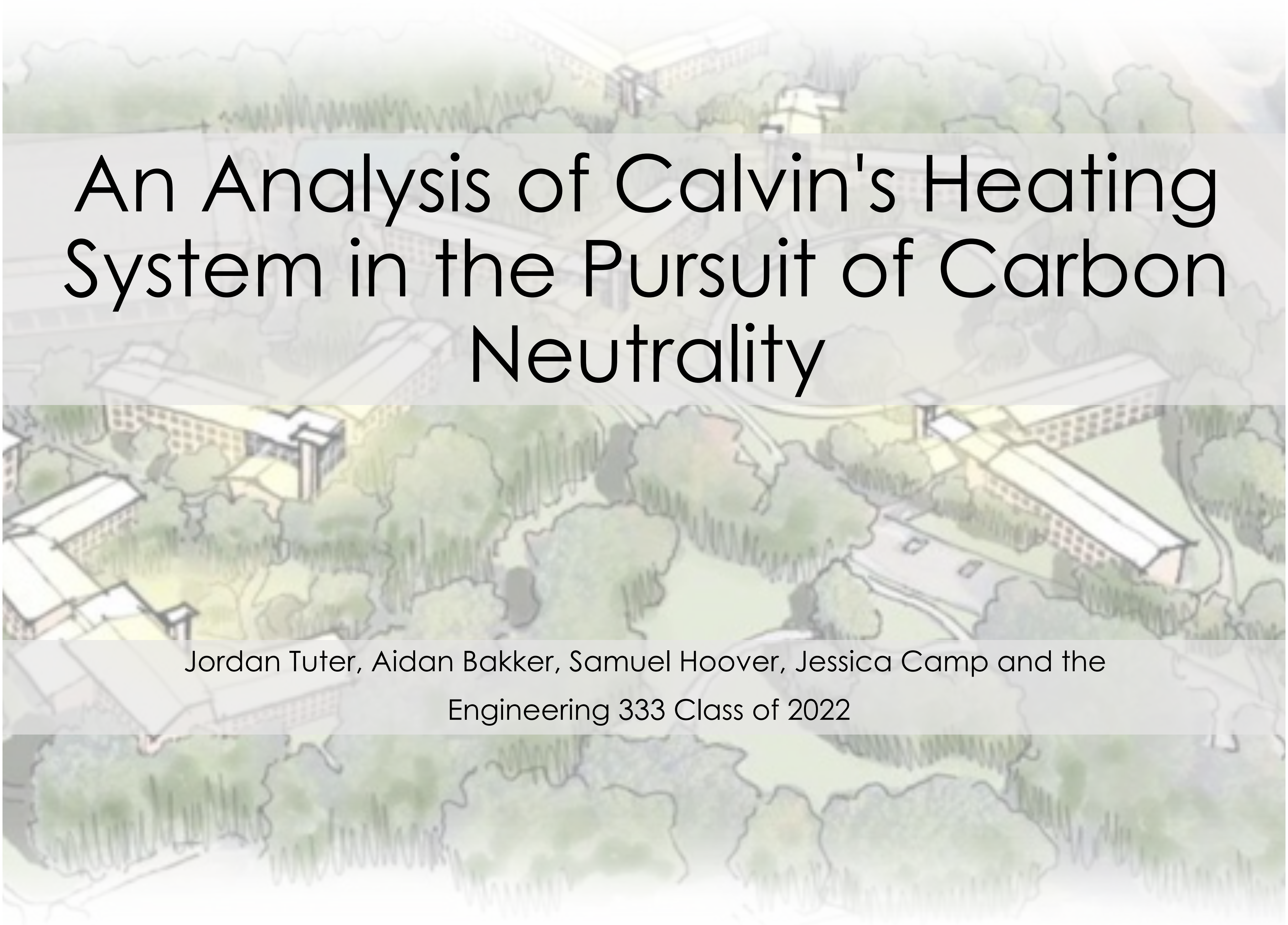

An Analysis of Calvin's Heating System in the Pursuit of Carbon Neutrality

Jordan Tuter, Aidan Bakker, Samuel Hoover, Jessica Camp and the

Engineering 333 Class of 2022

Carbon Neutrality

In 2017 President Michael K. Leroy signed sustainability commitment act...

Carbon Neutrality

President Leroy to President Boer

-Talk about sun funded/other steps

Who We Are

Section A

Section B

- Jess Camp & Sam Hoover: Section A
- Jordan Tuter & Aidan Bakker: Section B

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Our Research Question:

What would it take to eliminate Calvin's natural gas-related net CO_2 emissions from Heating?

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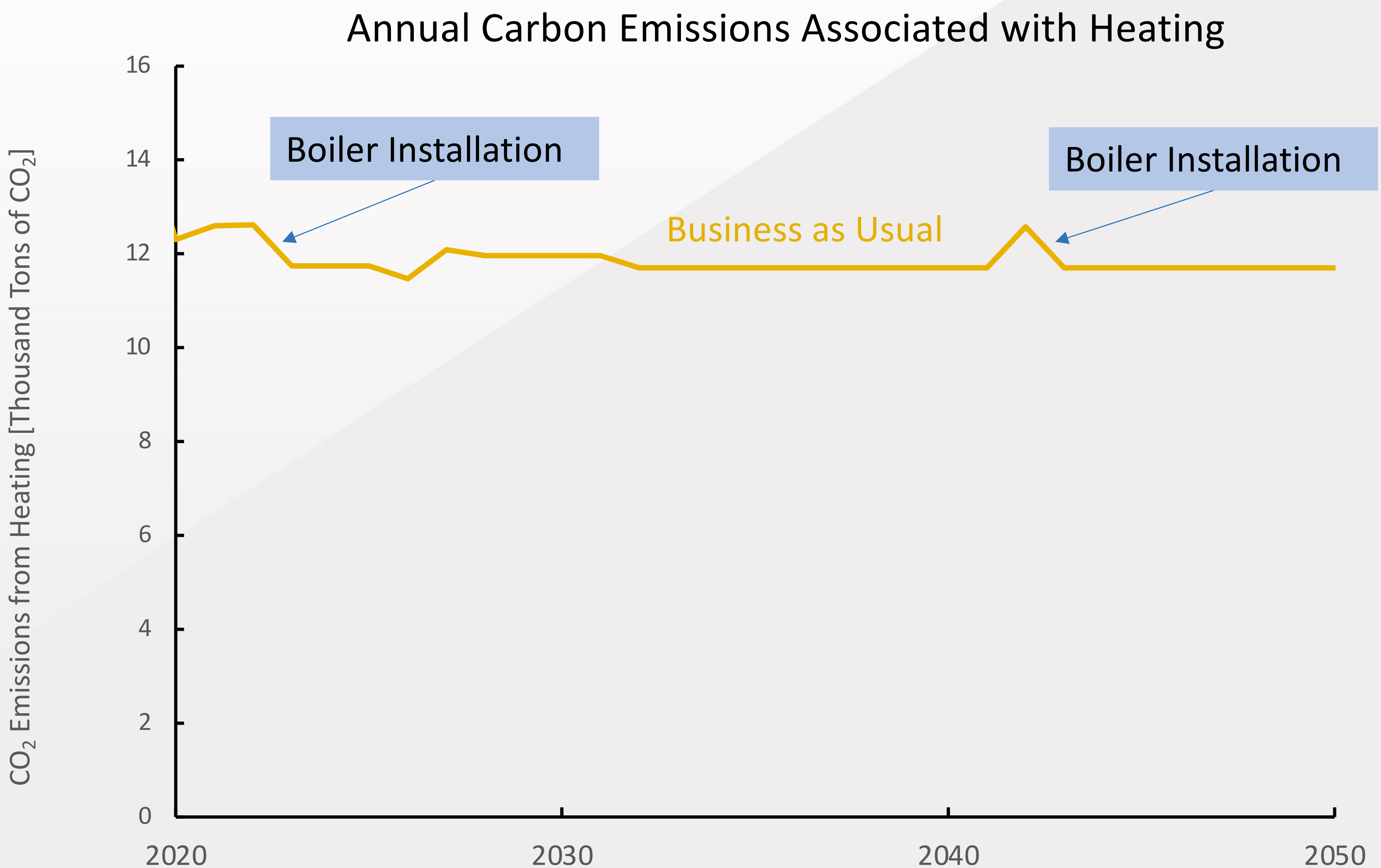
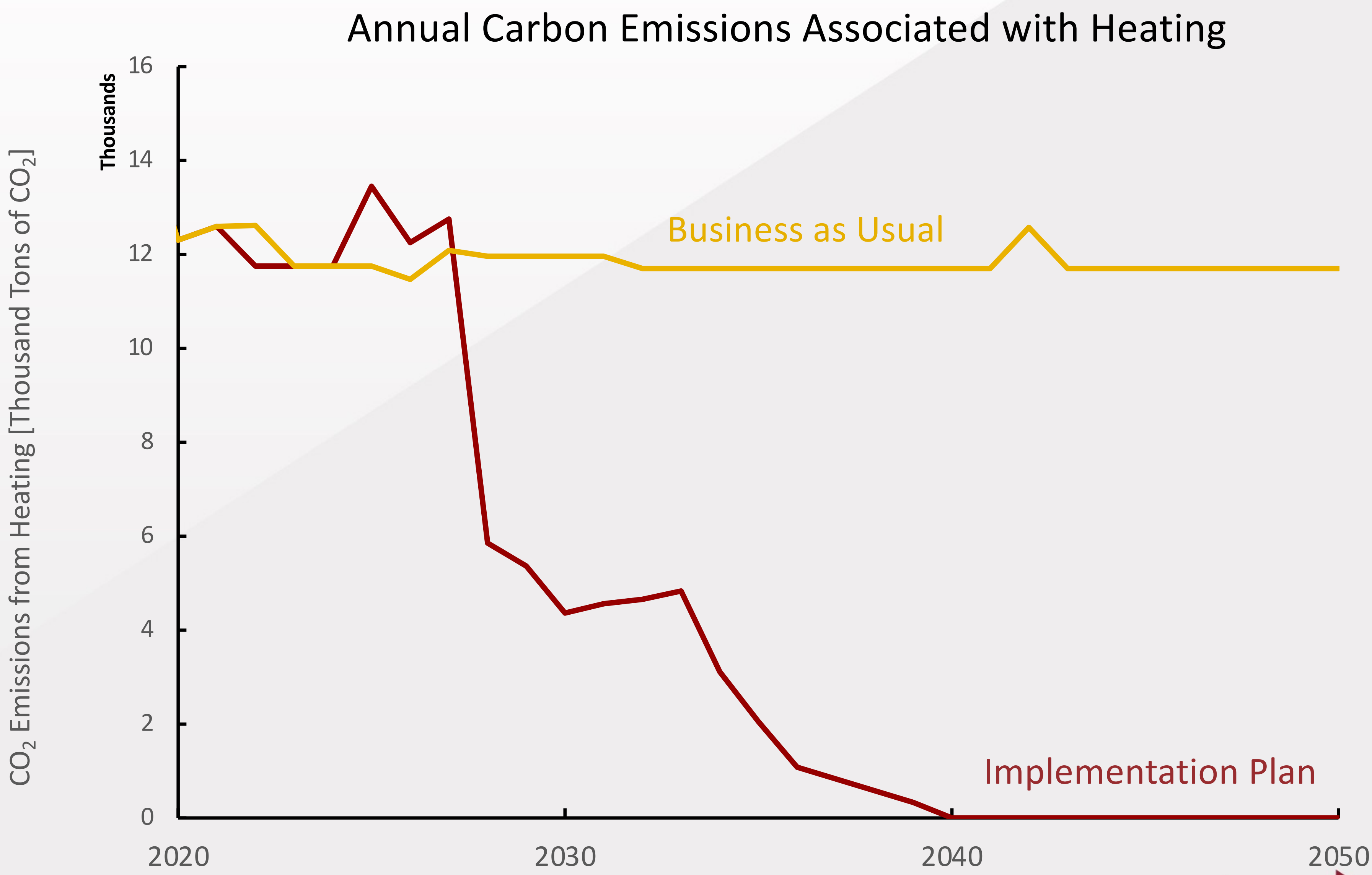
Key Concept: Hero Graphs

