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Decarbonization in the Built Environment

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

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Agenda

1. Objectives
2. Greenhouse Gas Inventory Basics
3. Building GHG Emissions
4. Building Electrification to Reduce GHG

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Learning Objectives

1. Gain insight how carbon emissions are accounted for in the built environment.
2. Comprehend what contributes to operational carbon emissions in buildings.
3. Explain how electrification of buildings reduces operational carbon.
4. Familiarize heat pump current technologies available for building electrification.

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Course Description

In this course, we will review how Buildings impact climate change, providing an understanding of operational and embodies carbon. In this one-hour overview, we will explore the contributions buildings have, explore technical solutions to minimize carbon impact and talk through different approaches for new and existing buildings.

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GREENHOUSE GAS INVENTORY BASICS

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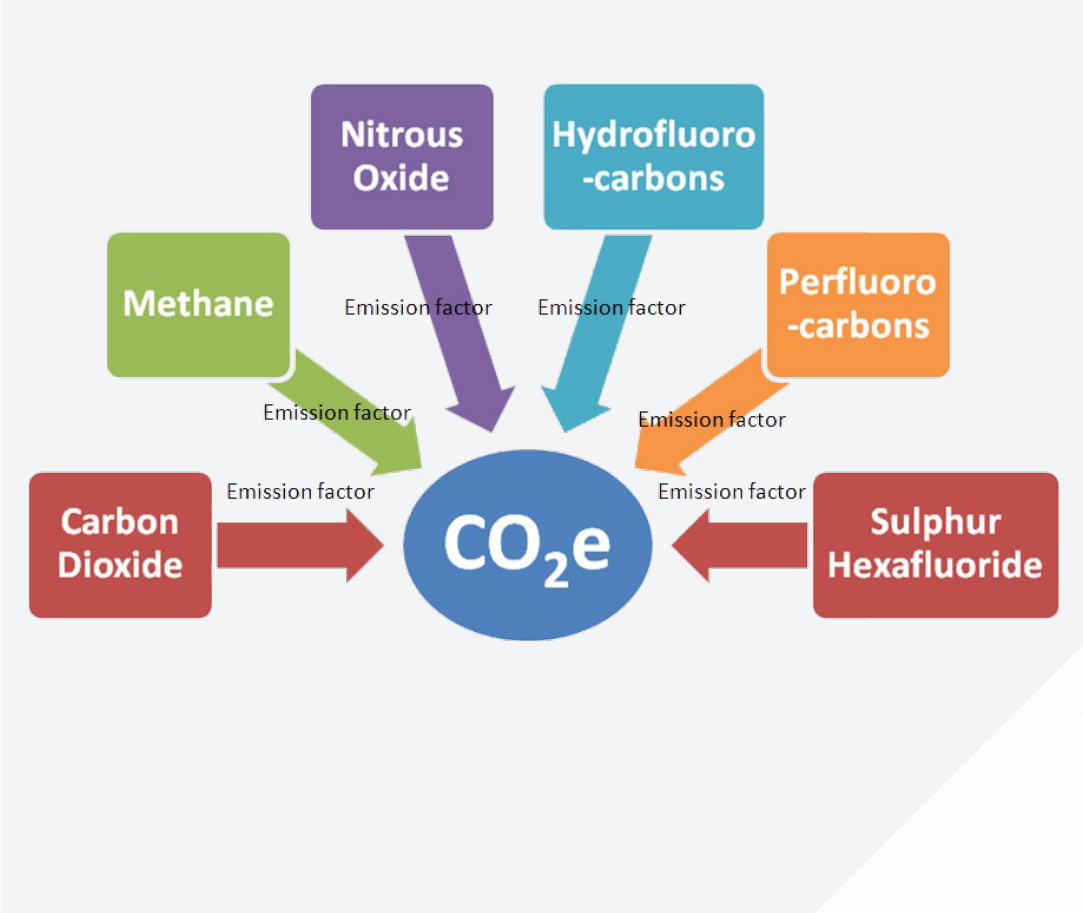
What are Greenhouse Gases?

- Gases that trap heat in the atmosphere are called greenhouse gases (GHGs).
- The Montreal Protocol and Kyoto Protocol identified specific GHGs to be reduced.
- GHGs are converted to Carbon Dioxide equivalent (CO2e) for easy comparisons.
- The CO2e amount is referred to as the "carbon footprint" of a product or service.



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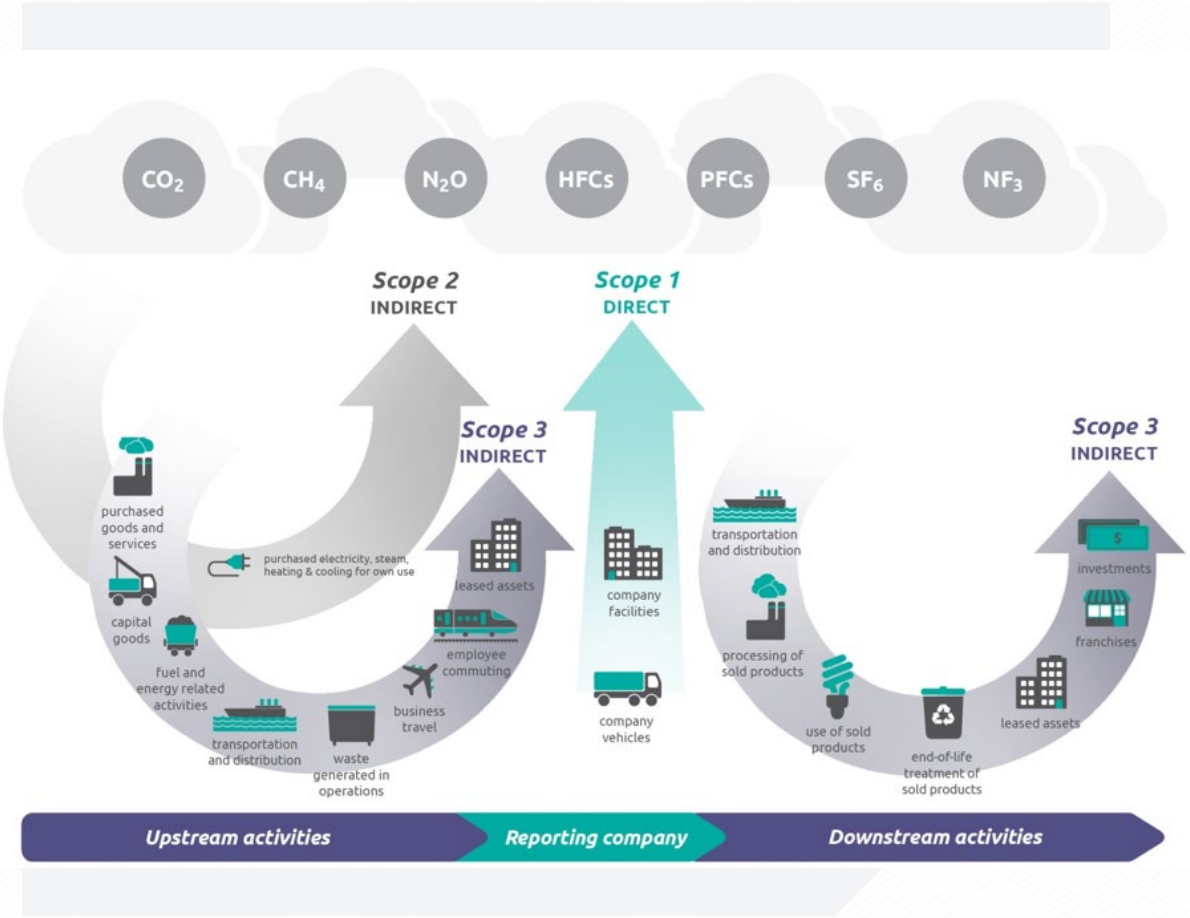
Greenhouse Gas Emission Types

- "Direct emissions" are from sources owned or controlled by a building owner.
- "Indirect emissions" are a consequence of activities at the building.
- Building professionals focus on Scopes 1 & 2.



ISO 14064 - Courtesy of the World Resources Institute ©

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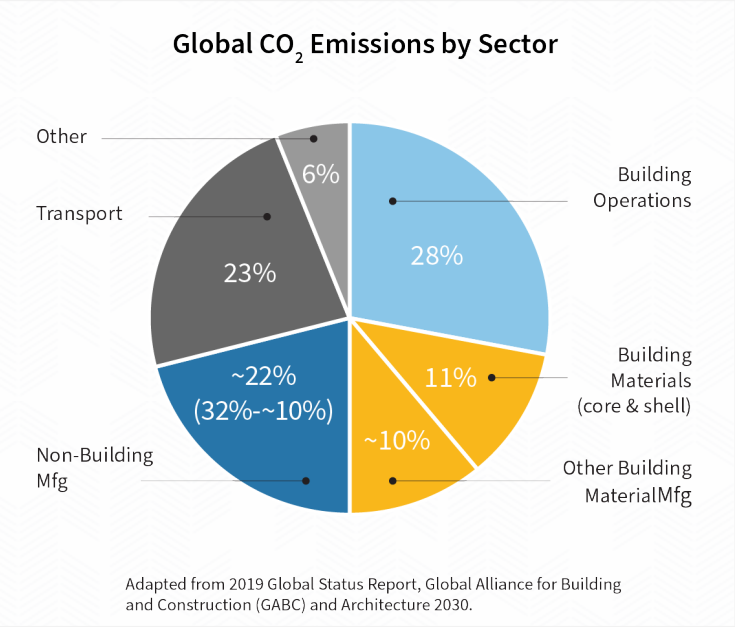
Greenhouse Gas Emissions in the Built Environment

- Carbon emissions are estimated to be 50/50 embodied carbon vs operational carbon for new construction between 2020 – 2050.



