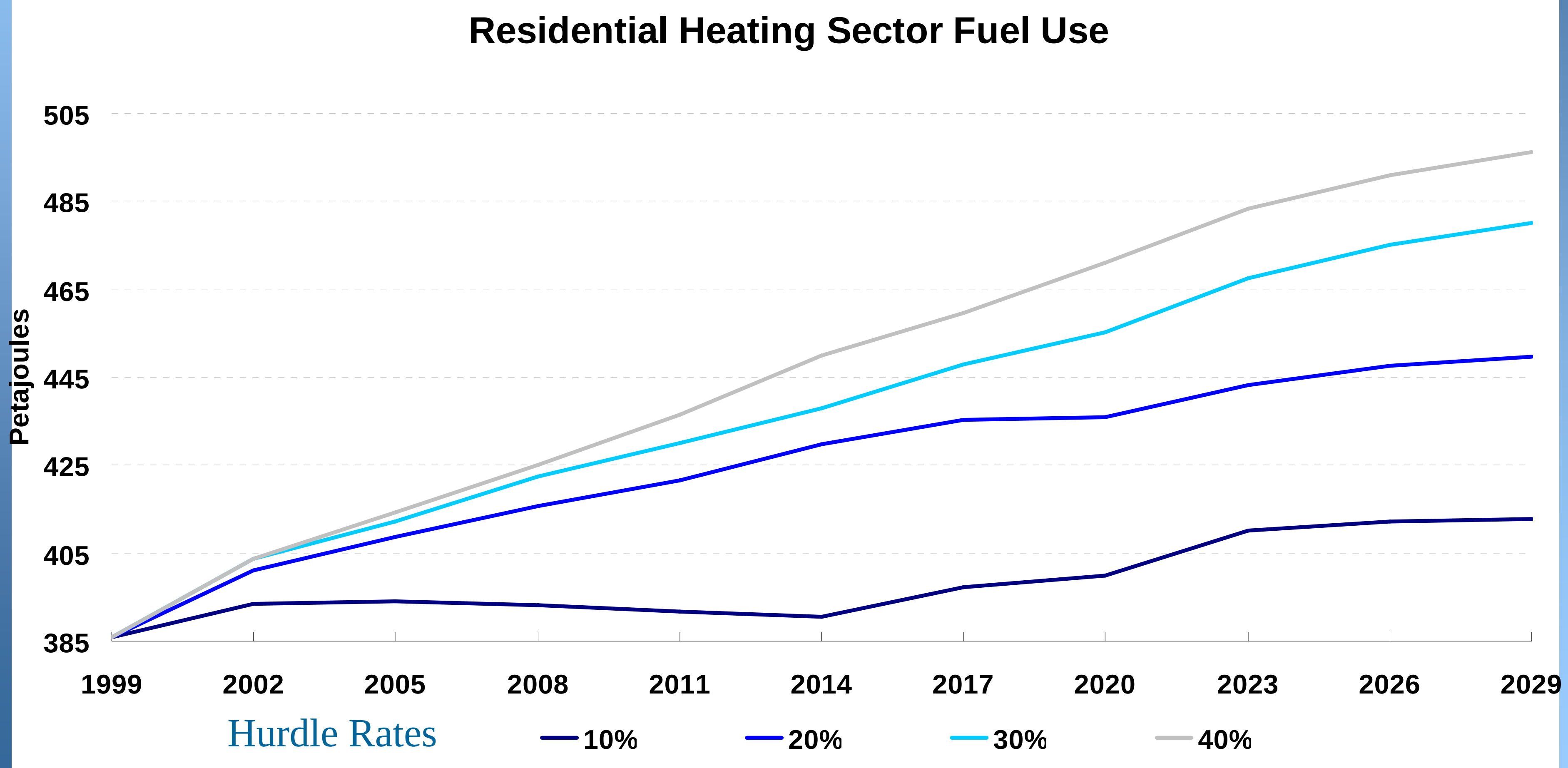
# Hurdle Rate Study Scenarios and Methods

- Case 1: Isolate the effect of the hurdle rate on key model results
  - Set all residential heating technologies at uniform hurdle rates (10%, 20%, 30%, 40%) and compare key model results
- Case 2: Promoting high-efficiency technologies
  - Identify high-efficiency technologies and lower the hurdle rates only for these technologies
    - 2a (AEO ref fuel price)
    - 2b (AEO ref fuel price +20%)

# Case 1: Isolating the Effect of Discount Rates

# Fuel Use



Residential Heating Sector Fuel Use
Petajoules
505
485
465
445
425
405
385
1999
2002
2005
2008
2011
2014
2017
2020
2023
2026
2029
Hurdle Rates
10%
20%
30%
40%