Hero Graph



*graph does not account for embodied carbon from new construction or destruction projects in either data set

Hero Graph



*graph does not account for embodied carbon from new construction or destruction projects in either data set

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Existing Systems

Key

RED – Main Heating Loop

BLUE – Upper Heating Loop

Existing Systems

- Who has their windows open during the day because the dorm is too hot?
- YOU ARE THE PROBLEM
- Not really, but this is a problem

Boiler Efficiency Timeline	
Age (years)	Energy Efficiency %
25+	60-70
20	75
15	80-85
<10	80-85

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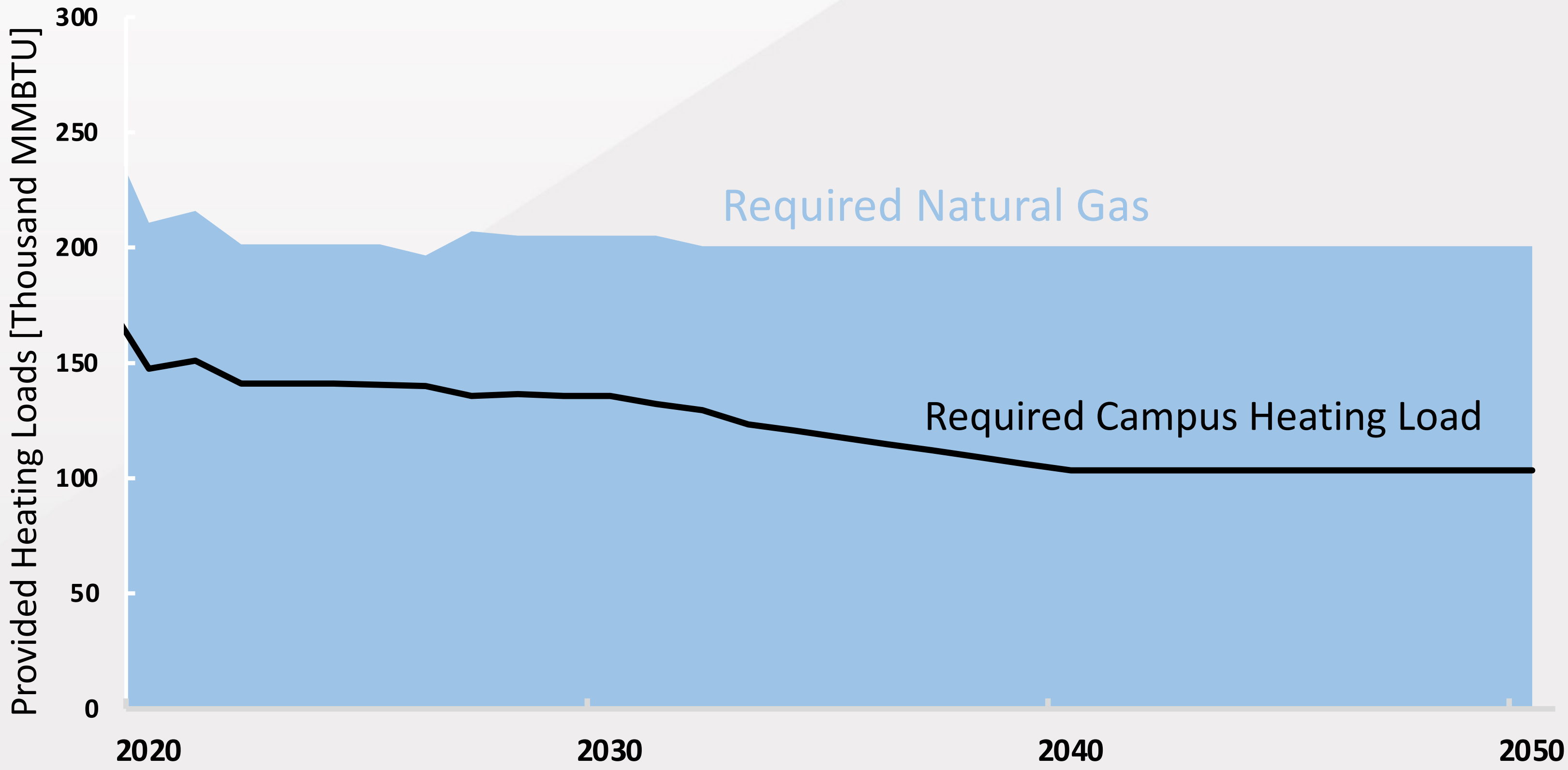
Existing Systems



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Strategy

- Reduce heating load with efficiency improvements
- Shift heating systems from natural gas to electricity
  - Reduces CO_2 emissions drastically by itself
- Implementing Carbon Free Electricity

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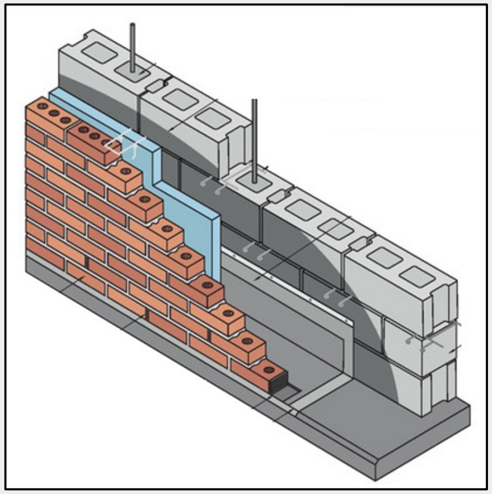
Heating Loads - Overview

Material	R/ Inch	R/ Thick-ness
Insulation Materials		
Fiberglass Batt	3.14	
Fiberglass Blown (attic)	2.20	
Fiberglass Blown (wall)	3.20	
Rock Wool Batt	3.14	
Rock Wool Blown (attic)	3.10	
Rock Wool Blown (wall)	3.03	
Cellulose Blown (attic)	3.13	
Cellulose Blown (wall)	3.70	
Vermiculite	2.13	
Air-entrained Concrete	3.90	
Urea terpolymer foam	4.48	
Rigid fiberglass (> 4 lb/ft^3)	4.00	
Expanded Polystyrene (bead-board)	4.00	
Extruded Polystyrene	5.00	
Polyurethane (foamed-in-place)	6.25	
Polyisocyanurate (foil-faced)	7.20	
Construction Materials		
Concrete Block 4 inch		0.80
Concrete Block 8 inch		1.11
Concrete Block 12 inch		1.28
Brick 4 inch common		0.80
Brick 4 inch face		0.44

- Thermal Resistance Networks
  - Main Loop
  - Upper Loop
  - Residence Areas
  - Miscellaneous Buildings
- Assumptions and Data Collection



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New Building Heating Loads

Stadiums (2025): 6000 [MMBtu]
Commons Union (2027): 0 [MMBtu]
New Apartment Building (2031): 1000 [MMBtu]

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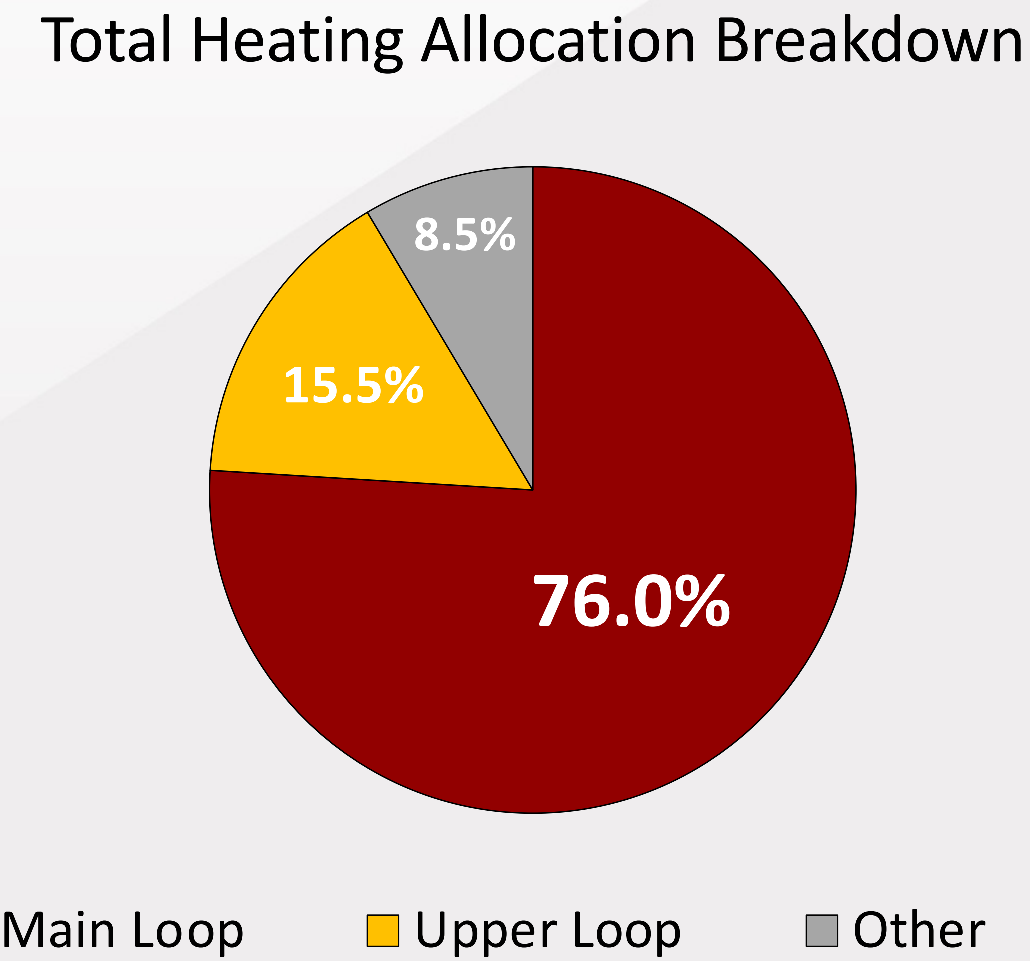
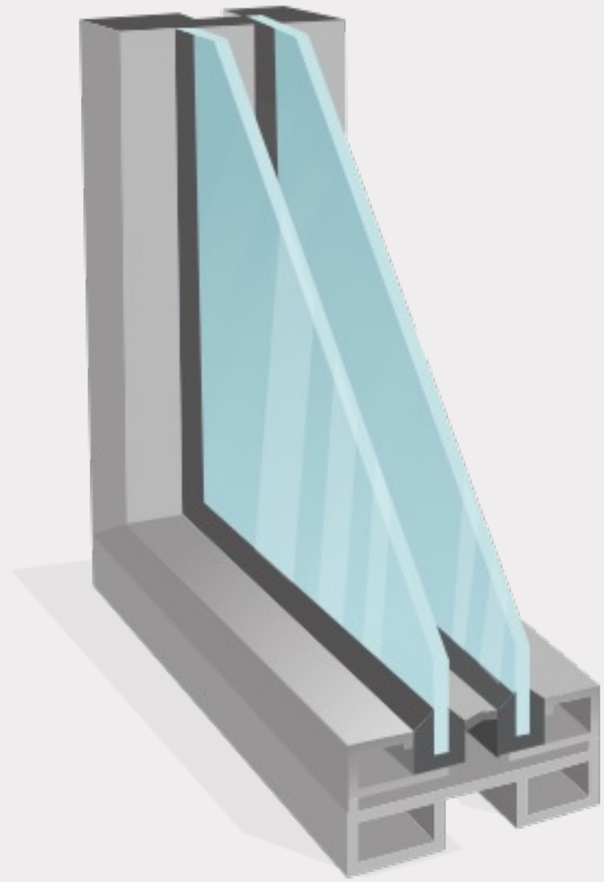
Heating Loads - Application