Carbon Leadership Forum©

- Today we focus on operational carbon.

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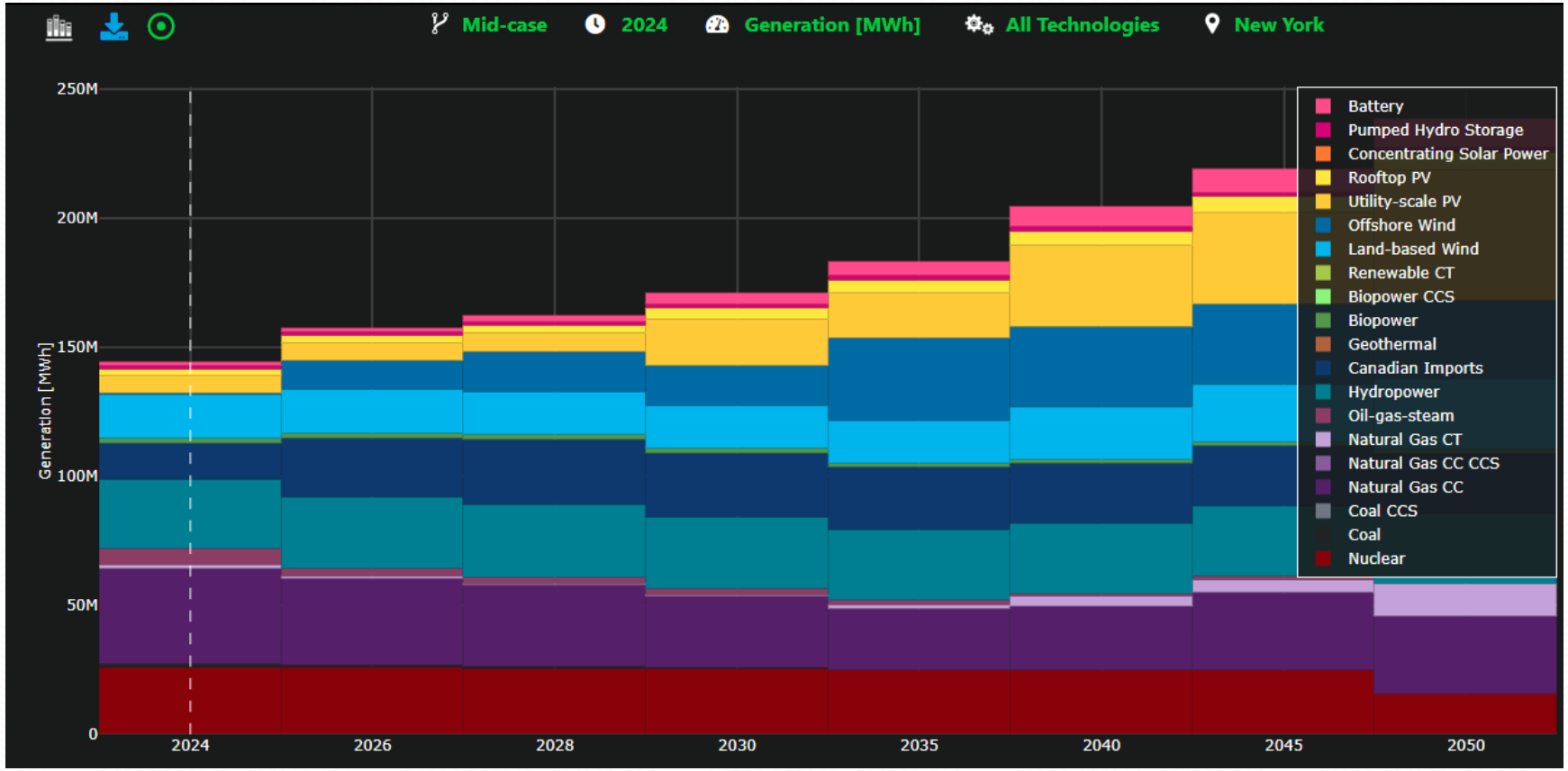
Greenhouse Gases Related to Electricity

- Understanding how carbon intensive electricity generation regionally is important when recommending building electrification.



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Greenhouse Gases Related to Electricity

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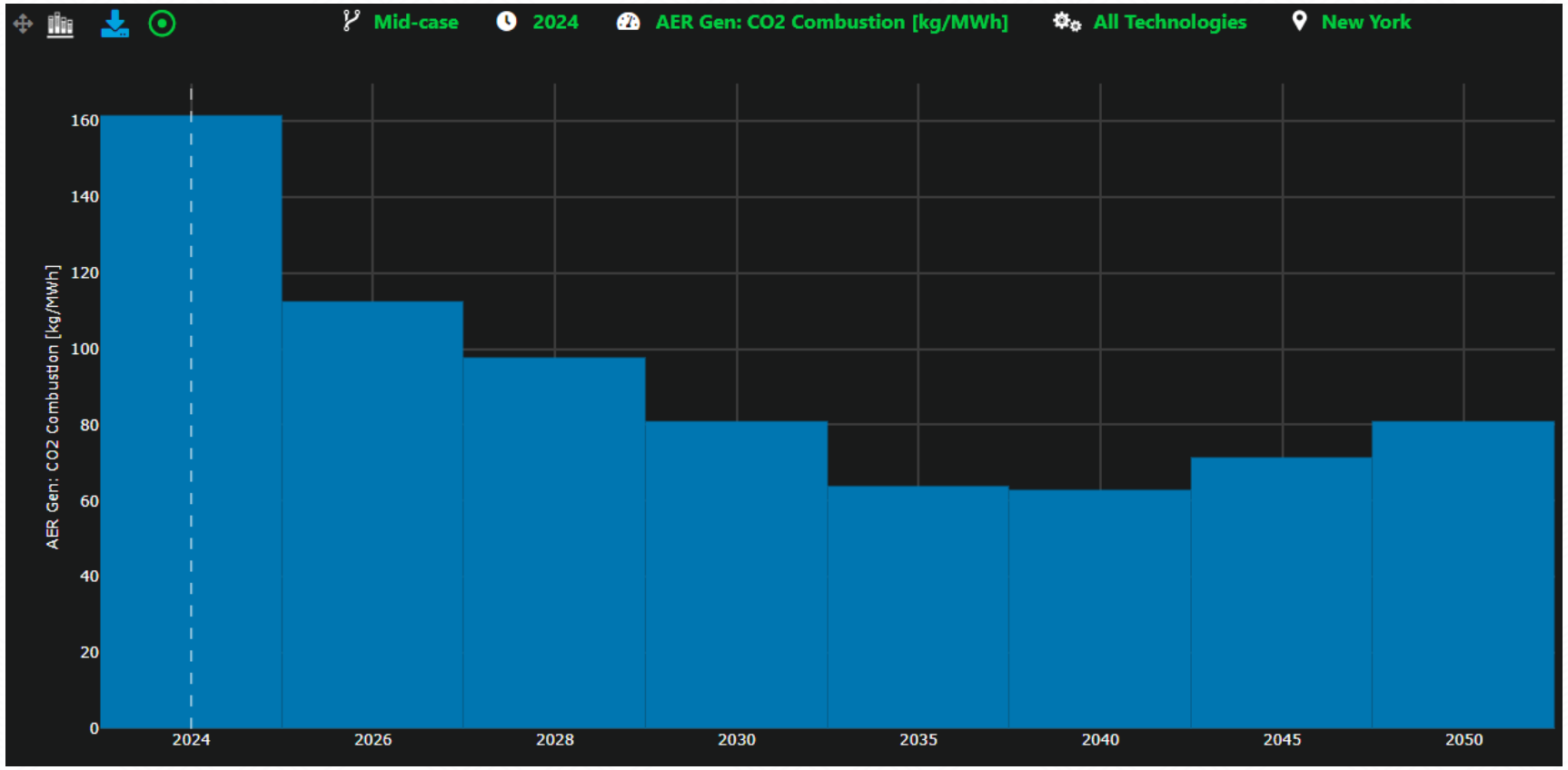

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Greenhouse Gases (GHG) Inventory

- Converting building energy usage to CO2e provides insight for a site's operational carbon values.

- 2019 Energy Benchmarking Public Disclosure information for 3360 S State Street:

Energy Fuel Type	Annual Consumption, MBTU	Current Regional Carbon Emissions Factors, kgCO2e/MBTU		
		Chicago	New York	Boston
Electricity	1,776.18	142.83	84.69	87.50
District Steam	6,264.68	66.40	44.93	66.40

Resources:
https://portfoliomanager.energystar.gov/pdf/reference/Emissions.pdf
https://www.boston.gov/departments/environment/building-emissions-reduction-and-disclosure#emissions-factors
https://www1.nyc.gov/site/buildings/codes/greenhouse-gas-emission-reporting.page

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Decarbonization In Buildings

- For buildings decarbonization is focused on:

Limiting energy use

(to limit carbon created by generating energy)

Going all electric (Electrification)

(no fossil fuels burned on site + electricity generate CAN be from renewable means)

Generating renewable/carbon-free electricity on site

(typically solar panels, also referred to at Photovoltaic panels or PV)

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ELECTRIFICATION
THE NEXT STEP
NO SCOPE 1 AT BUILDING

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“Electrification”

2017 Tesla Model S 75 ©EVOX Images

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“Electrification”
Cars vs. Buildings

- Electric is 100% efficient
- Gasoline / Diesel engines are 30 – 45% efficient.
- With todays’ electric grid emissions electric cars are typically lower carbon

- Electric is 100% efficient
- Gas Boilers are 80 – 90% efficient (it is easy to heat with fire).
- BUT with todays’ electric grid emissions electric resistance heating is a higher carbon source

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When is Electric Heating Better?