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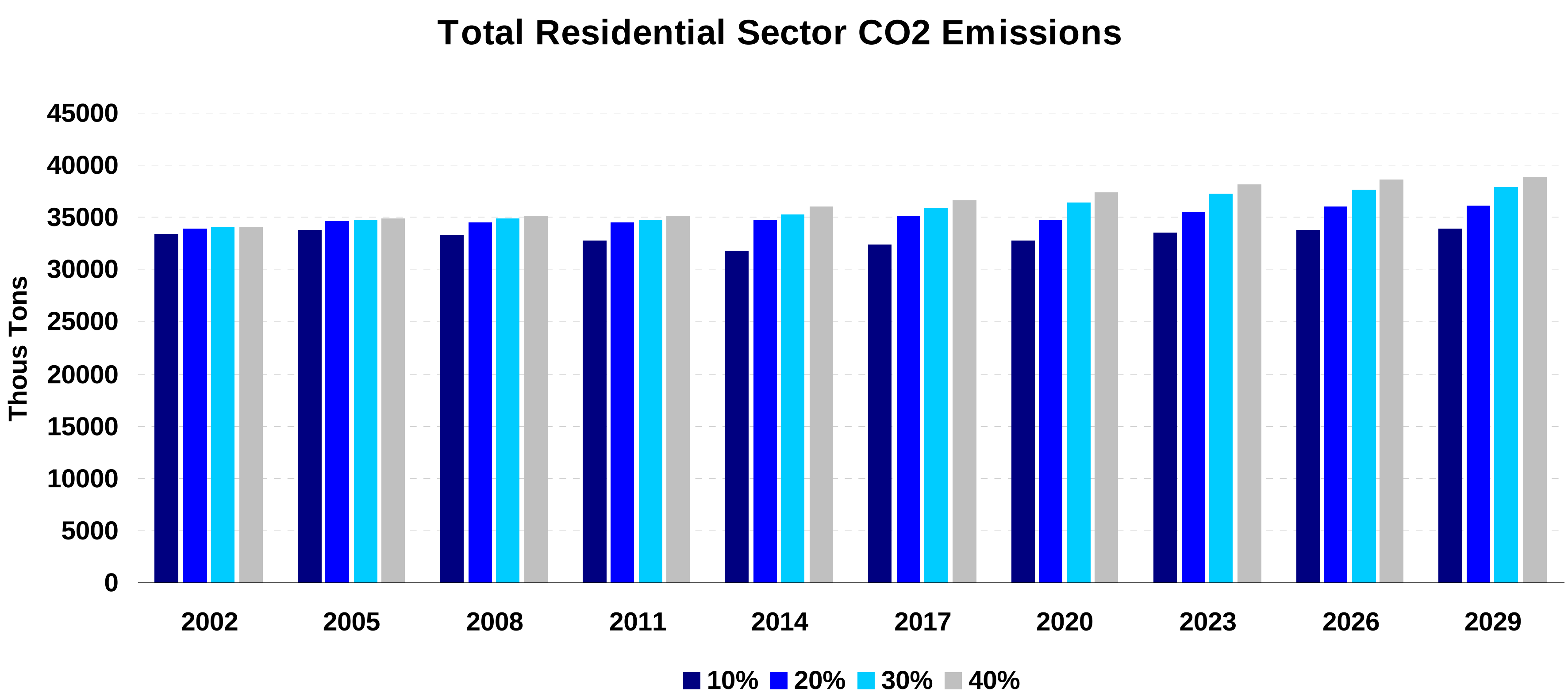
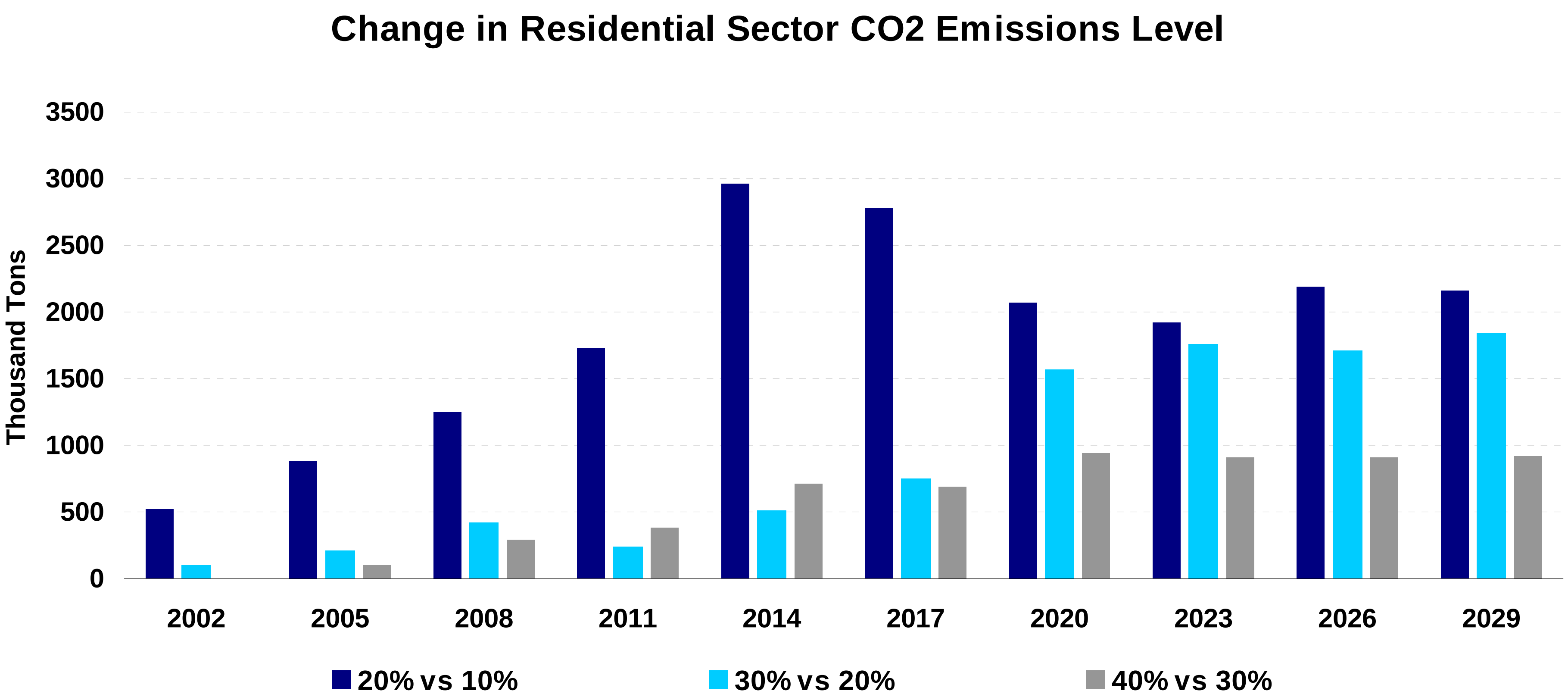
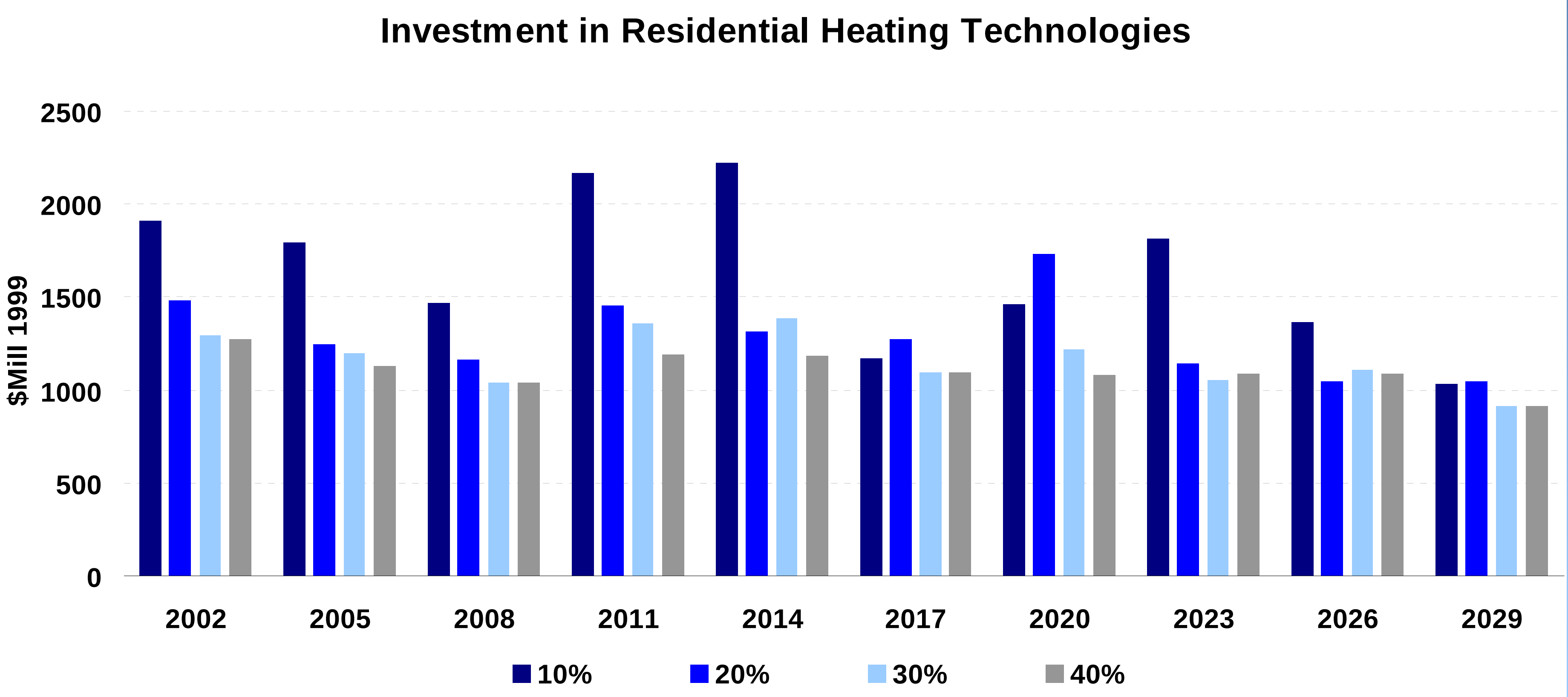
# $CO_2$ Emissions