Efficiencies – Dorm Windows

- Double Pane Windows
- 2.7% Heating Load Reduction



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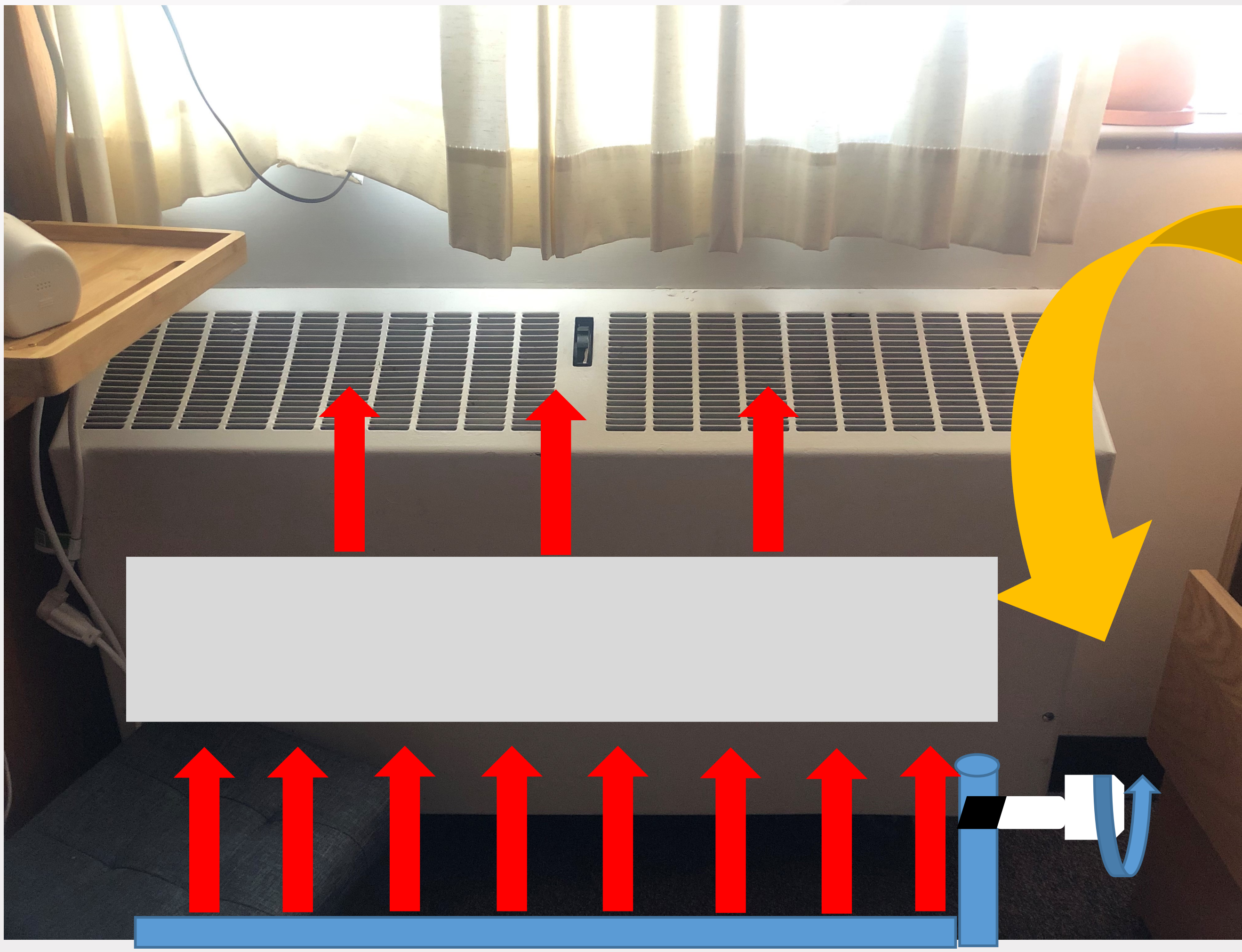
Thermostatic Valves

- 1% Heating Load Reduction



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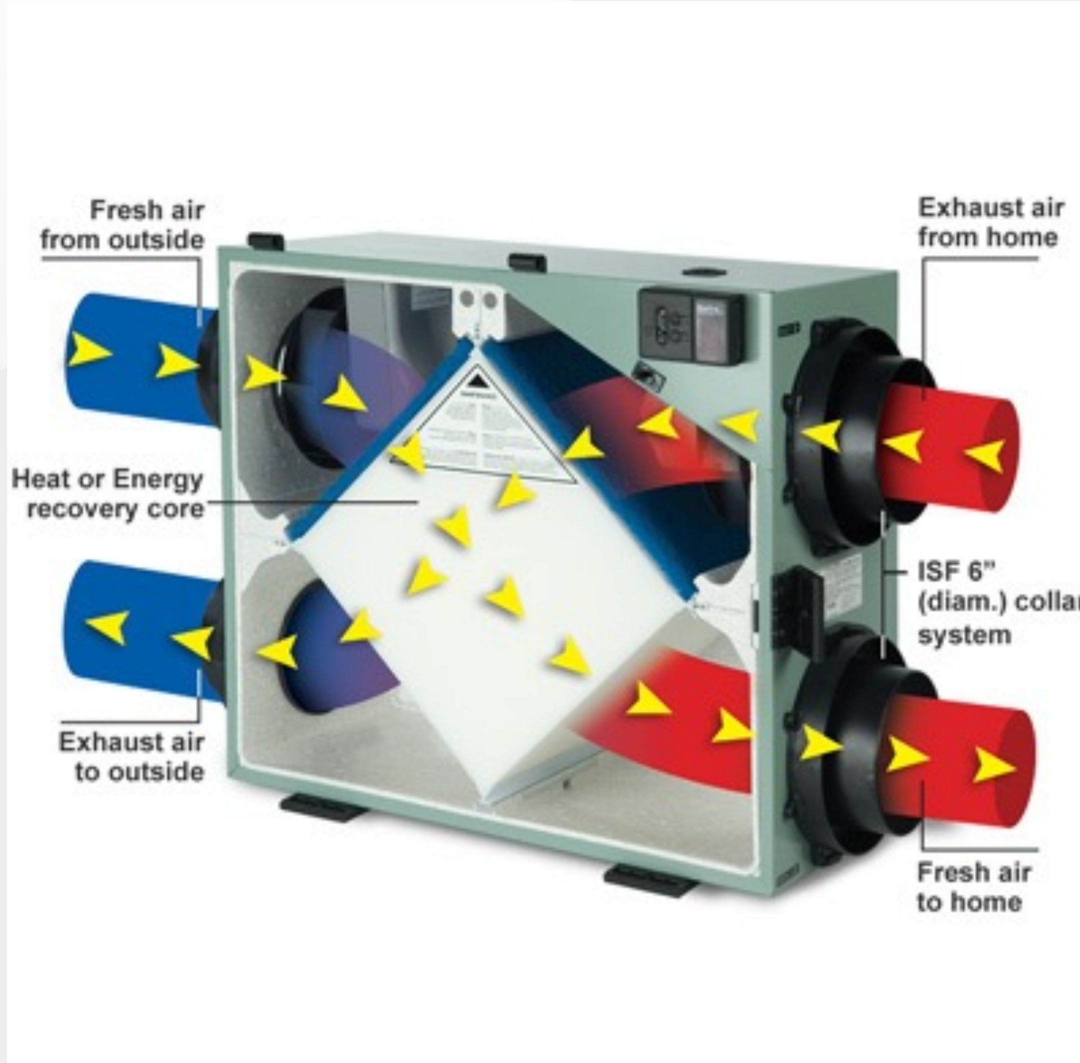
Energy Recovery Systems

20% Heating
Load Reduction



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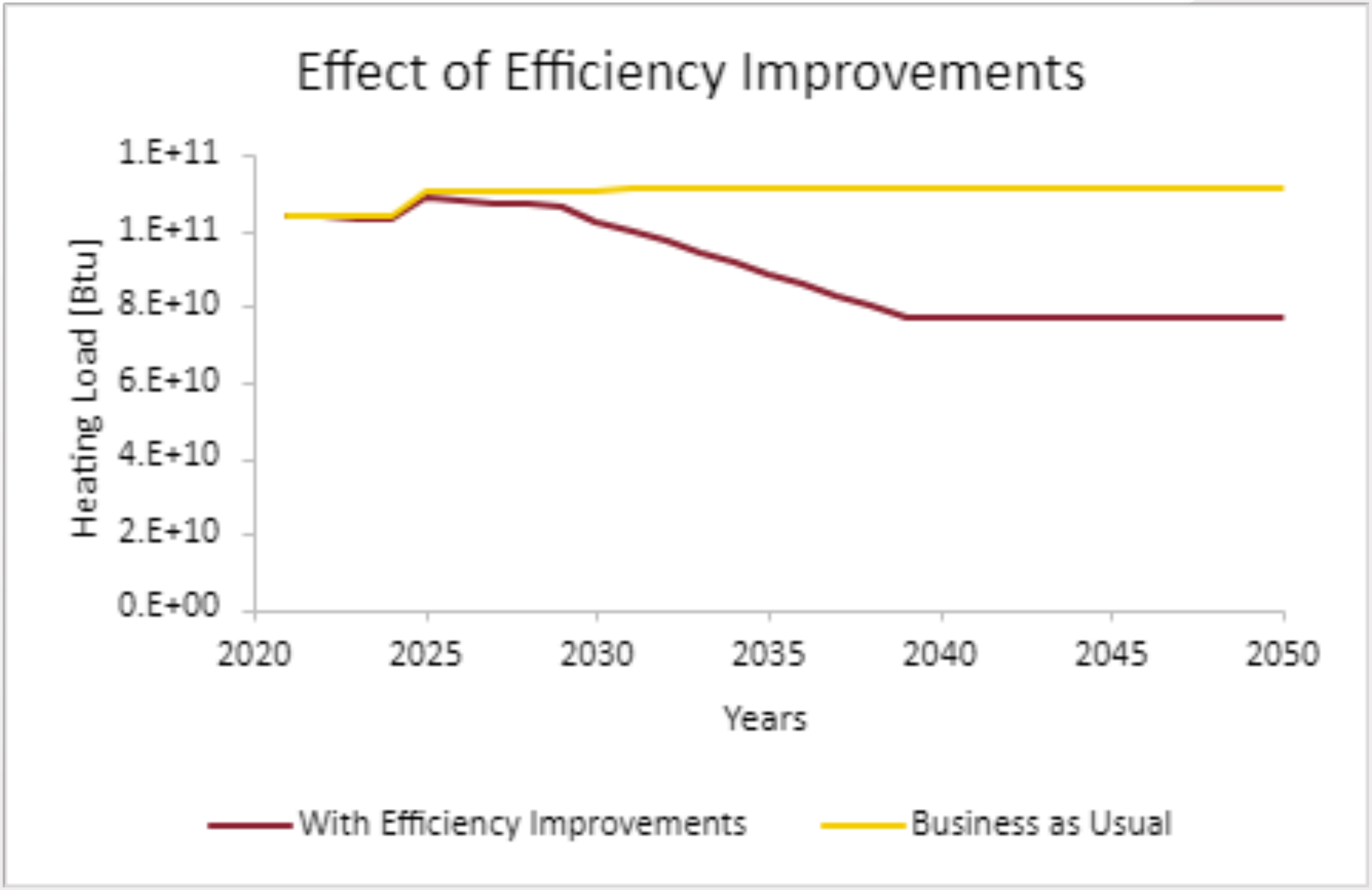