- **Today Electric Heating with a COP of 1.6 or better is the lowest emissions per BTU**

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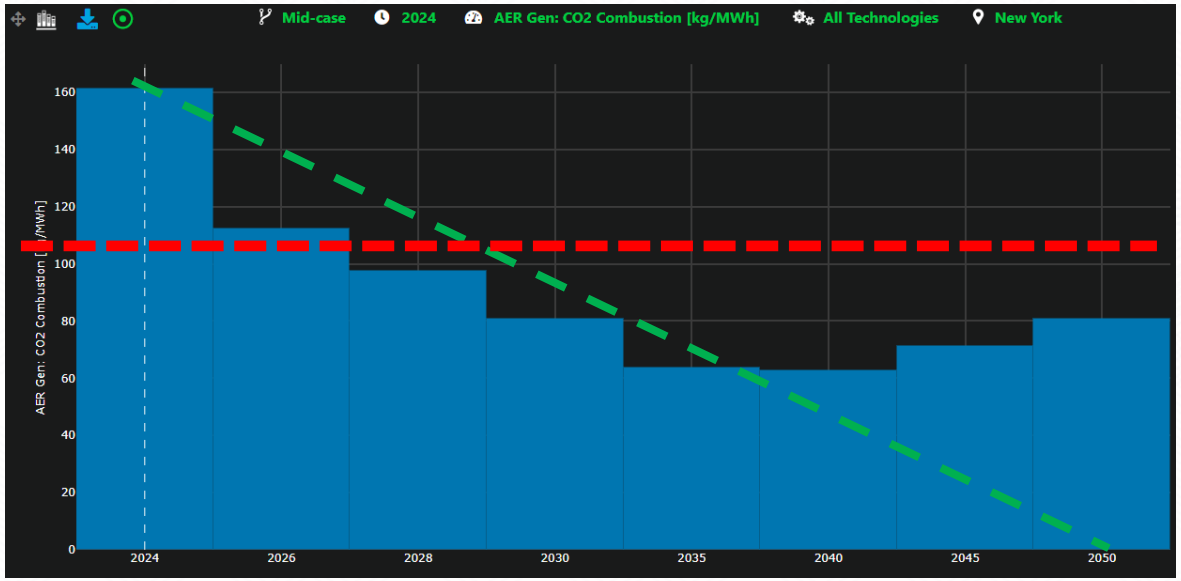
Greenhouse Gases Related to Electricity

- Understanding how carbon intensive electricity generation is regionally is important when recommending building electrification.

Gas/Electric Break-Even Line



NREL CAMBIUM, https://cambium.nrel.gov/

Reductions Driven by:

- Increased Off-Shore Wind Capacity
- Increased Utility Scale PV Capacity
- Reduced Natural Gas Dependency

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WHAT IS DRIVING ELECTRIFICATION?

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Drivers

- Climate Change
- Local Legislation:
  - NYC LL97
  - NYC LL154 (no gas allowed)
  - Boston – BERDO 2.0
- Institutional/Corporate ESG Goals

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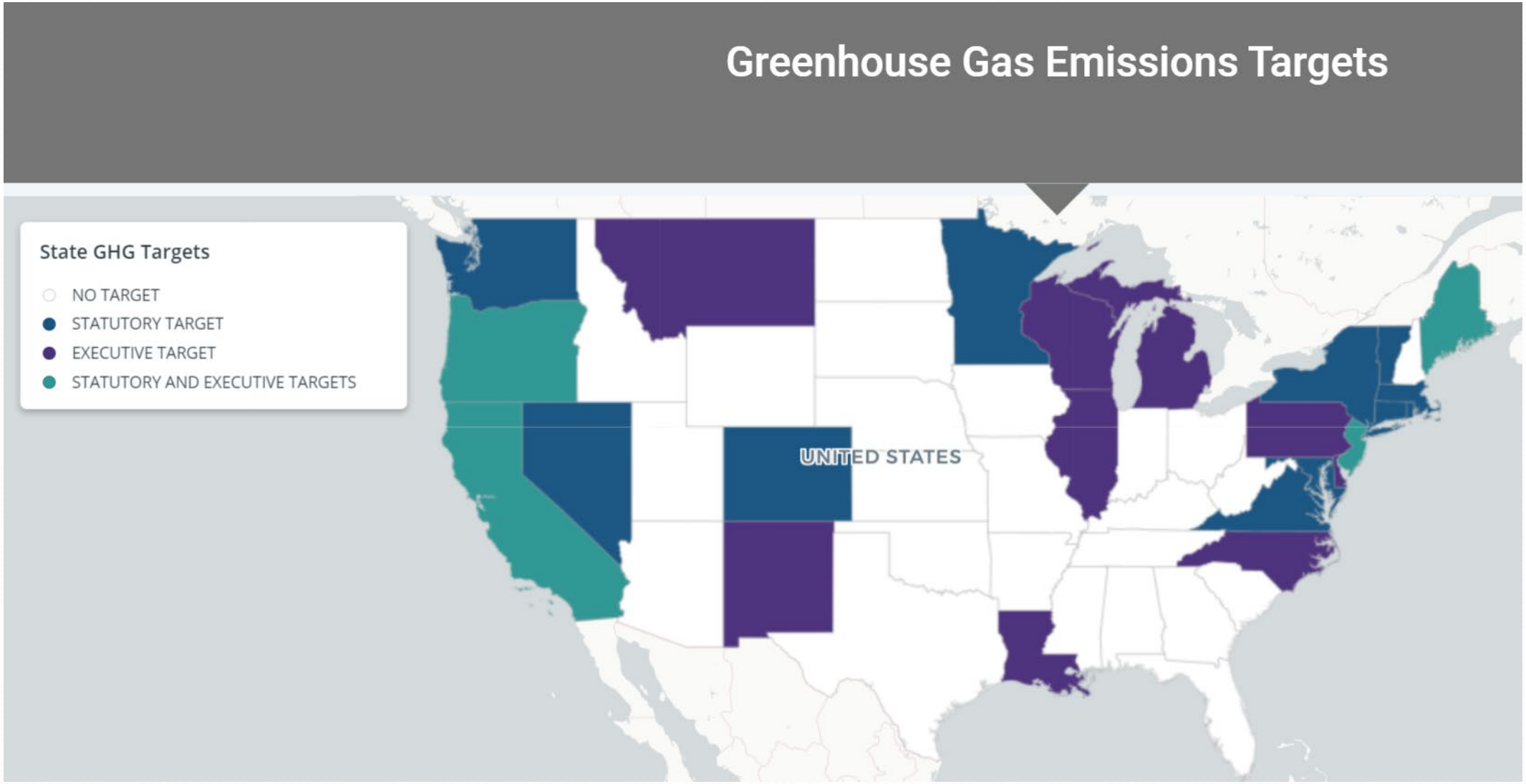
Where Are Decarbonization Policies Happening?