# Changes in $CO_2$ Emissions



# Investment Levels



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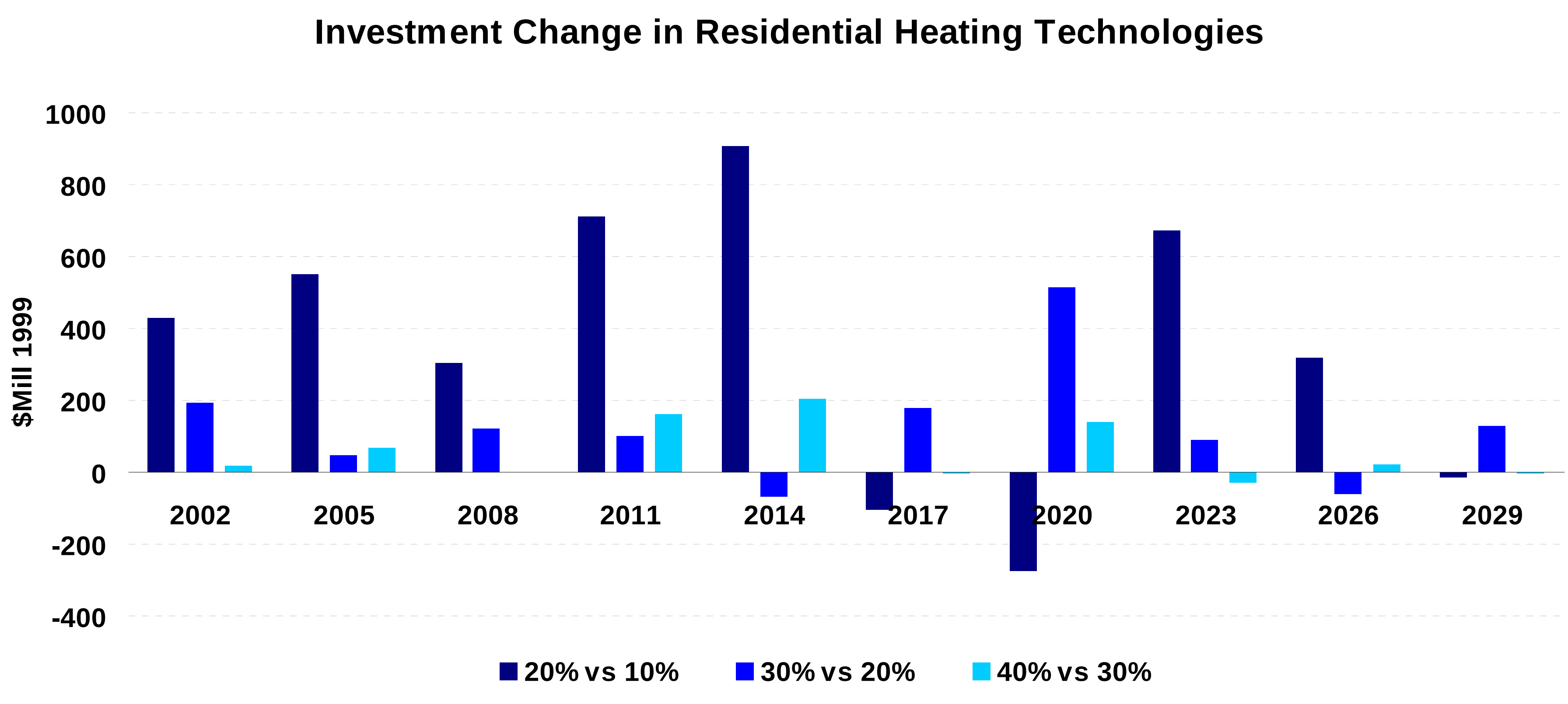
# Changes in Investment Levels



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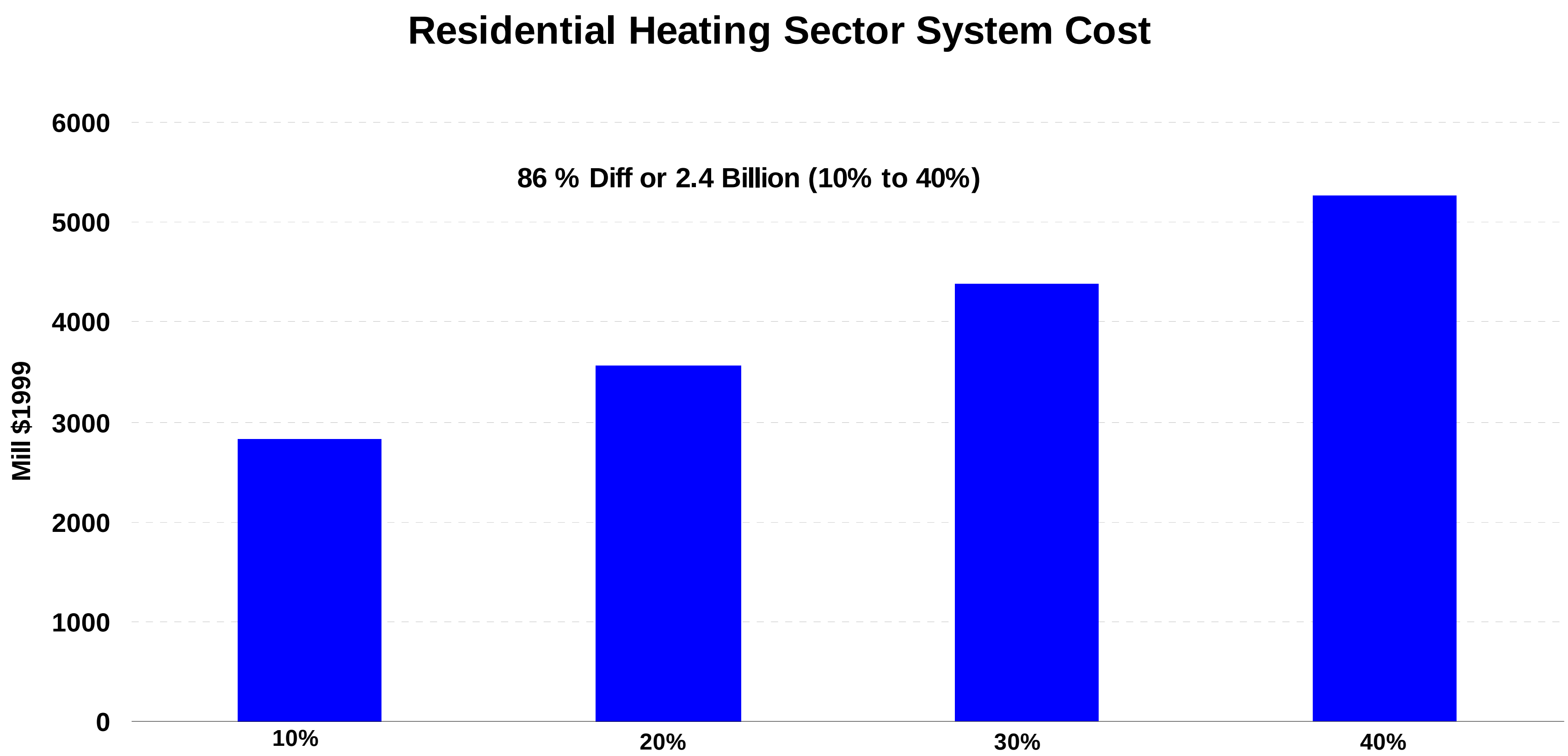
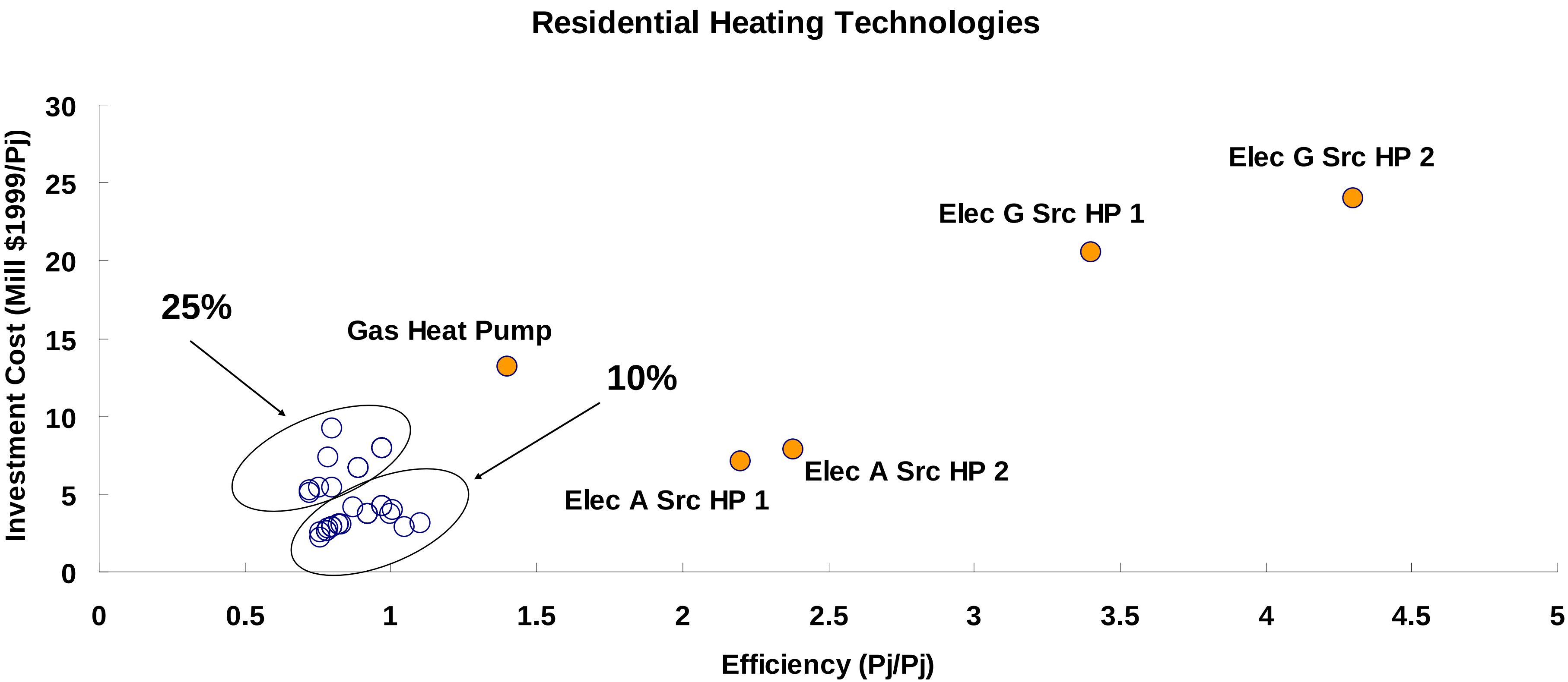
# System Cost