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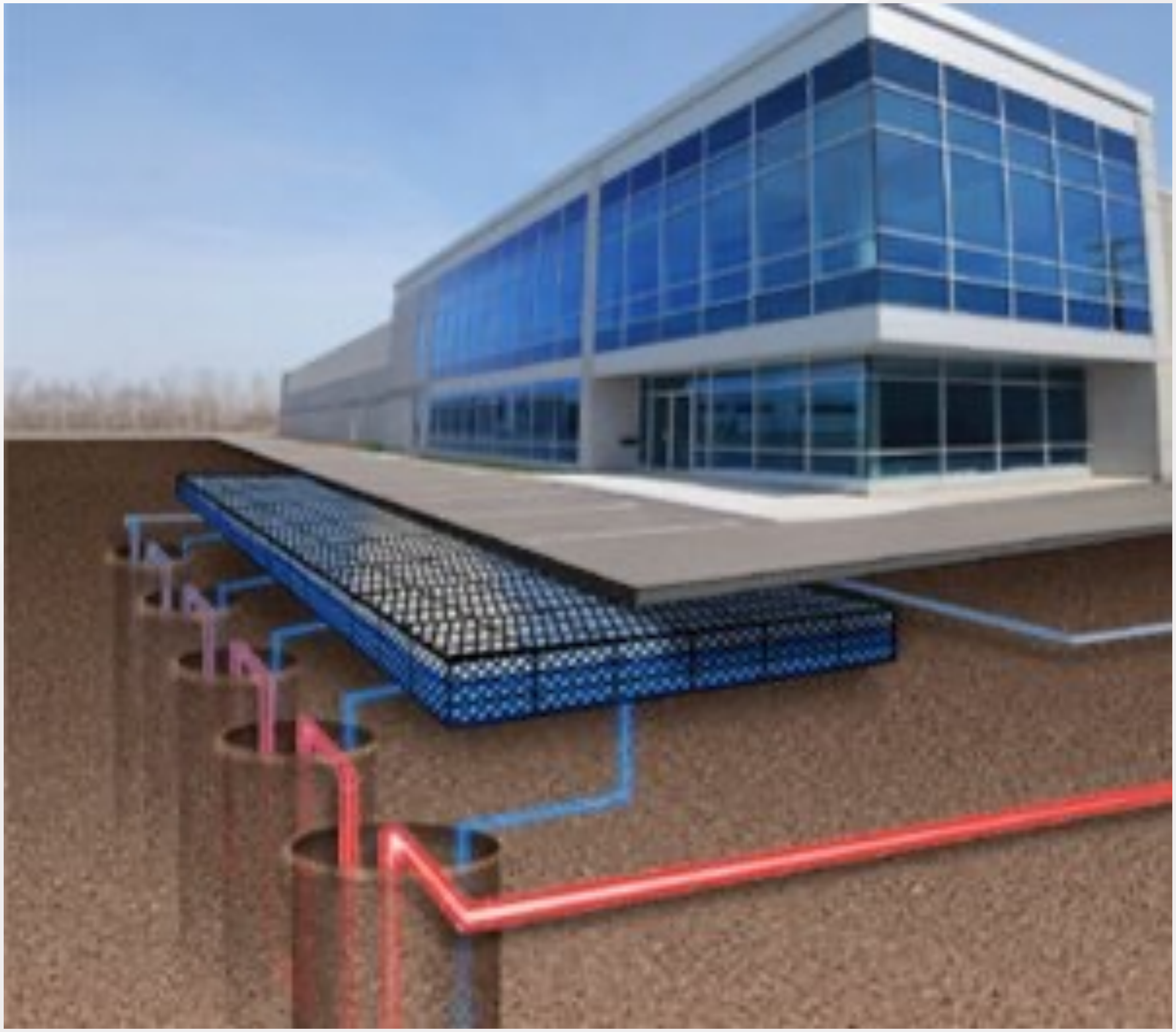
Main Heating Loop

Ground Source Heat Pumps



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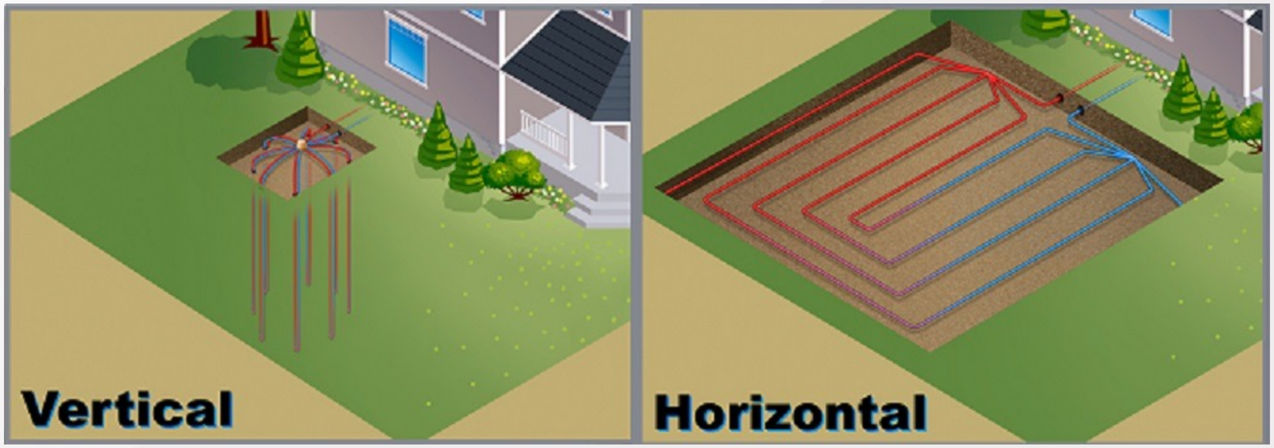
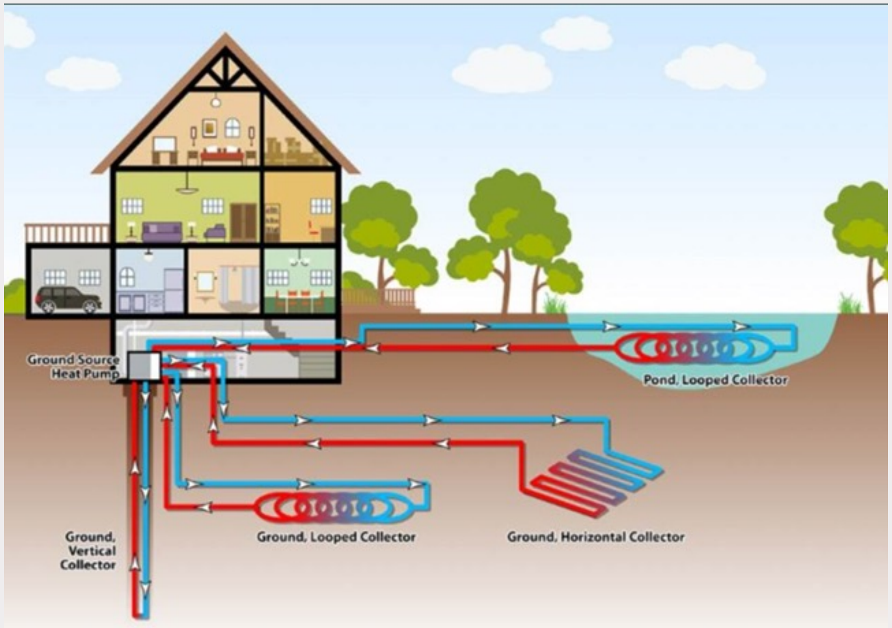
What are Bore Holes and why do we need them?