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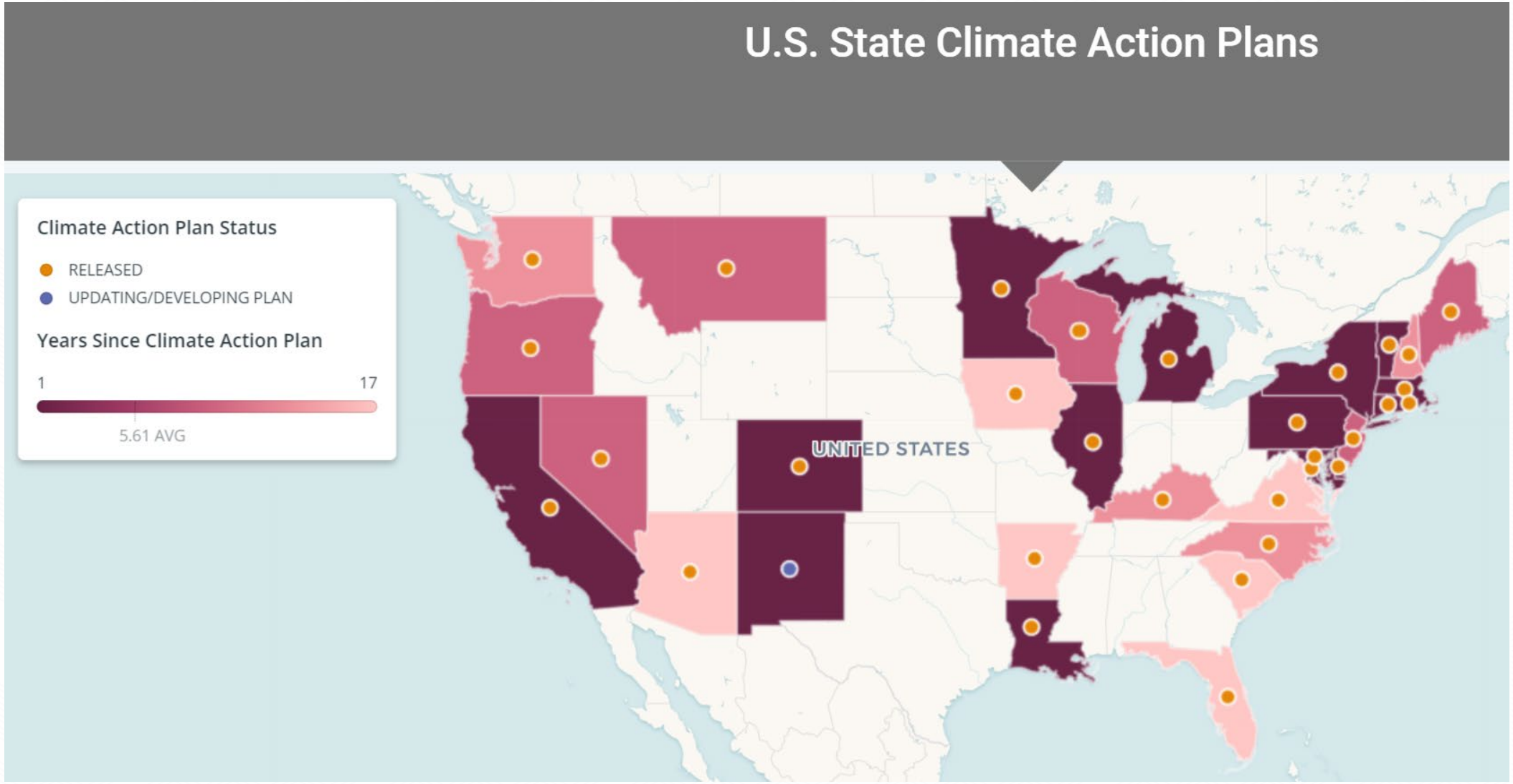
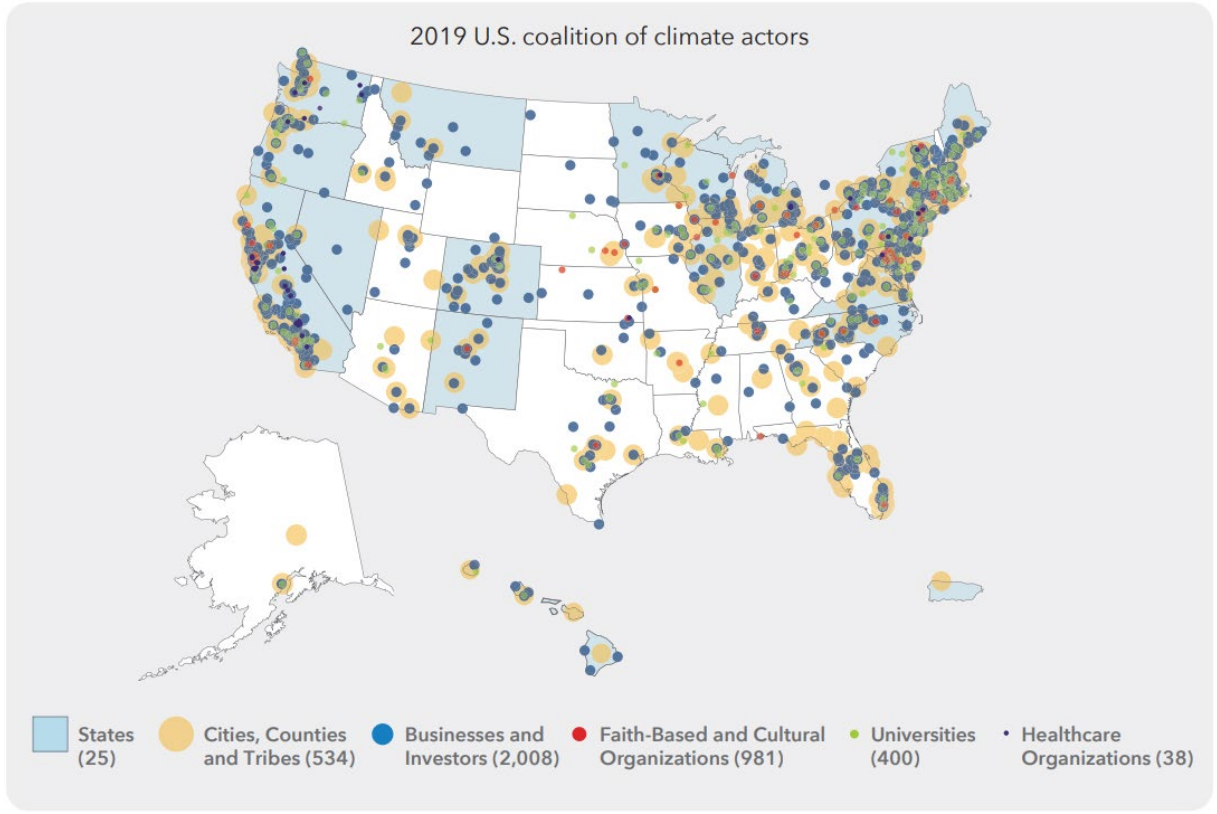
Where Are Decarbonization Policies Happening?



Where Are Decarbonization Policies Happening?

Figure ES-3 | **Actors Supporting the Paris Agreement**



▲ Thousands of leaders, with real policy and financial power across our federal system in the United States, have committed to climate action in their jurisdictions or within their organizations.

From Executive Summary:
https://americaisallin.com/sites/default/files/2022-09/executive-summaryaccelerating-americas-pledge.pdf

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nyc LL97 carbon emissions calculator

200 Liberty Street

LL84 2023 (calendar year 2022)

Building Inputs

	Building Input	Area (SF)	
1	Office	1,437,074	x
2	Parking	50,000	x
3	Data Center	48,536	x

+ Add Building Type

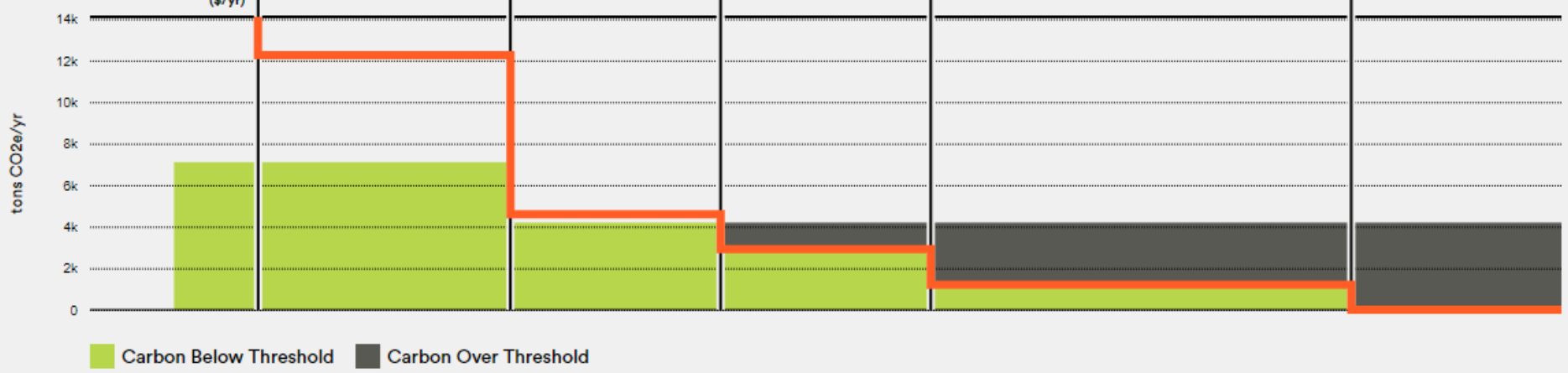
Utility Inputs

Electricity (kWh)	$/kWh
19,842,074	0.22
Natural Gas (therms)	$/therm
2	0.997
Steam (mLbs)	$/mlb
25,513	35
Fuel Oil #2 (gal)	$/gal

carbon | cost

Annual Carbon Threshold Summary

	2024-2029	2030-2034	2035-2039	2040-2049	2050-
Emissions (tCO2e/yr)	7,102	4,193	4,193	4,193	4,193
Threshold (tCO2e/yr)	12,262	4,596	2,918	1,195	0
Est Penalty ($/yr)	$0	$0	$341,722	$803,495	$1,123,802