| Scenario | Dollars Per Ton of CO2 Reduction |
|---|---|
| 20% vs 10% | $39.40 |
| 30% vs 20% | $90.40 |
| 40% vs 30% | $151.51 |



# Case 2: Promoting High Efficiency Technologies

# Technical and economic characteristics of residential heating technologies



# Discount Rate Structure for promoting investment in high efficiency technologies

***Discount Rate***

| Technology | Case 2 High | Case 2 Med | Case 2 Low |
|---|---|---|---|
| Elec Ground Src HP 1 | 0.4 | 0.15 | 0.1 |
| Elec Ground Src HP 2 | 0.4 | 0.15 | 0.1 |
| Gas Heat Pump Base | 0.3 | 0.3 | 0.15 |
| Elec Air Src HP 1 | 0.2 | 0.1 | 0.1 |
| Elec Air Src HP 2 | 0.2 | 0.1 | 0.1 |

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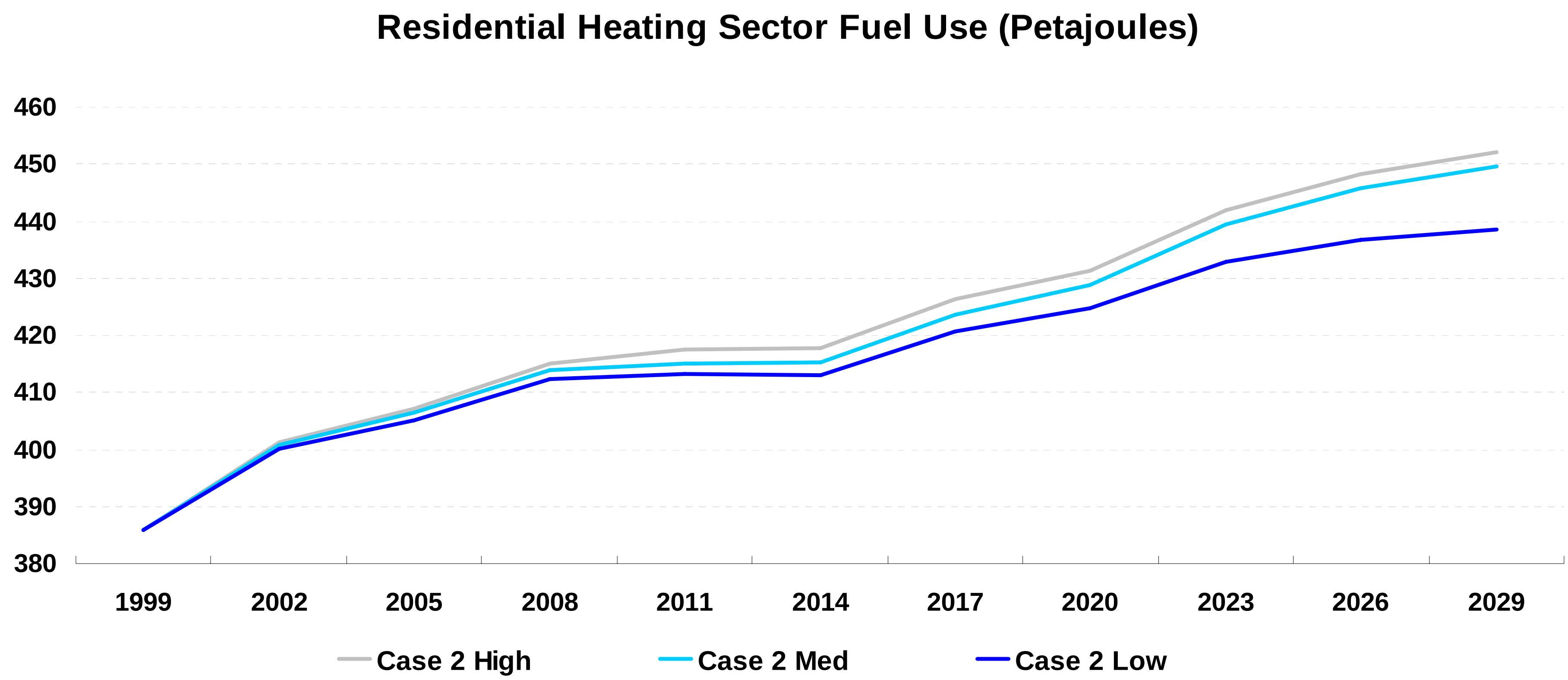
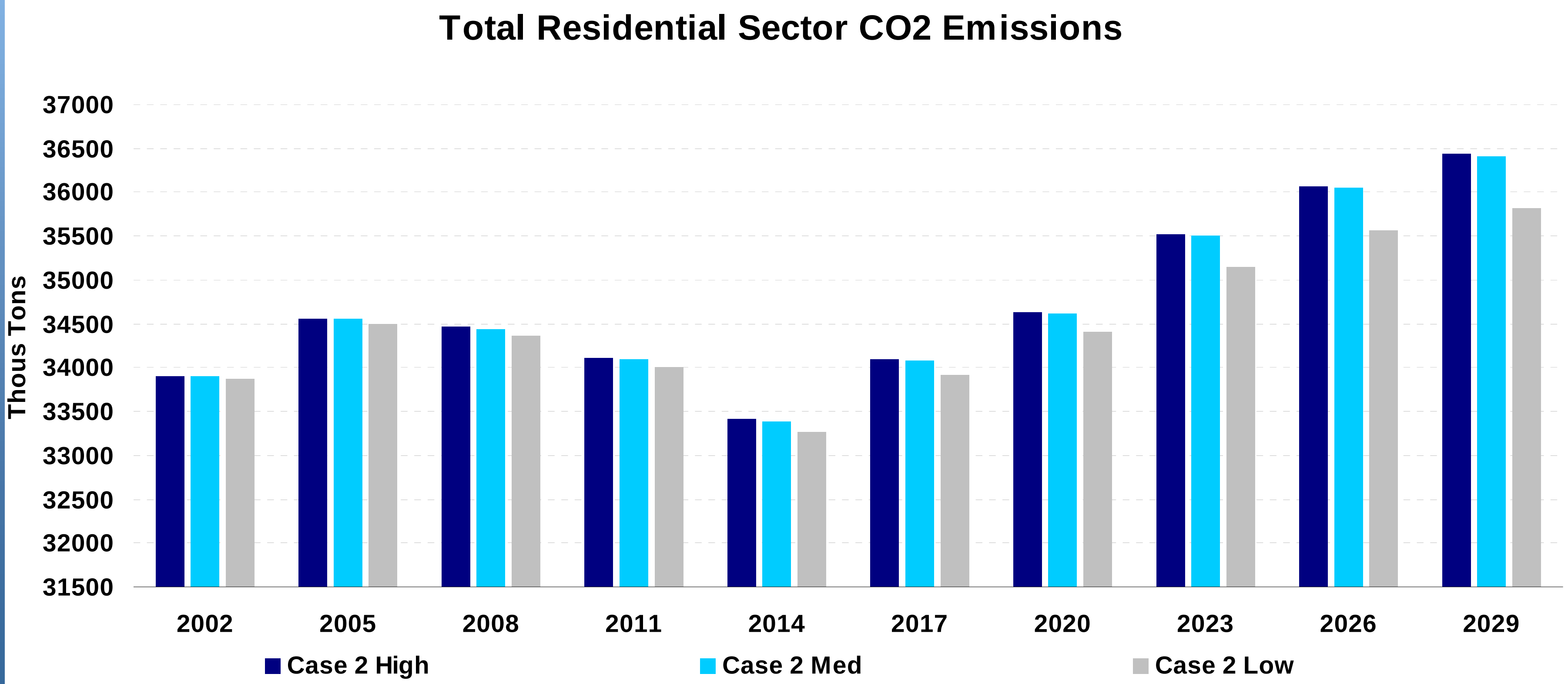
# Case 2a: AEO Reference Fuel Price