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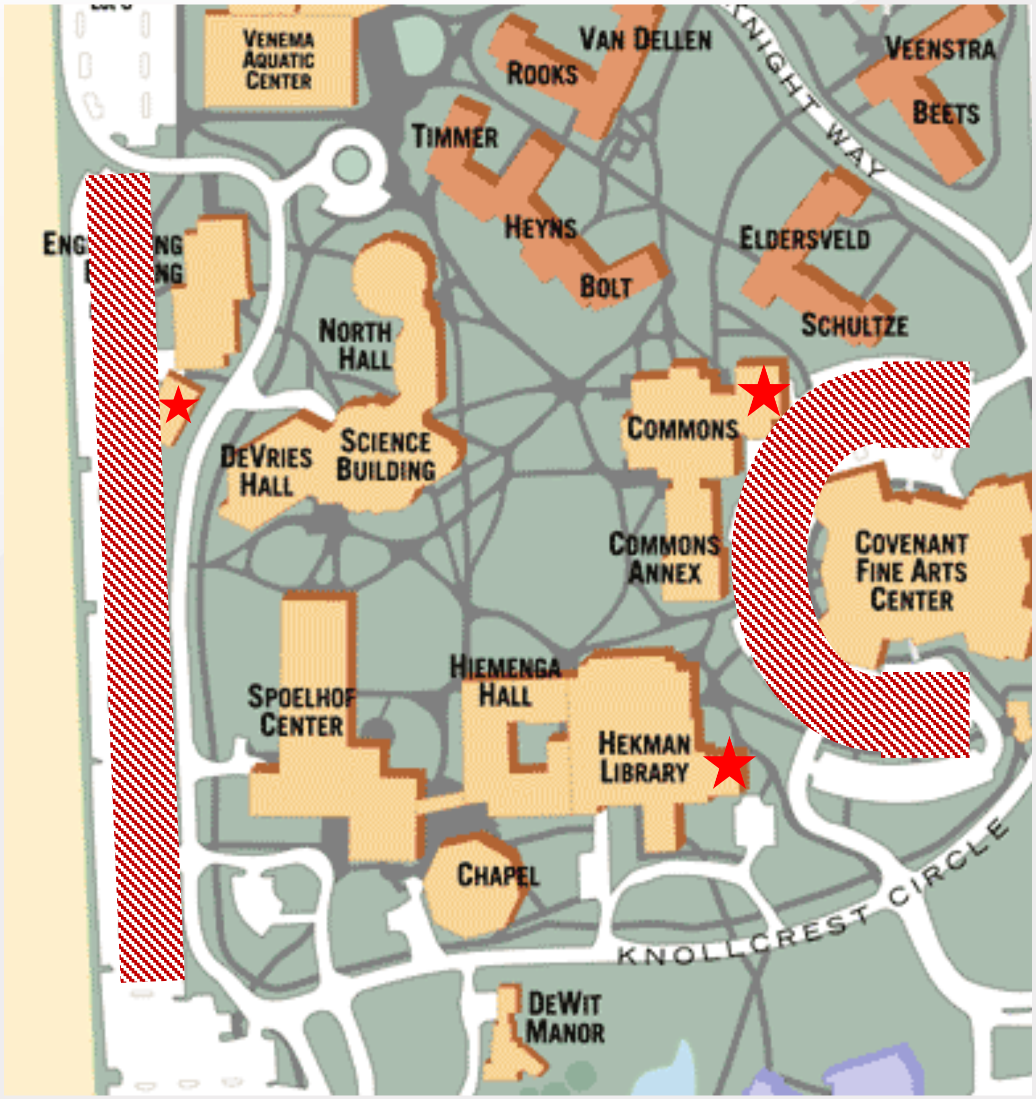
Main Loop Bore Field



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Solution #1

Key

RED – Main Heating Loop
BLUE – Upper Heating Loop
PURPLE – Facilities
ORANGE – KE Apartments
BLACK – Off Campus Housing

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Other Bore Field Locations

Upper Heating Loop: Lot 8

Facilities and Campus Safety: Lot 8

KE Apartments: Lot 17

Off Campus Housing: Backyards/Front Yards

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Solution #2

Upper Heating Loop: Console Heat Pumps

Everything Else: Air Source Heat Pumps

- Facilities and Campus Safety
- KE Apartments
- Off Campus Housing

Console Heat Pumps

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Upper Heating Loop

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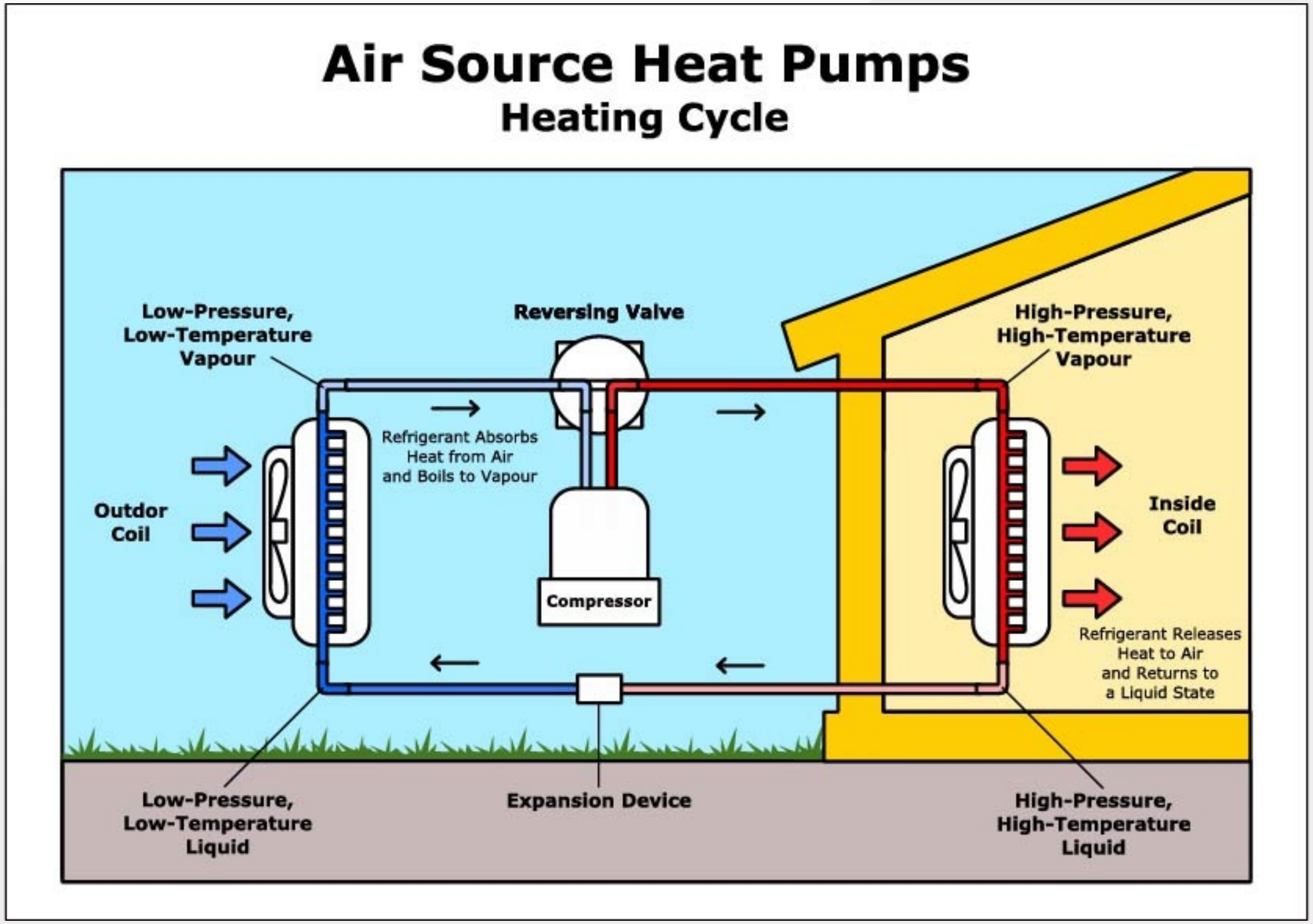
Air Source Heat Pump



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Add ducts to buildings as needed

Another Consideration - Renewable Natural Gas

Animal Type	MMBtu/Animal/Year	# Animals Needed for Calvin Need
Dairy Cow	48.55	2,904
Beef Cow	40.59	3,474
Swine	15.68	8,991
Poultry	2.25	62,761

Energy Crop	MMBtu/ton, dry	Tons of Crop Needed
Willow	17.1	8,246
Poplar	15.55	9,068
Switchgrass	15.86	8,890
Miscanthus	15.8	8,924
Biomass sorghum	14.48	9,738
Pine	12.42	11,353
Eucalyptus	12.37	11,399
Energy Cane	15.8	8,924
Forest Residue	17.19	8,202
Forest Thinnings	18.05	7,812
Primary/Secondary residue	17.19	8,202
Mixed Wood	13	10,846

Landfill	MMBtu/day	Tons of Landfill Needed
	386	1,788,432

Waste Water	MMBtu/day	Million Gallons/day
	2.4	58,750

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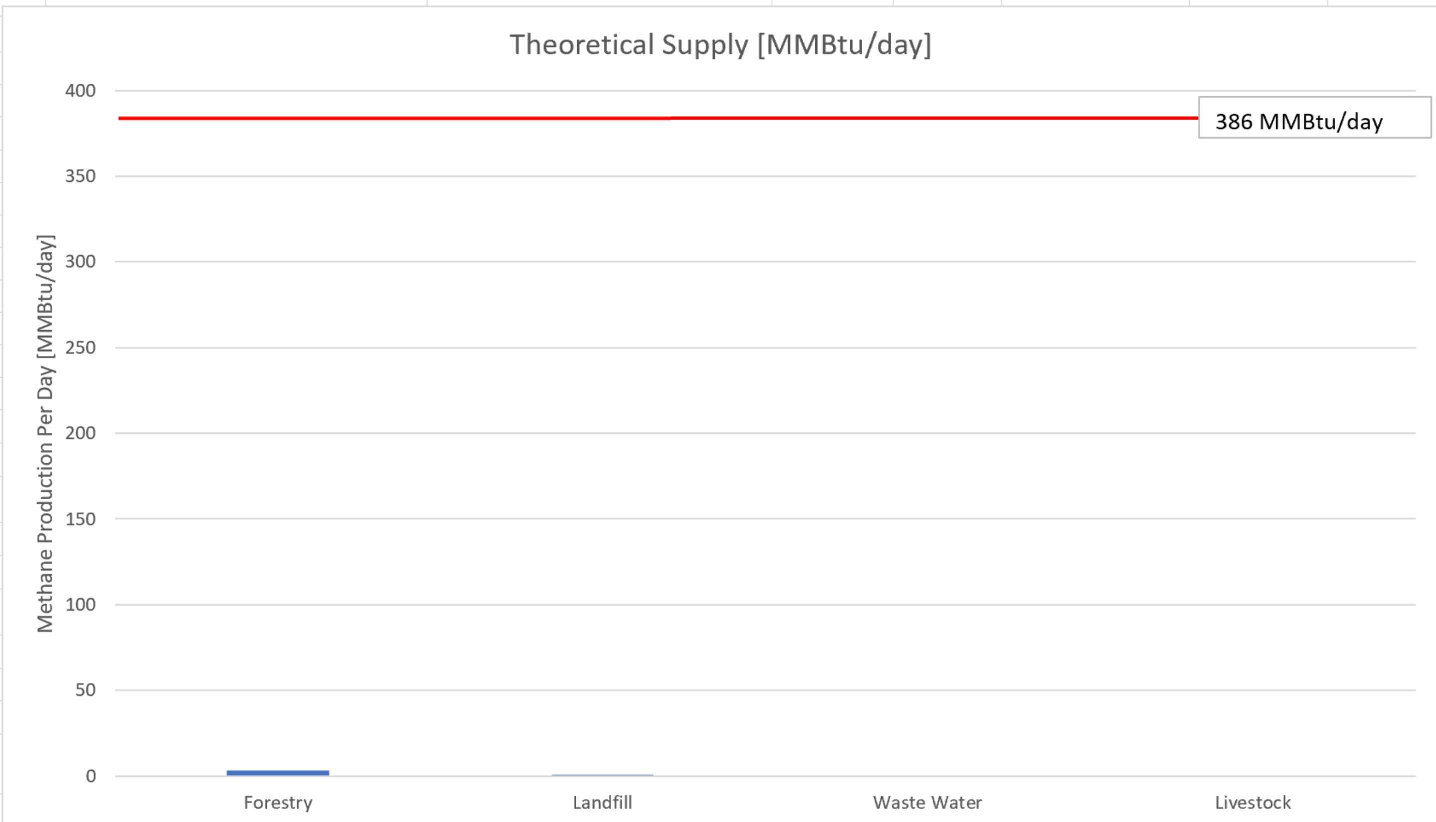
Renewable Natural Gas