units: absolute | normalized — group: summary | end uses

Calculator engine by AKF Group LLC

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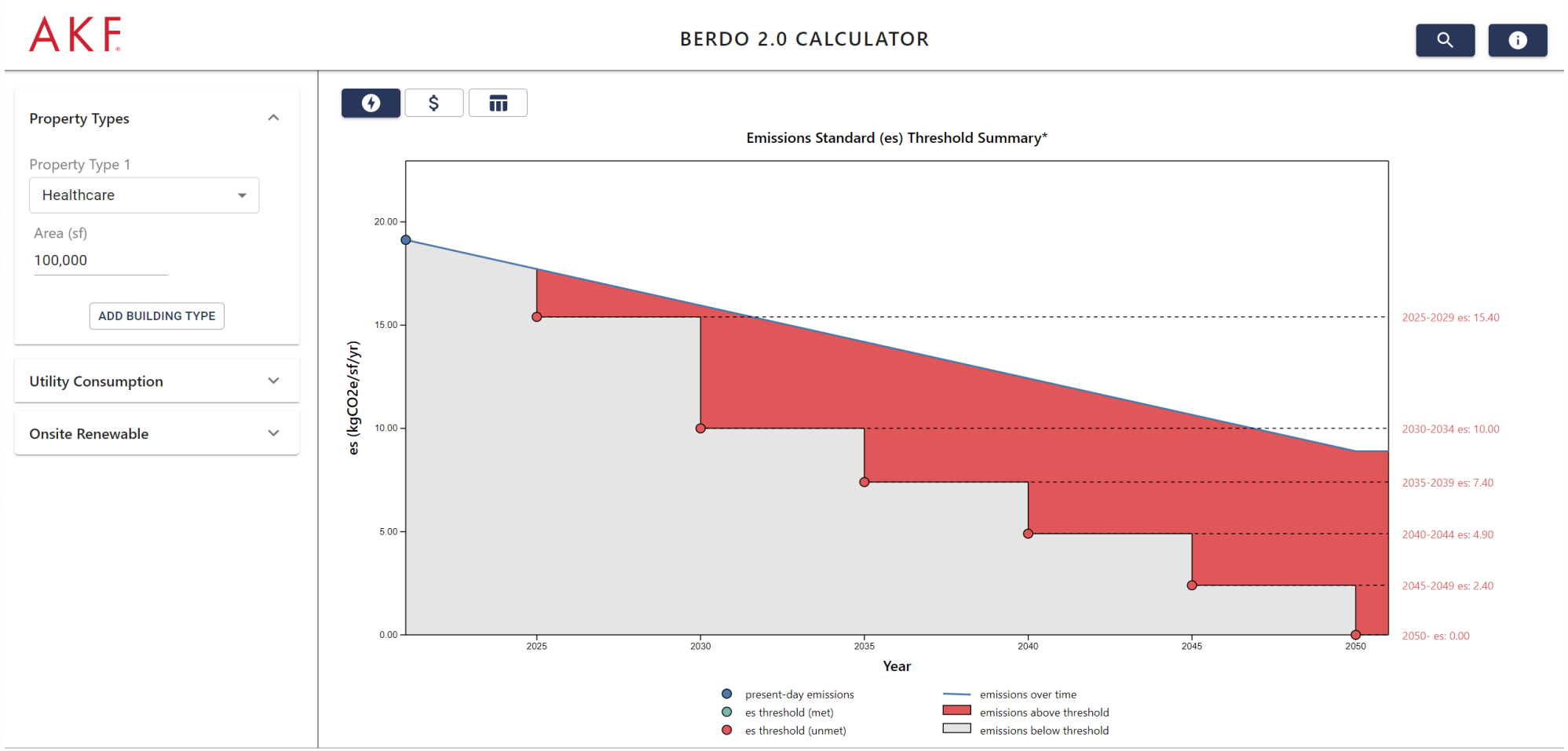
BERDO 2.0 Calculator



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TECHNOLOGY

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Technology

- Air Source Heat Pumps

- Variable Refrigerant Flow

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Air Source Heat Pumps

- Lower Carbon Consumption (today)
- Marginal increase in peak HVAC load
- Improving Heating Efficiency and Range

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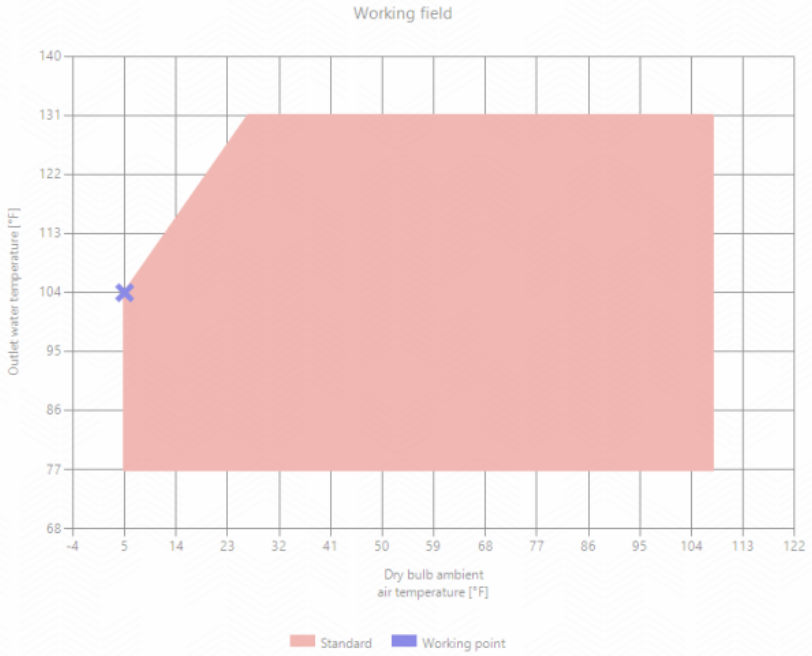
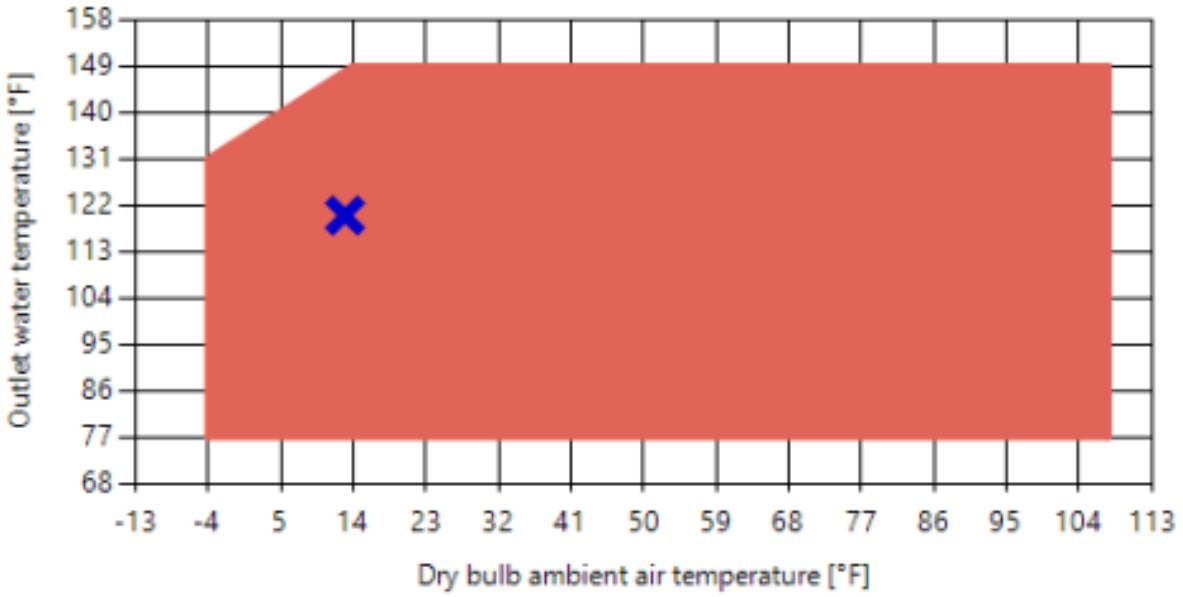
“Electrification” Equipment Options

Air Source Heat Pump - Heating and Cooling

- Increased equipment options (2 – 3 and more on the way)
- Up to >120°F at 5°F OAT
- Module size should be carefully evaluated
- Consider Coil effects of 100 - 120°F Water