# Fuel Use

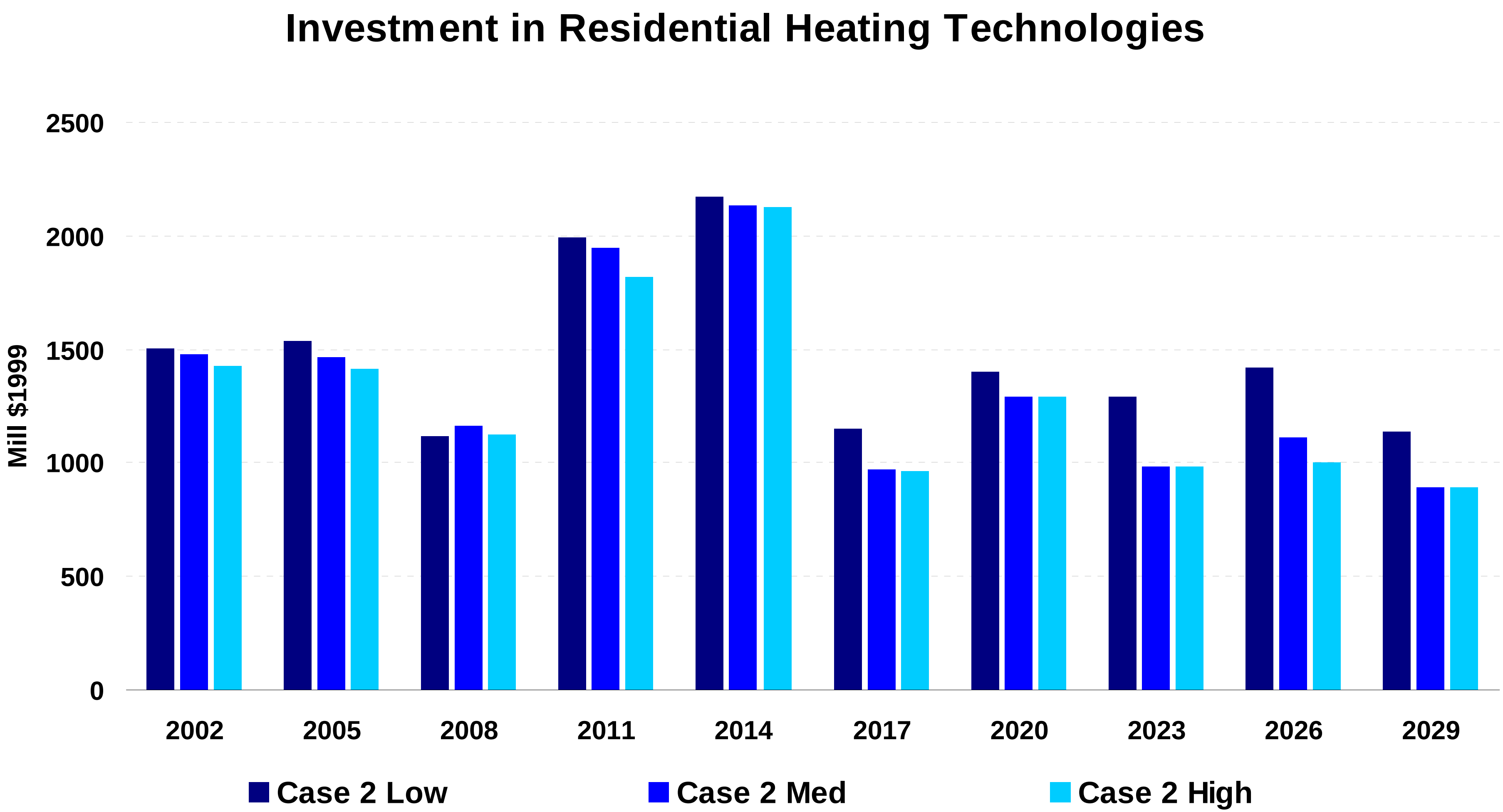


Residential Heating Sector Fuel Use (Petajoules)
460
450
440
430
420
410
400
390
380
1999
2002
2005
2008
2011
2014
2017
2020
2023
2026
2029
Case 2 High
Case 2 Med
Case 2 Low