Source	Forestry	Landfill	Waste Water	Livestock
Theoretical Supply [MMBtu/day]	3.158	0.590	0.045	0
Still Needed [MMBtu/day]	382.842	385.410	385.955	386.000



1%

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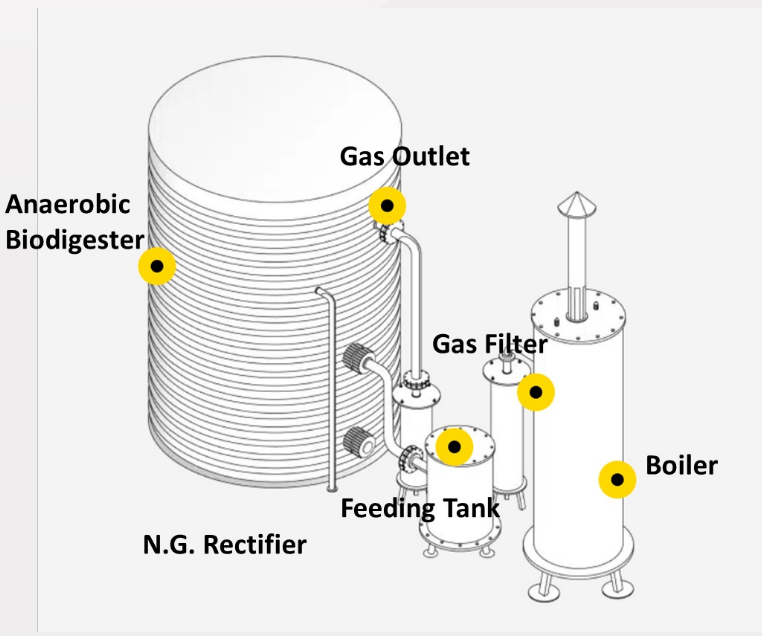
HOMEBIOGAS Commercial System

- Anaerobic Process
- Small size (2 cars Approx.)
- Food Capacity: [2200 lb./day]
- Biogas production: 96 [m^3/day]

The HomeBiogas Commercial system is compact waste to energy solution



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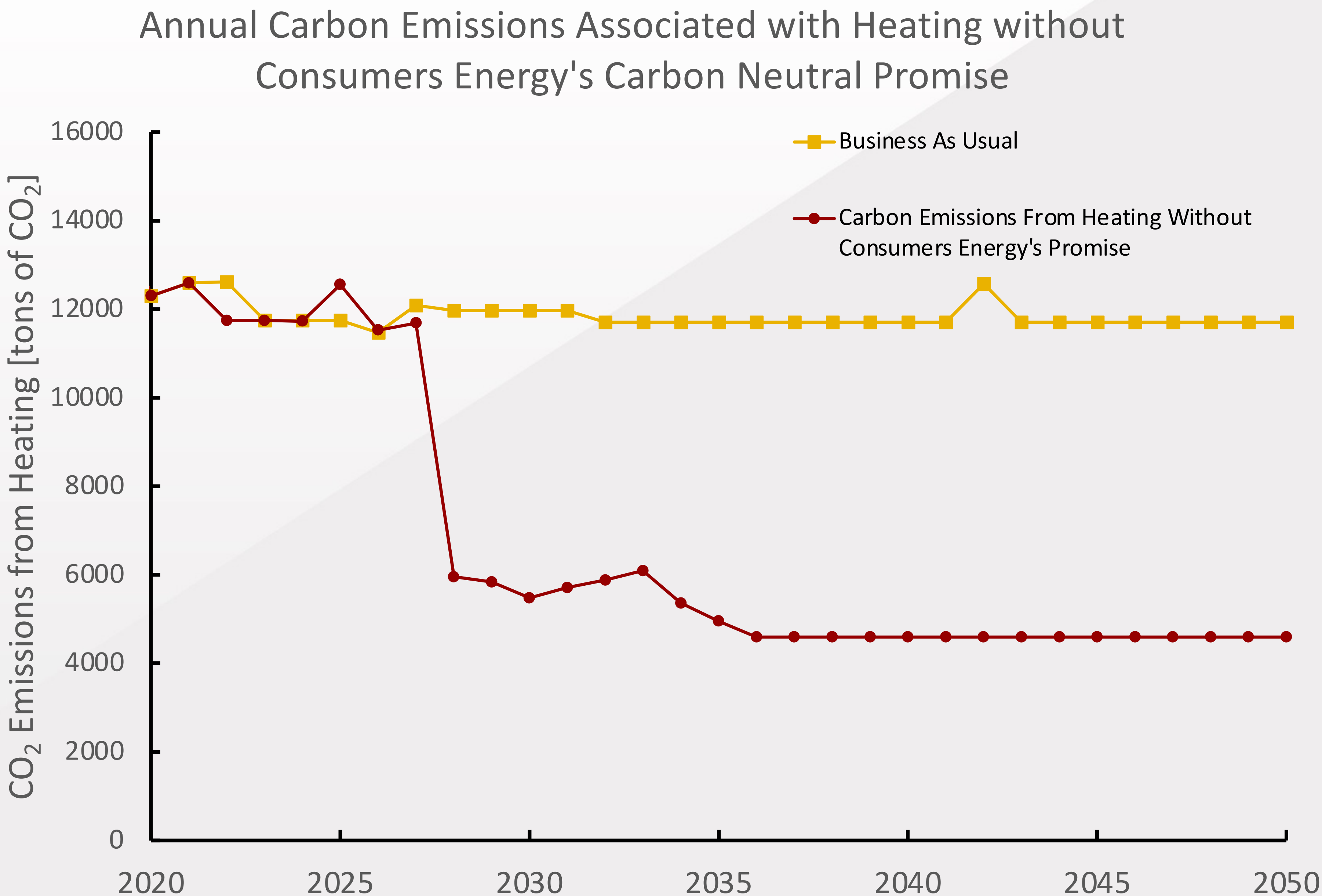

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Bring Carbon Down to Zero

SunFundED™

Consumers Energy
Count on Us®

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Sun FundED

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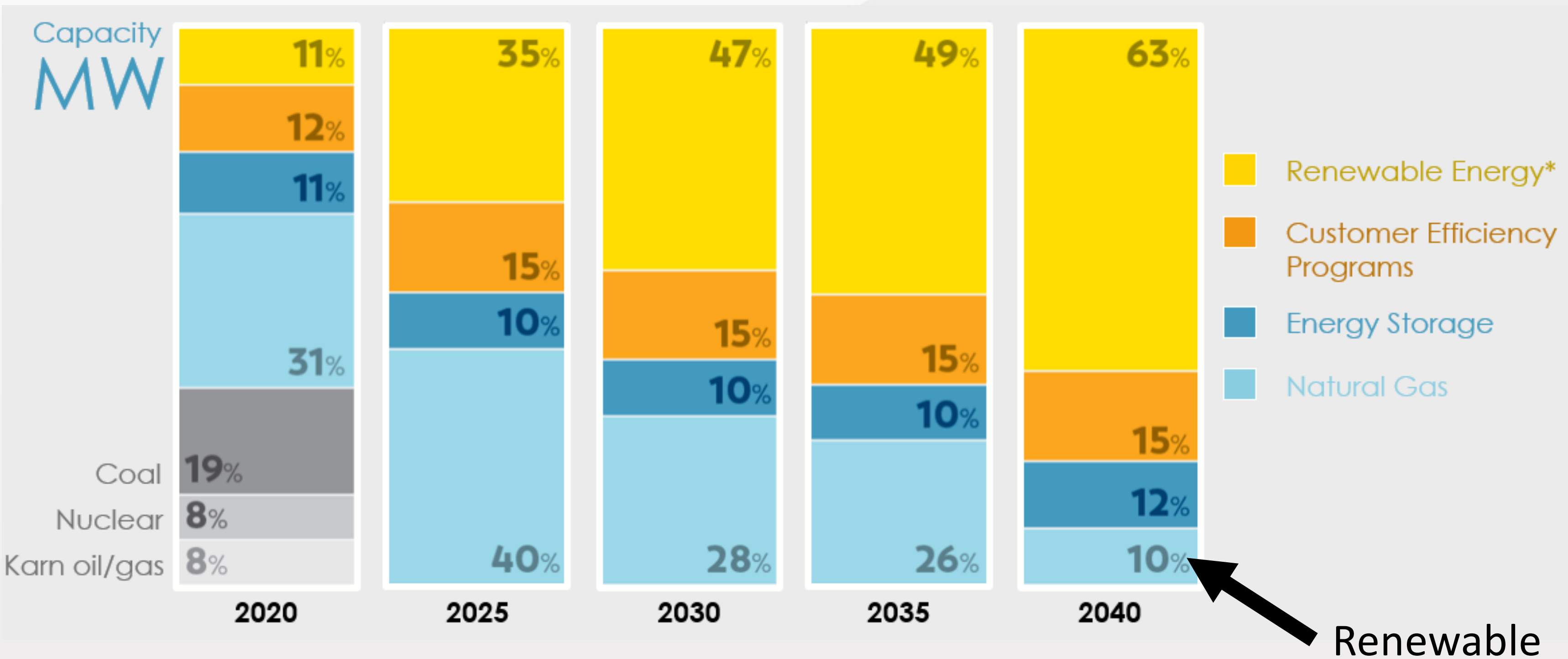
Consumer Energy



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Immediate Action!