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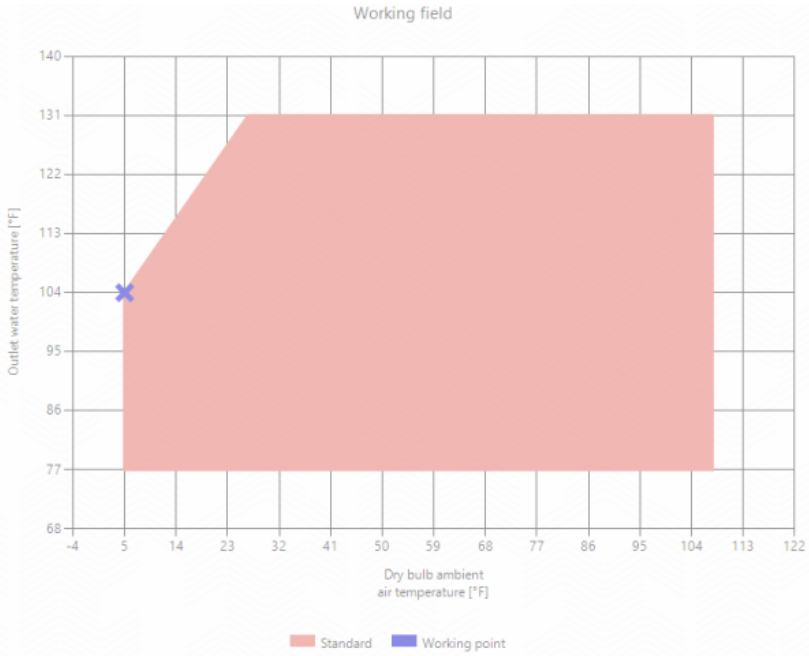
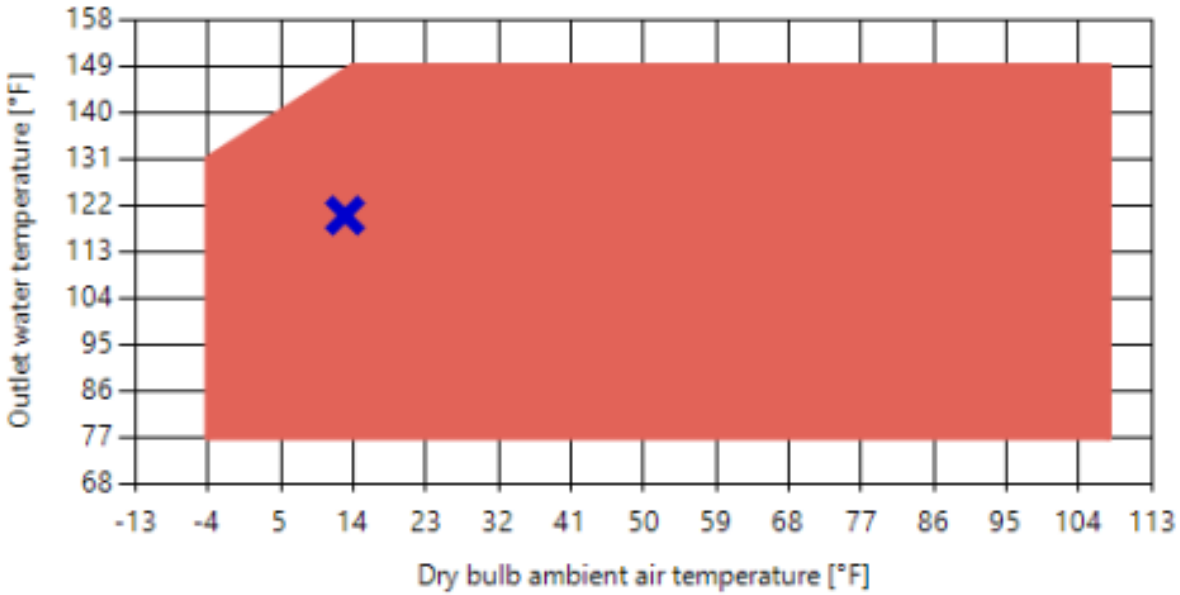
“Electrification” Equipment Options

2017 Tesla Model S 75 ©EVOX Images





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APPROACH

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New Buildings: Design for Low Carbon

1. High performance envelope enables minimizing size and cost of all-electric heat pump systems
2. Optimize both internal equipment loads and ventilation through advanced controls
3. Evaluate high performance heat pump system options
4. Maximize on-site energy generation with integrated solar PV roof and shading design

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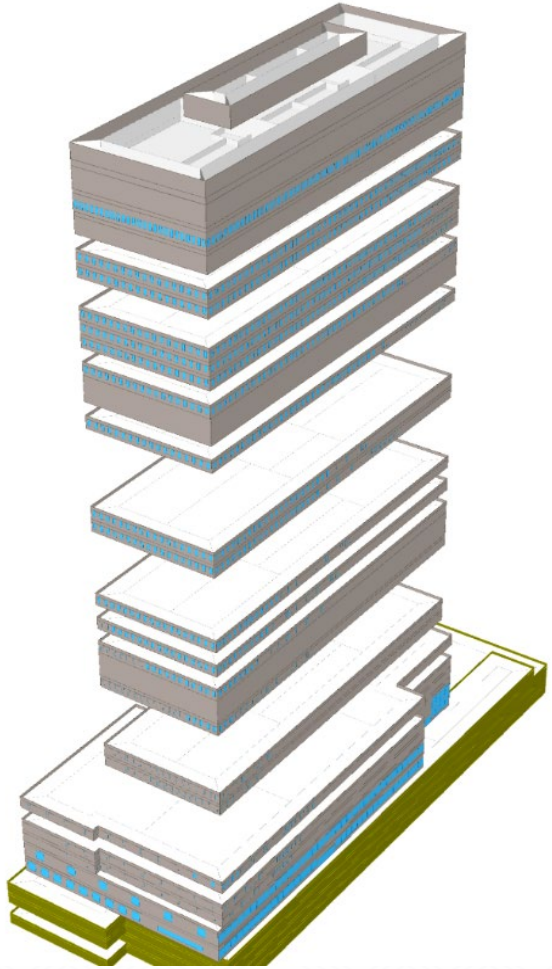
Existing Building System Analysis

1. Review Utility & Building Data Analysis
2. Discuss Preliminary Carbon Reduction Measures (CRMs).
3. Engage with Utility Incentive Provider
4. Calibrate Energy Model
5. Review Results from Macro to Micro



Energy Model Rendering

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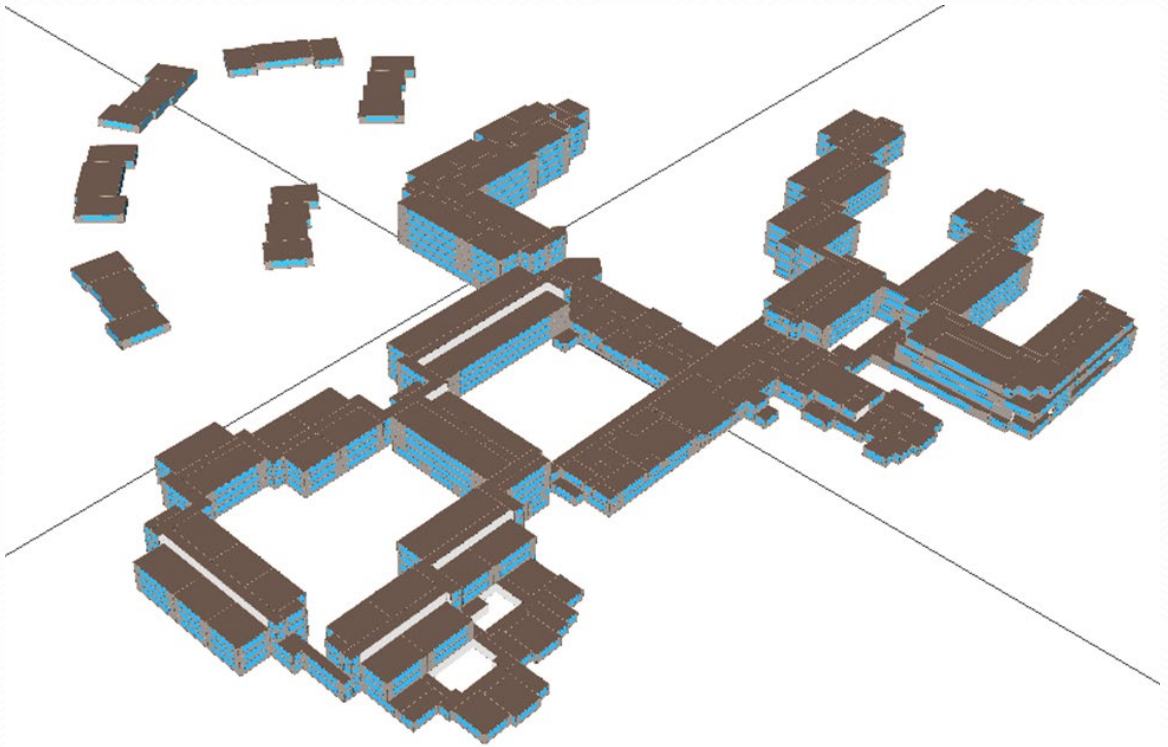
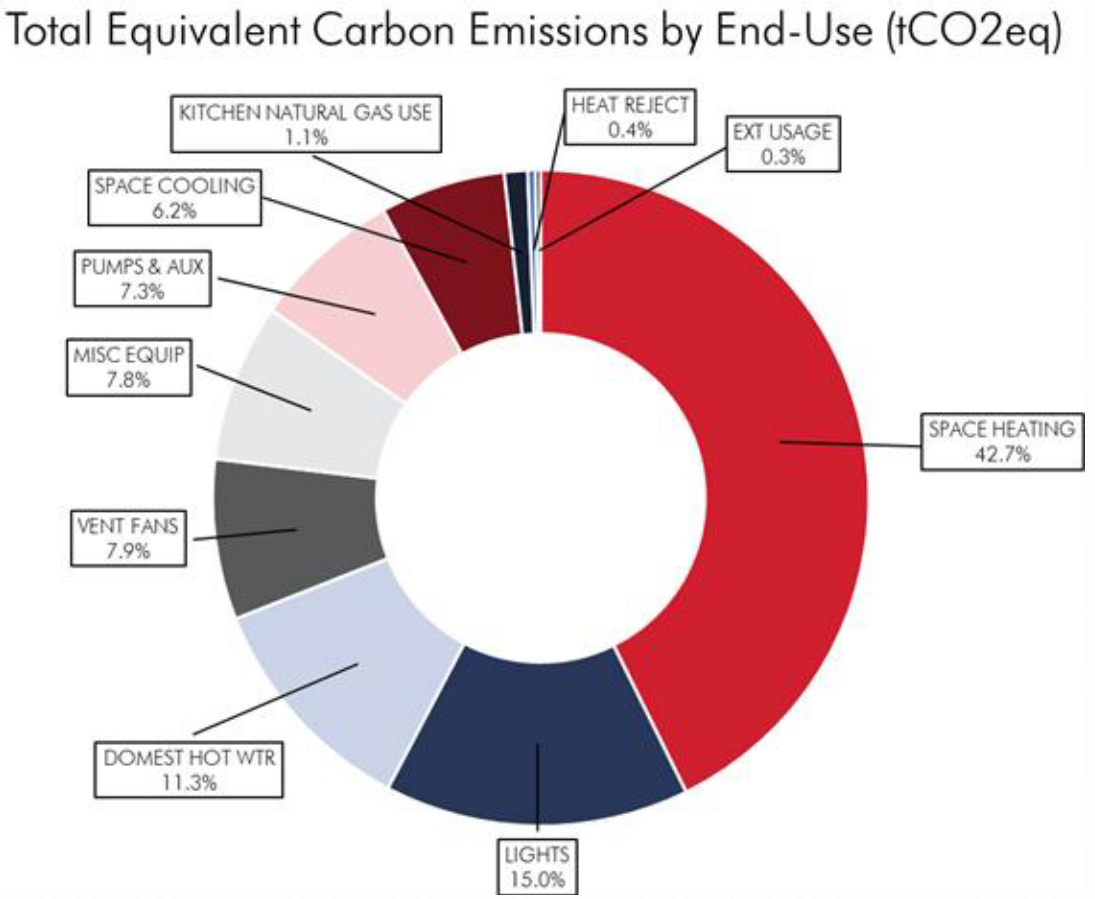
Carbon Emissions Baseline