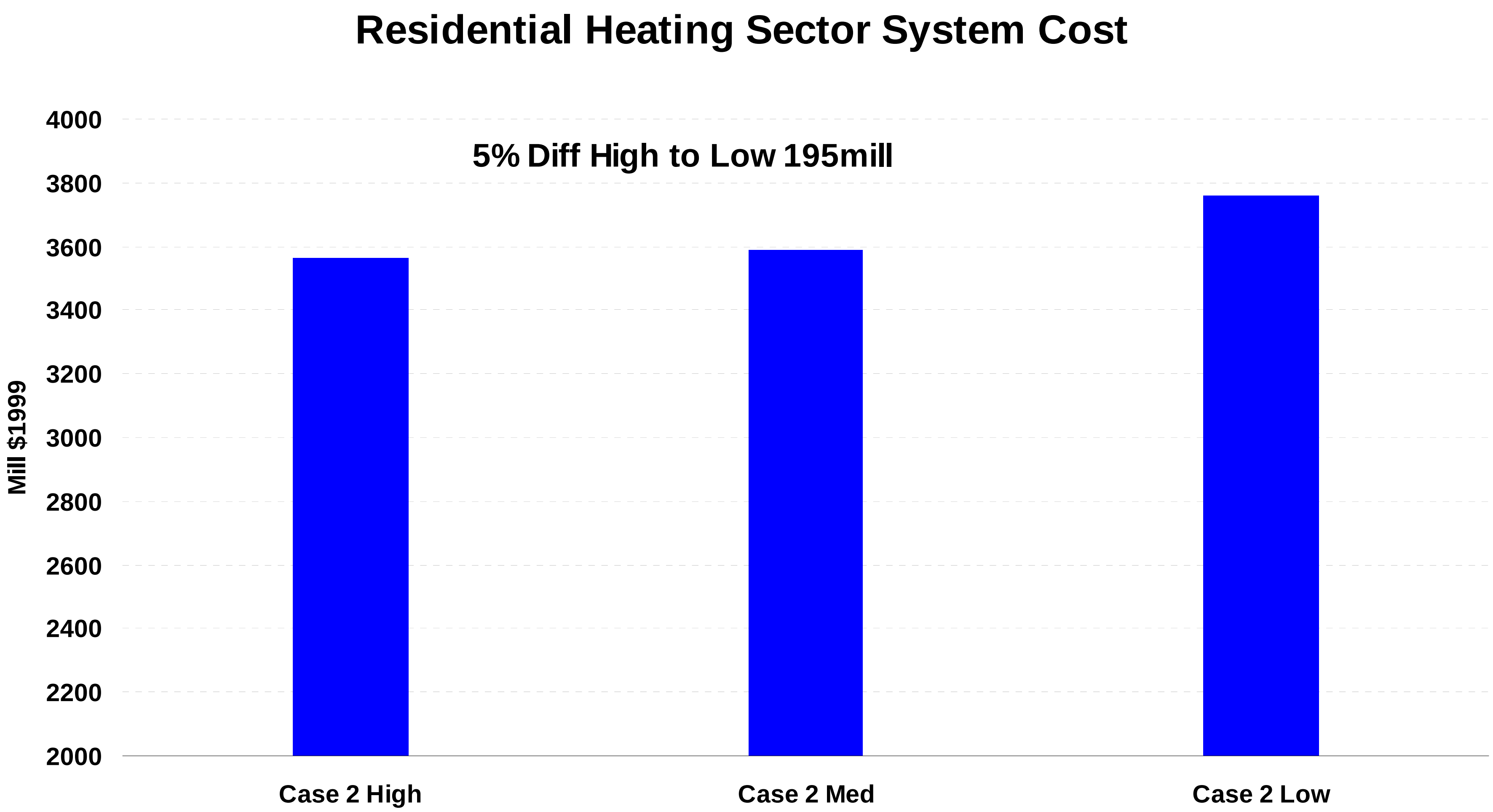
# $CO_2$ Emissions



# Investment Levels



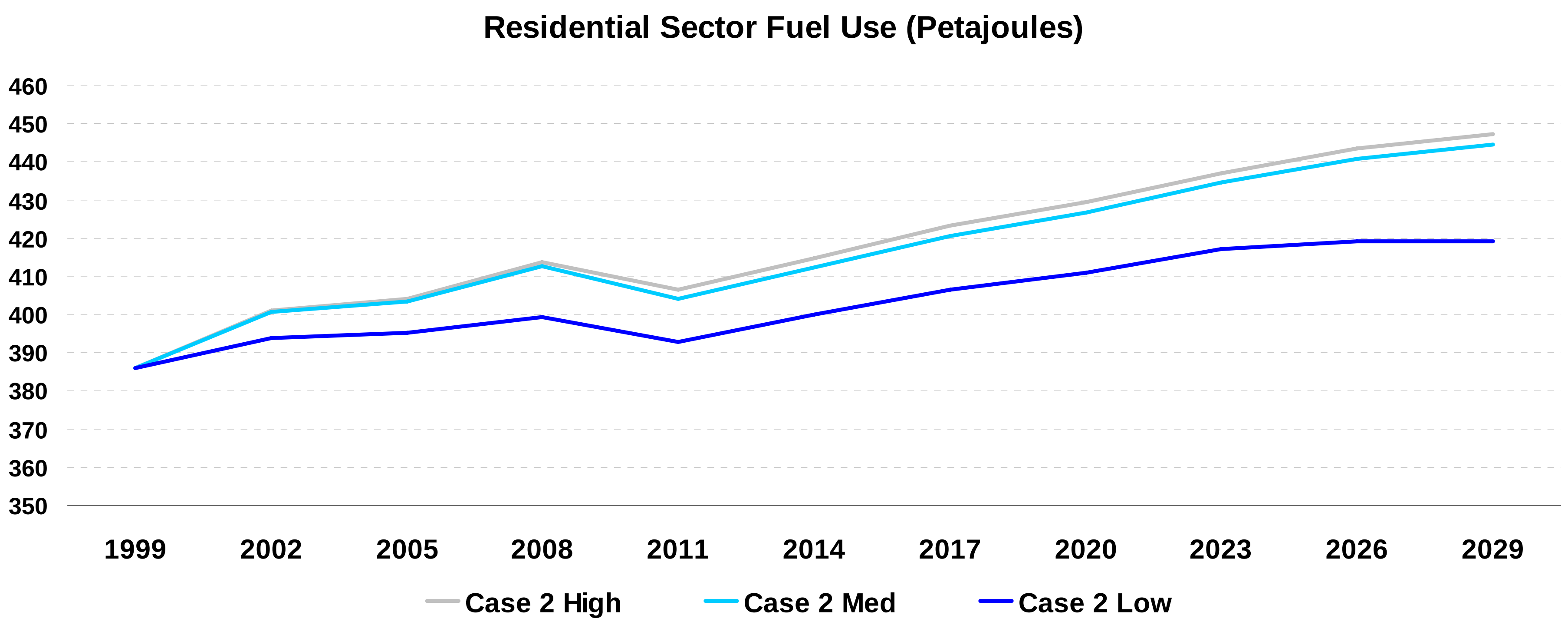
# System Cost



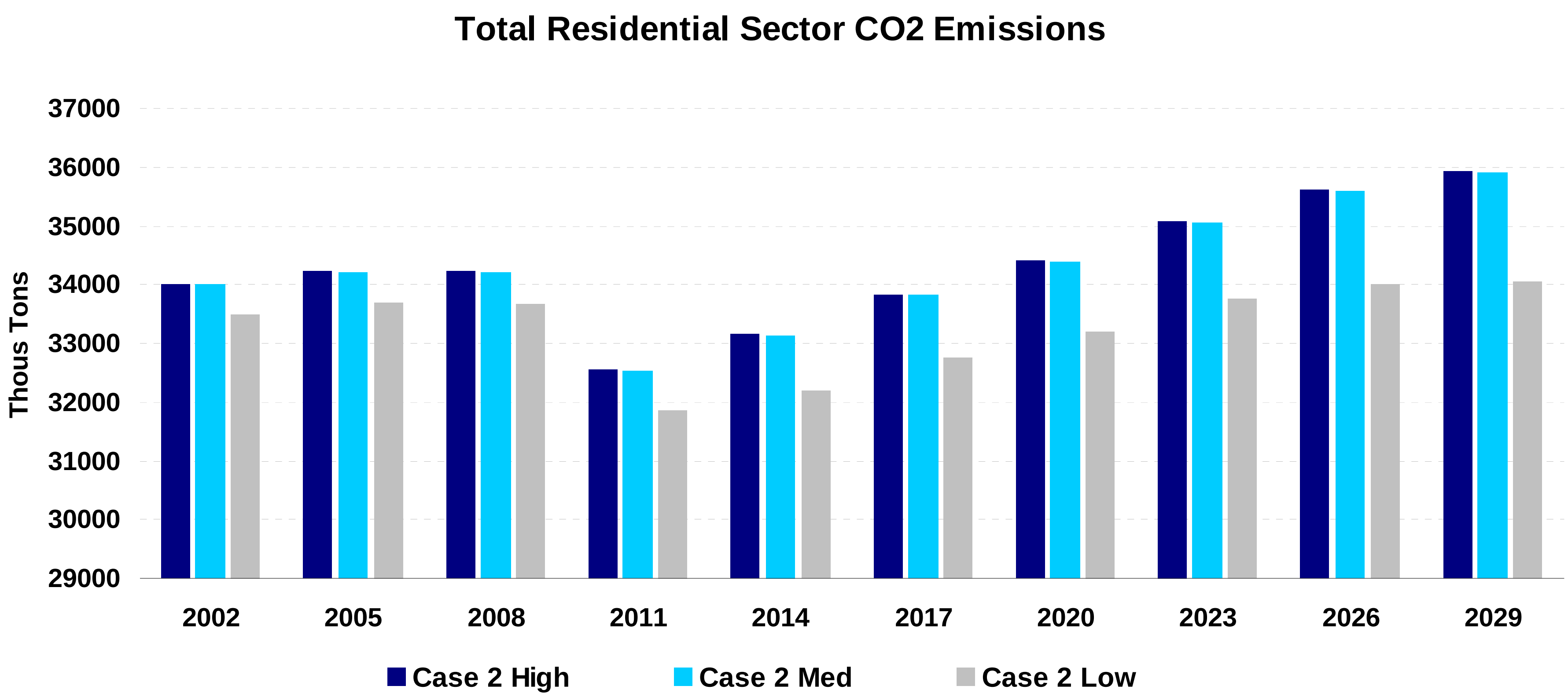
Residential Heating Sector System Cost
5% Diff High to Low 195mill
Mill $1999
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