Valves

Bore Hole Data

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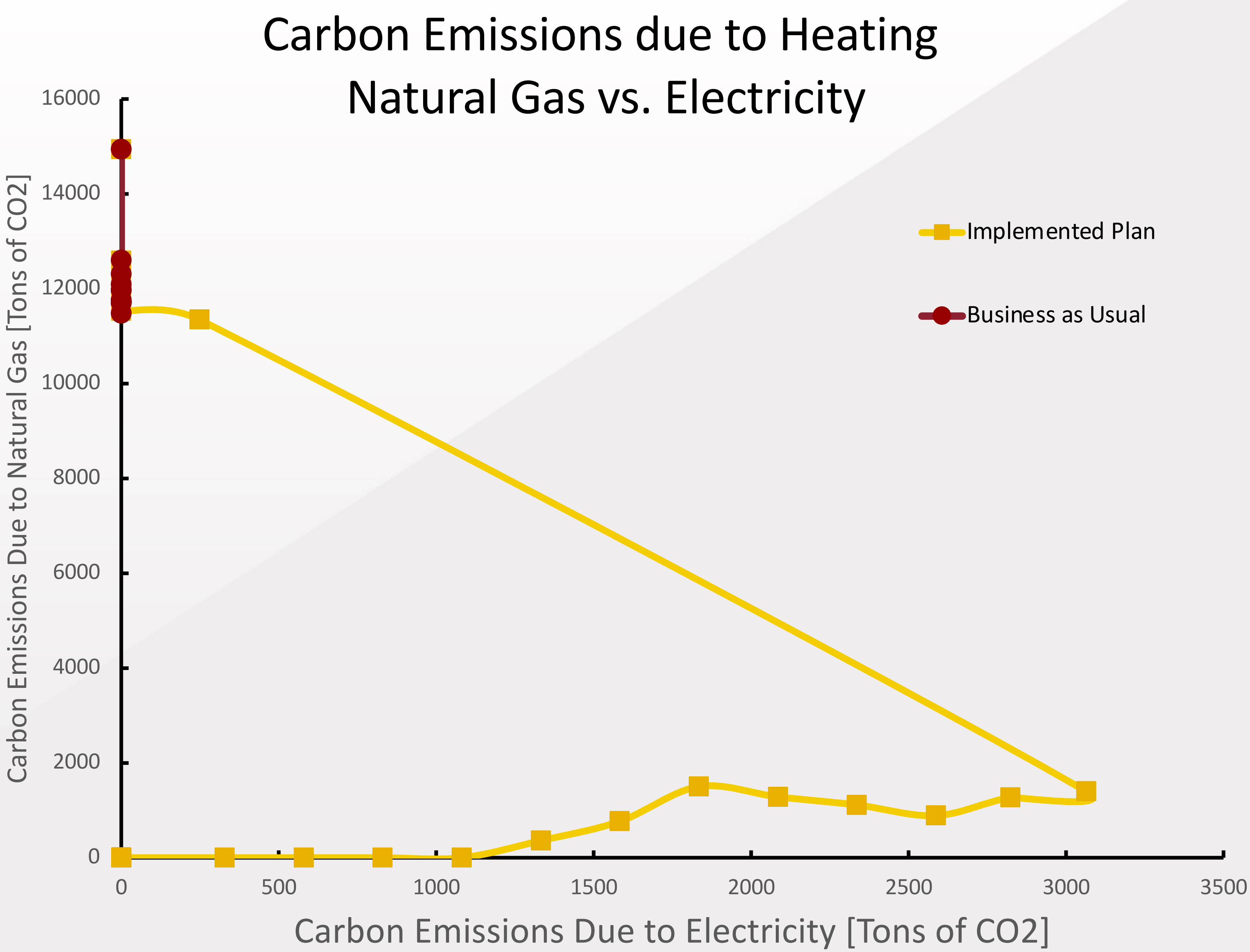
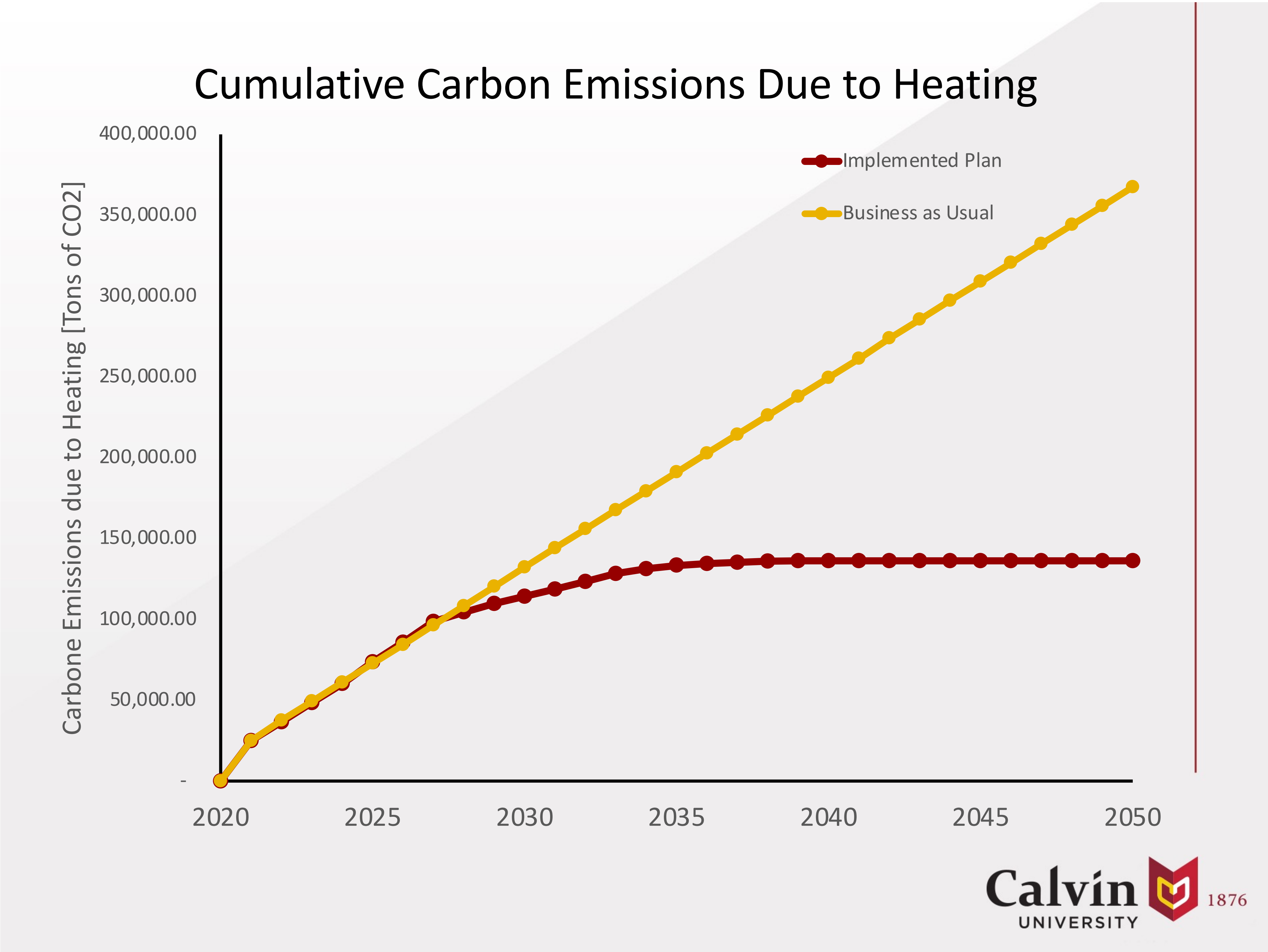

Carbon Emissions due to Heating
Natural Gas vs. Electricity
Carbon Emissions Due to Natural Gas [Tons of CO2]
16000
14000
12000
10000
8000
6000
4000
2000
0
0
500
1000
1500
2000
2500
3000
3500
Carbon Emissions Due to Electricity [Tons of CO2]
Implemented Plan
Business as Usual


Cumulative Carbon Emissions Due to Heating
Carbone Emissions due to Heating [Tons of CO2]
400,000.00
350,000.00
300,000.00
250,000.00
200,000.00
150,000.00
100,000.00
50,000.00
-
2020
2025
2030
2035
2040
2045
2050
Implemented Plan
Business as Usual
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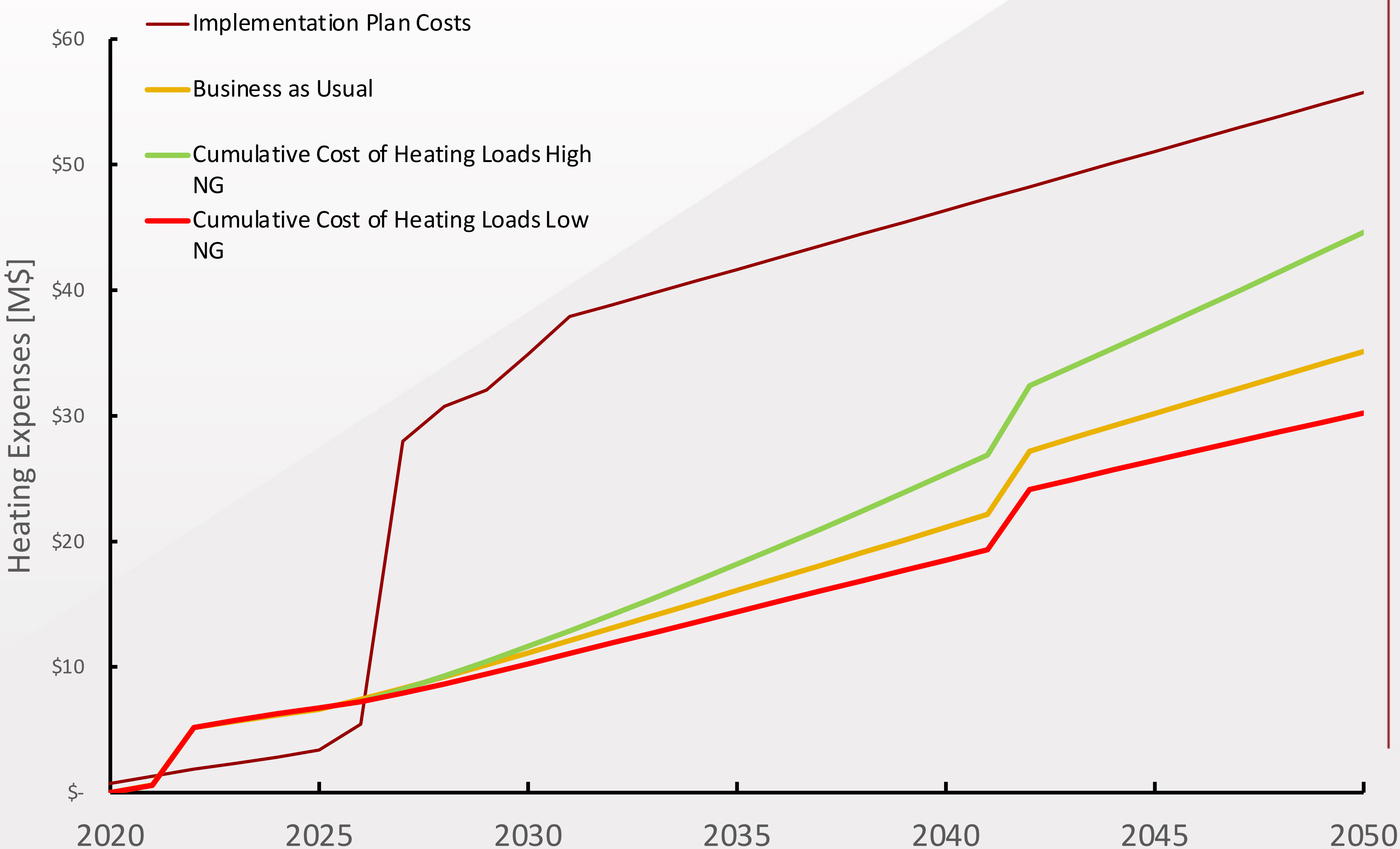
Cumulative Heating Expenses Since 2020