Case 2 High
Case 2 Med
Case 2 Low

# Case 2b:
# AEO Ref Fuel Price +20%

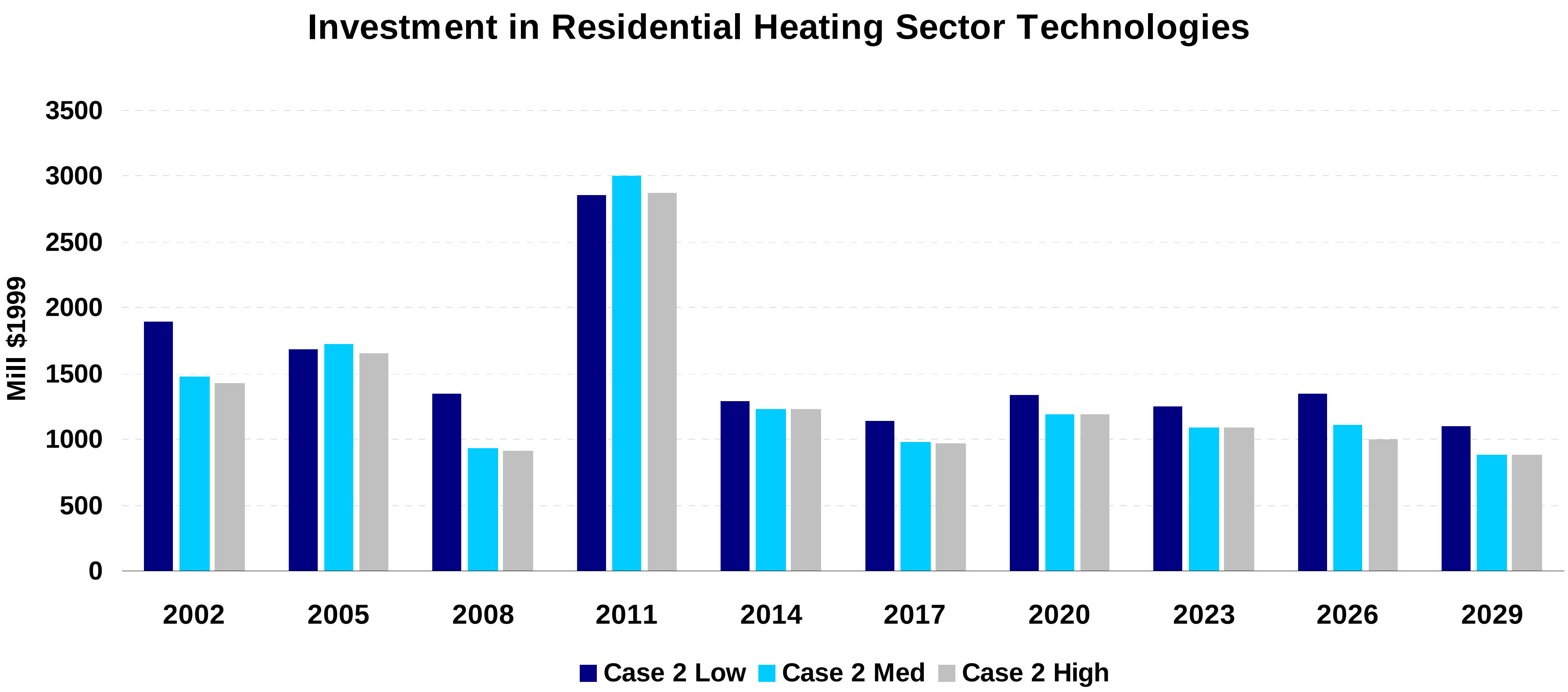
# Fuel Use


Residential Sector Fuel Use (Petajoules)
460
450
440
430
420
410
400
390
380
370
360
350
1999
2002
2005
2008
2011
2014
2017
2020
2023
2026
2029
Case 2 High
Case 2 Med
Case 2 Low