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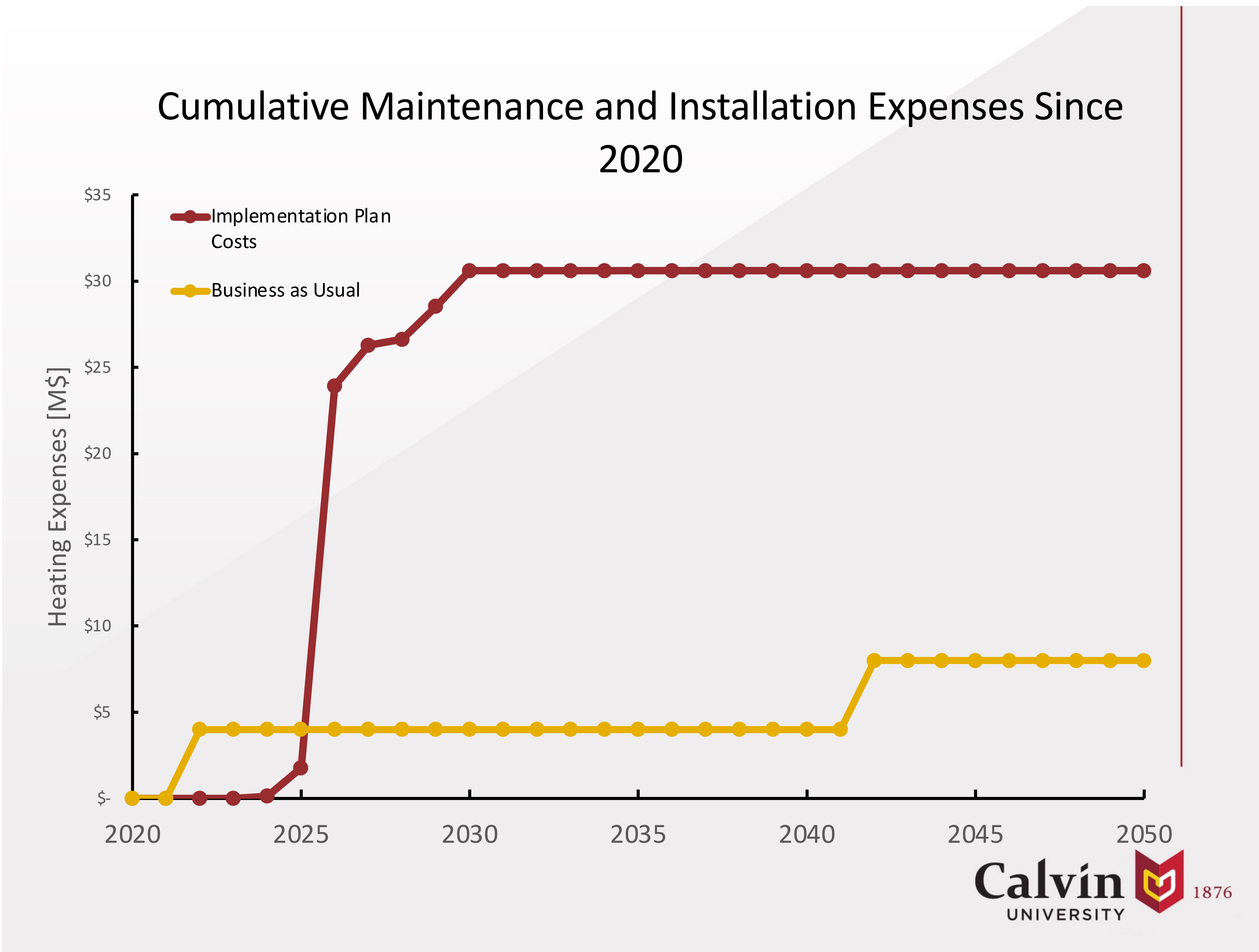

Cumulative Maintenance and Installation Expenses Since 2020
Heating Expenses [M$]
$35
$30
$25
$20
$15
$10
$5
$-
2020
2025
2030
2035
2040
2045
2050
Implementation Plan Costs
Business as Usual
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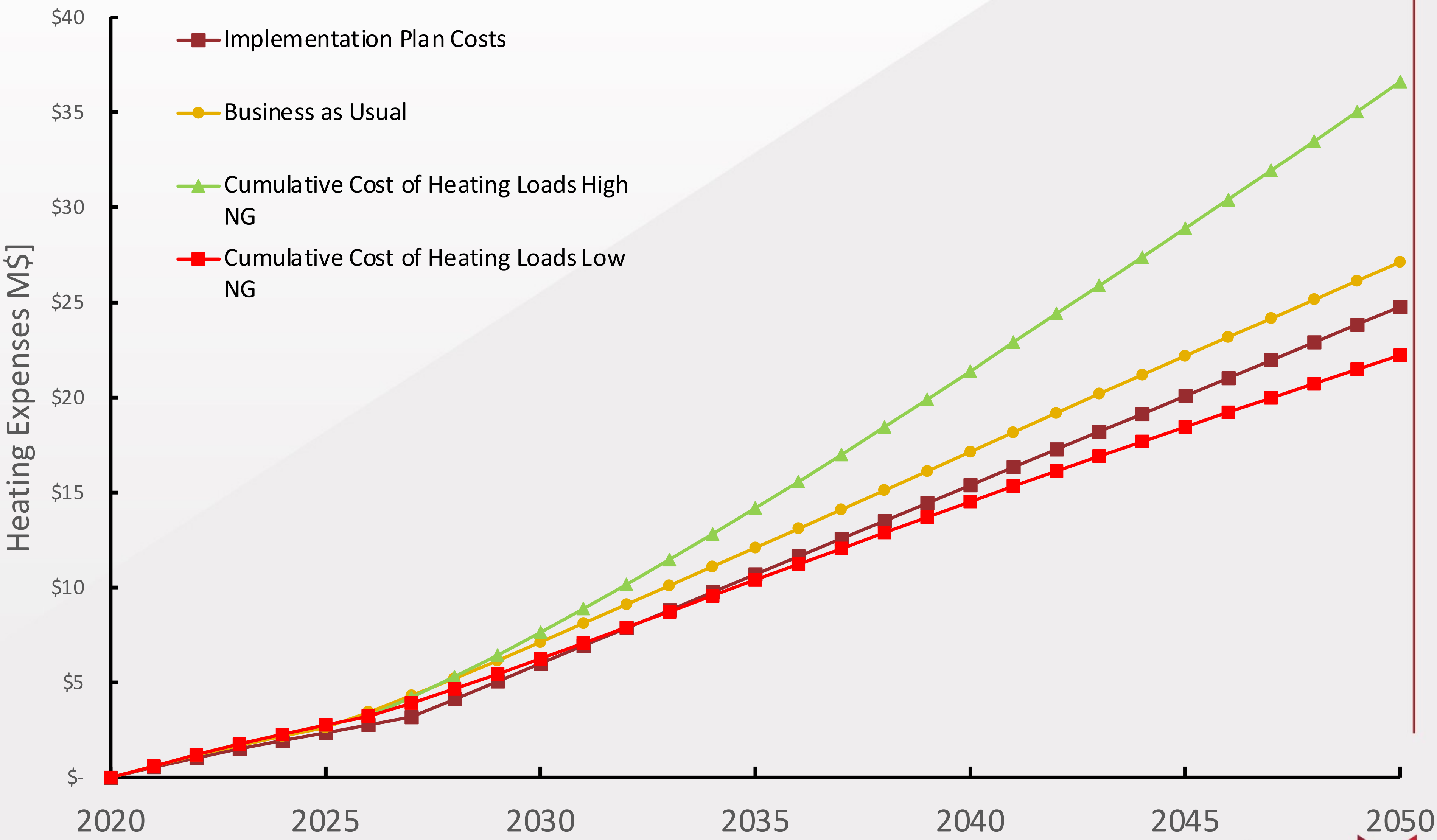
Cumulative Operating Expenses Since 2020



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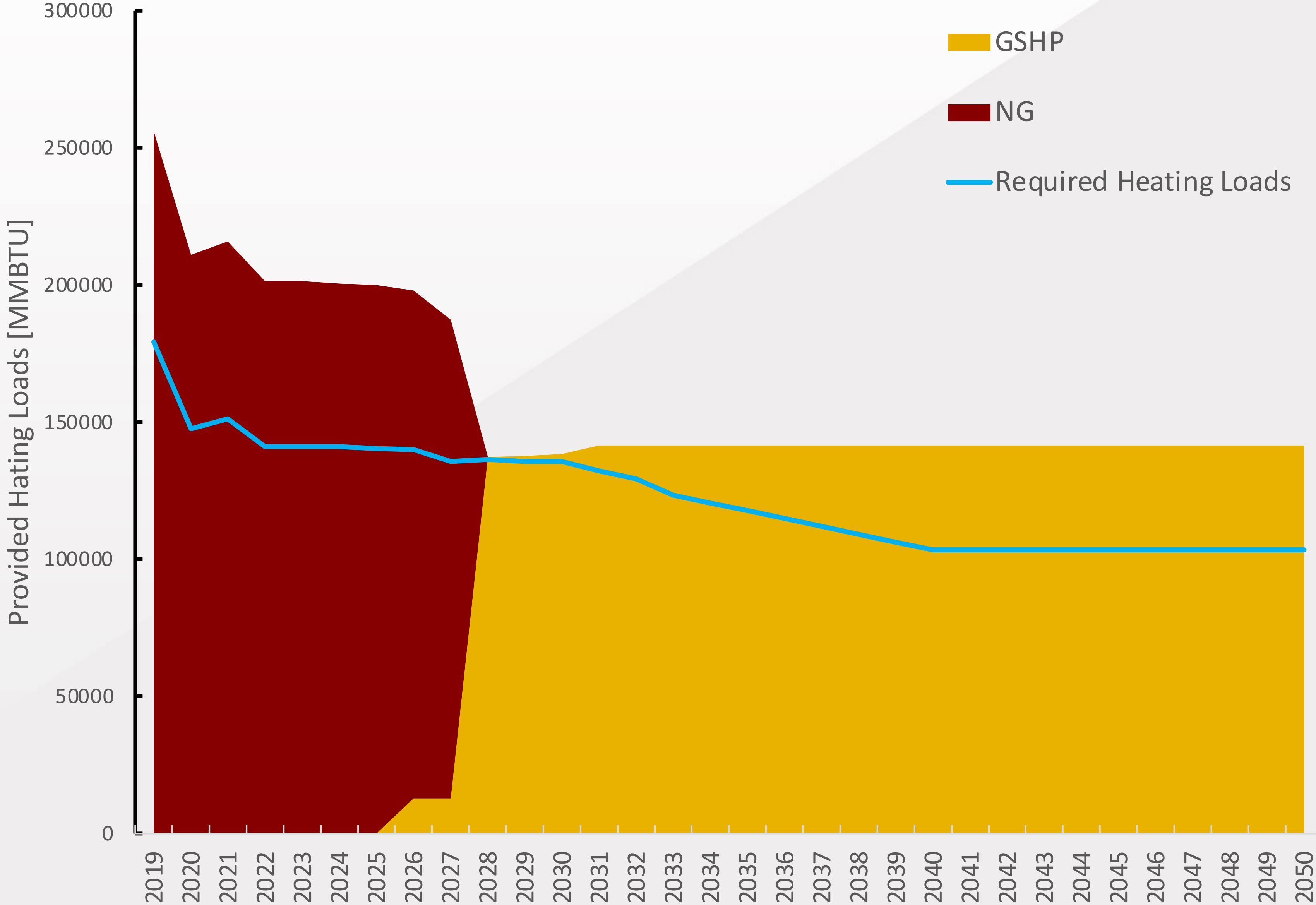
Sources Provided to Overall Required Heating Loads



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Full Circle, What Would it Take?

- Carbon Neutral by 2040
- Total Capital Investment:

  $31.33 Million
- Estimated Annual Cost

  Crossover: 2067

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Acknowledgements

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Acknowledgements

- Professor Heun
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