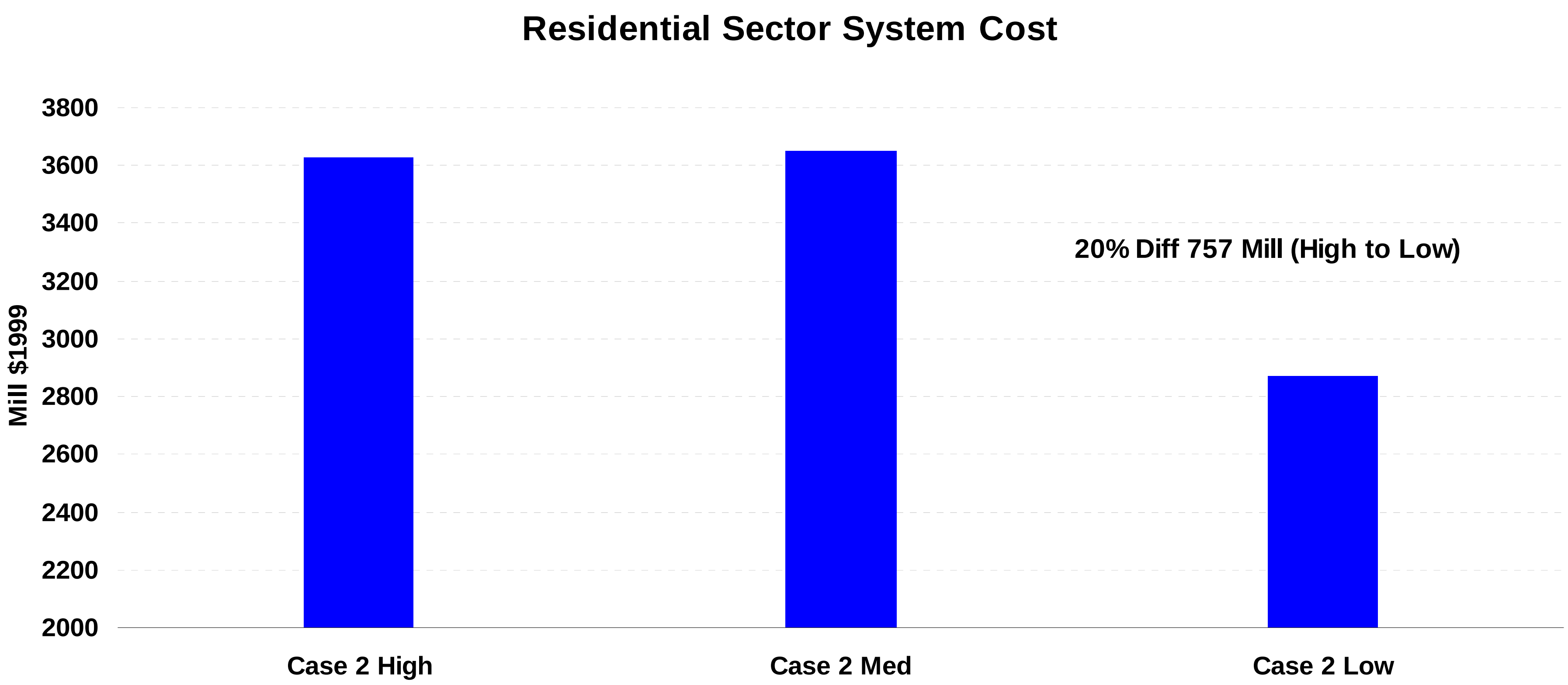
# $CO_2$ Emissions



# Investment Levels



# System Cost


Residential Sector System Cost
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
Mill $1999
20% Diff 757 Mill (High to Low)
Case 2 High
Case 2 Med
Case 2 Low

# Differences Between AEO High Price and Policy/Price Scenario

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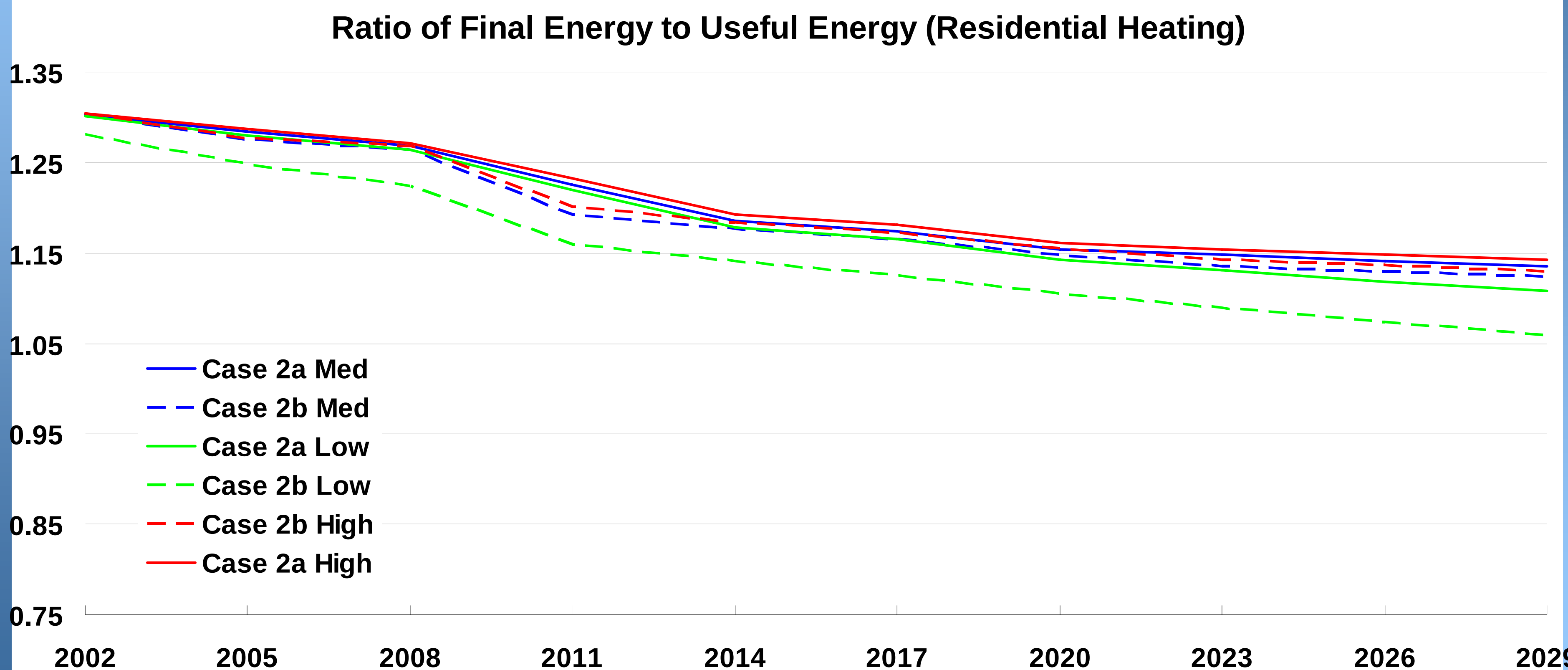

Ratio of Final Energy to Useful Energy (Residential Heating)
1.35
1.25
1.15
1.05
0.95
0.85
0.75
2002
2005
2008
2011
2014
2017
2020
2023
2026
2029
Case 2a Med
Case 2b Med
Case 2a Low
Case 2b Low
Case 2b High
Case 2a High

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# Observations on NE-MARKAL

We gained a few critical insights on NE-MARKAL's behavior and responsiveness—

- Technology-specific hurdle rates have significant influence on key model results (fuel use, GHGs, cost)
- Threshold effects are observed for hurdle rates between 10% and 20% for this set of technologies
- Patterns of investment are less clear, but policy/price signals do seem to induce stronger diffusion of high-efficiency technologies
- Need to better understand what criteria should be used to more to develop robust hurdle rates (e.g., explore income effects)

# Policy Insights and Challenges

Our efforts to explore GHG policies that target the residential sector should consider the following:

- Climate policies that aim to shift consumer preferences (i.e., hurdle rates) could have great impact if effective, esp. given limited opportunities for fuel-switching in region

- Marketplace for residential heating technologies is highly bifurcated into:
  - many lower cost, medium-efficiency products, AND
  - a few very high cost, high-efficiency products

- High degree of uncertainty about future consumer preferences, especially in a high fuel price environment

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