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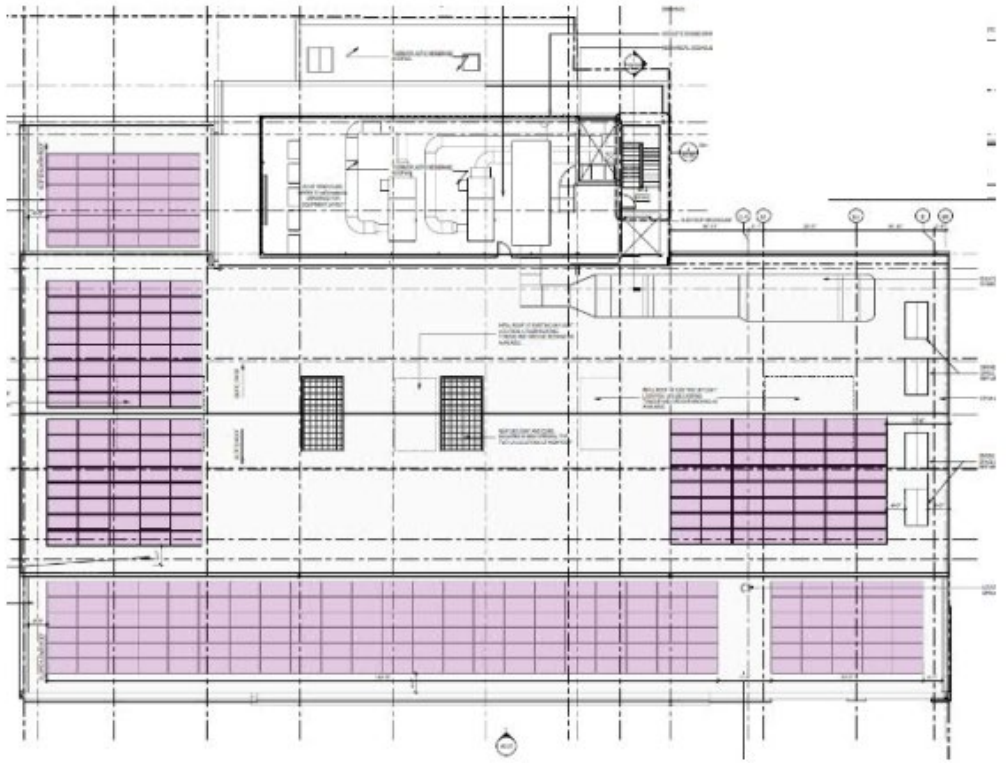
Decarbonization Approaches

There are a few approaches towards decarbonization found in the industry today:

1. Equipment-Swap Electrification Planning

2. Bottom-Up Decarbonization Planning

3. Resource Efficient Electrification Planning



Rooftop PV Design Layout

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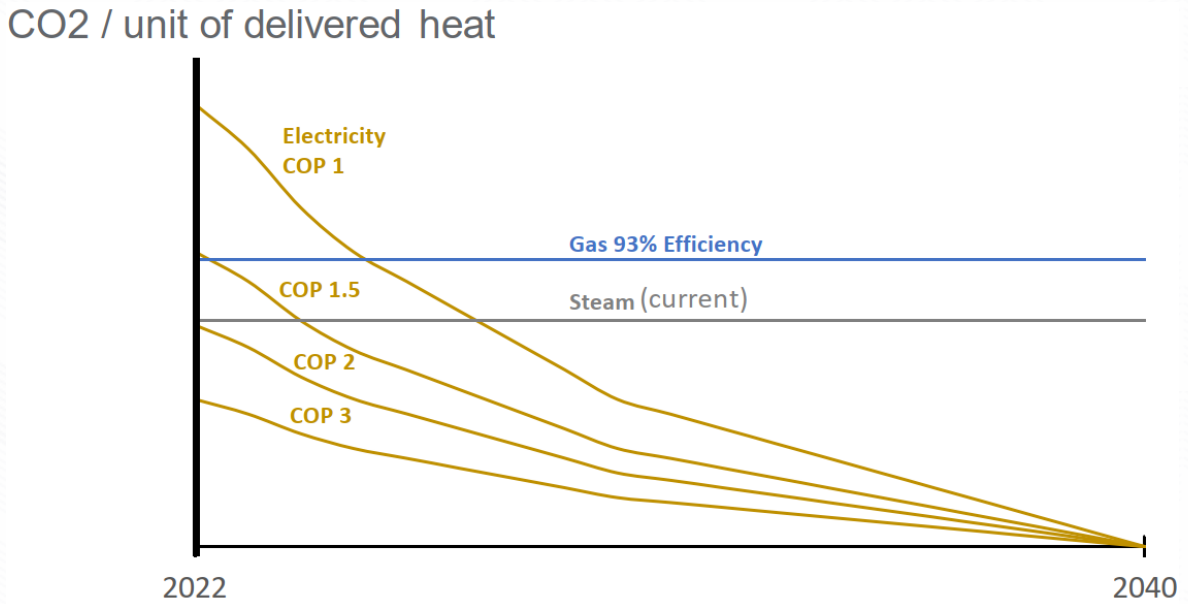
Equipment-Swap Electrification Planning

- Replacing direct emissions heating equipment and indirect emissions heating equipment with electrical substitutes with no distribution system impact.

- However, simple heating system substitutions with electric resistance and inefficient heat pumps do not provide a benefit to the building in the short-term, and can be more expensive.



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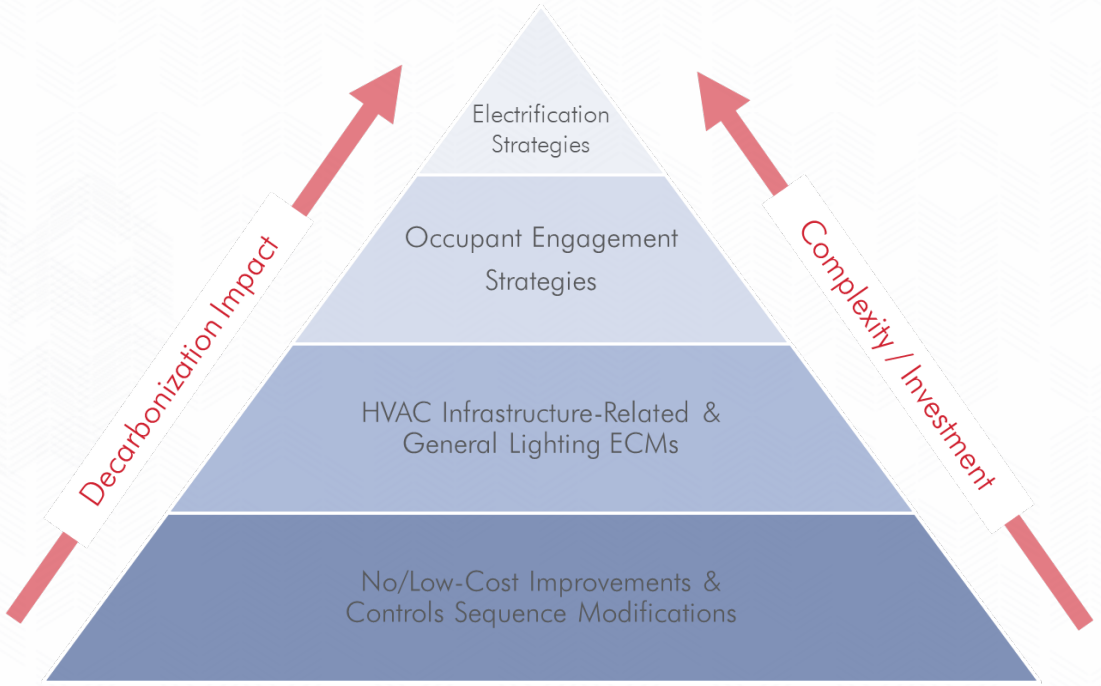
Bottom-Up Decarbonization Planning

Drivers:

1. Immediate energy reduction
2. Ease of implementation
3. Capital Cost Scheduling
4. Tenant Lease Renewals
5. Equipment & System End of Useful Life



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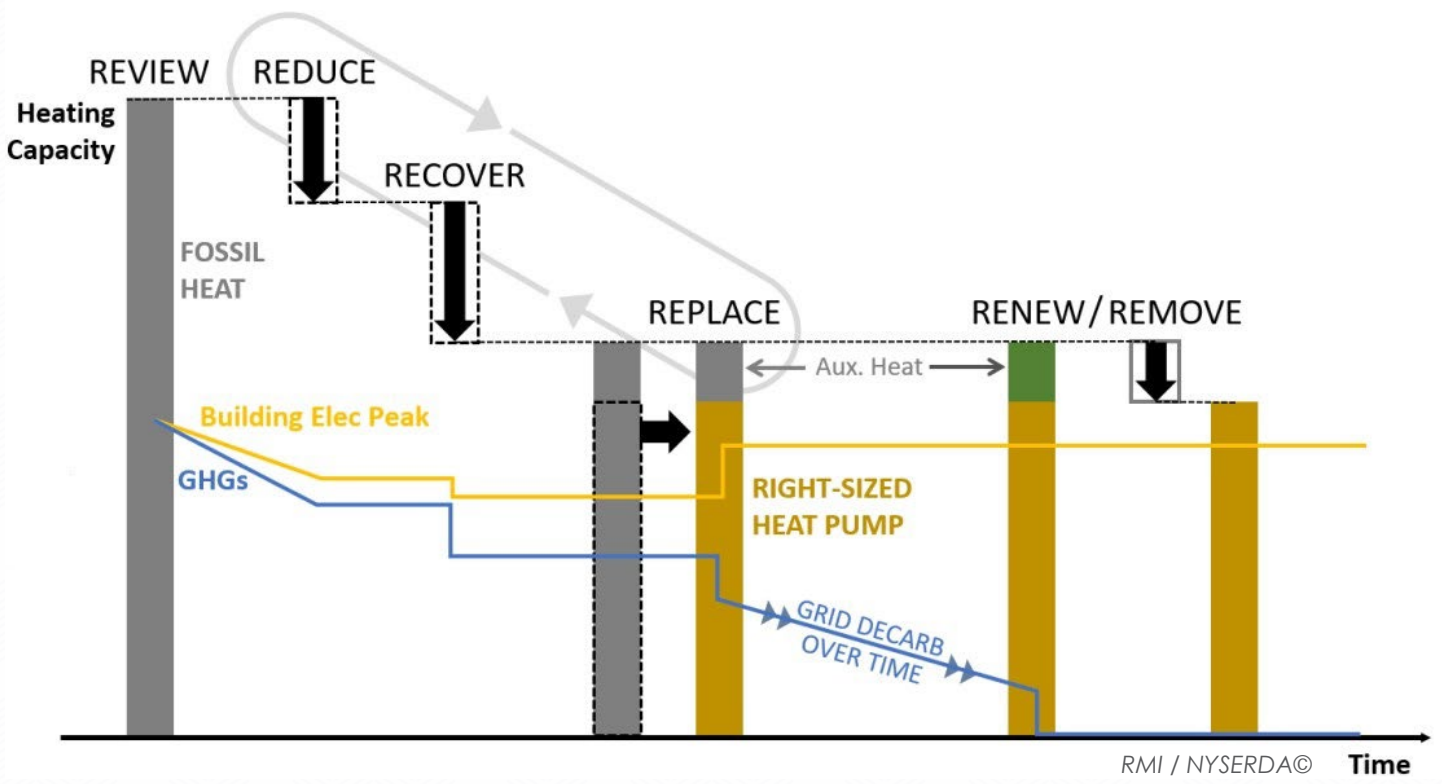
Resource Efficient Electrification Planning



Similar to the Bottom-Up approach but applies emphasis towards heat recovery strategies.

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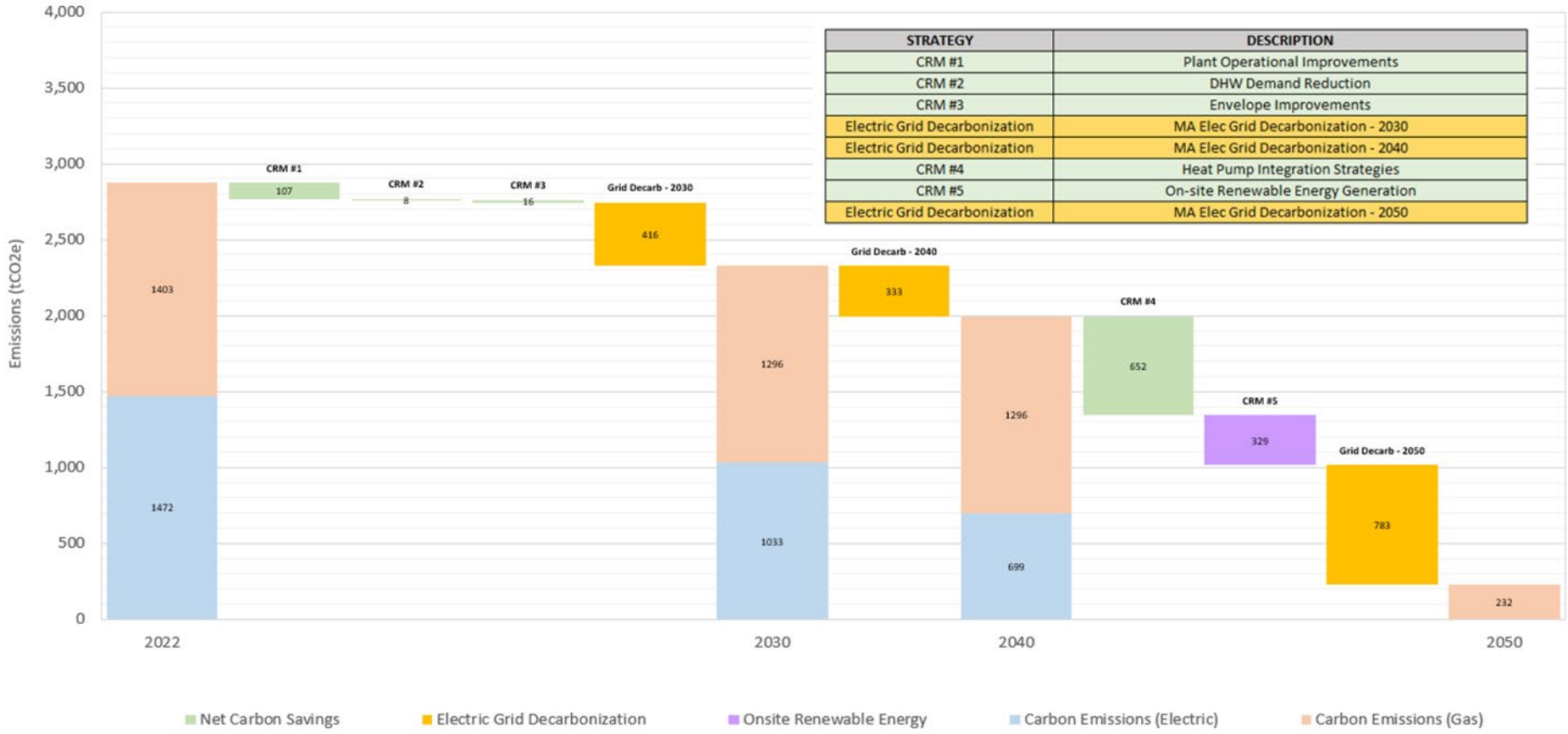
Develop Decarbonization Roadmap

Goal: Provide the building owner a carbon reduction pathway while acknowledging electrical grid improvements.



STRATEGY	DESCRIPTION
CRM #1	Plant Operational Improvements
CRM #2	DHW Demand Reduction
CRM #3	Envelope Improvements
Electric Grid Decarbonization	MA Elec Grid Decarbonization - 2030
Electric Grid Decarbonization	MA Elec Grid Decarbonization - 2040
CRM #4	Heat Pump Integration Strategies
CRM #5	On-site Renewable Energy Generation
Electric Grid Decarbonization	MA Elec Grid Decarbonization - 2050

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Decarbonization Strategies

SOURCE OPTIONS	CENTRAL OPTION 1 Partial / Phased Heat Recovery Chiller	CENTRAL OPTION 2 Air to Water Heat Pumps on Roof	LOCAL OPTION 1 Floor By Floor Air Source Heat Pump	LOCAL OPTION 2 Distributed Water Source Heat Pump
	 			 
First Cost	$$	$$$$	$$$	$$$
Utility Costs	$$	$$$	$$$	$$$
Carbon Impact	Good, Future Flexibility	Best	Best	Better but still need heat source to CW loop
Tenant Impact	Minimal	Minimal	Major	Major
Coordination with Existing Infrastructure	Best	Difficult	Most Invasive	Most Invasive
Impact to Leasable Area	Best	Best	Poor	Fair
Maintenance/ Staffing	Good, Central Point	Good, Central Point	Fair, multiple locations	Fair, multiple locations
Pro	- Low utility costs - Lower carbon impact - Future Fossil Fuel free option (phased approach)	- Lowest carbon impact (Fossil Fuel Free)	- Can focus on one or several floor at a time - Low carbon impact (Fossil Fuel free)	- Can focus on one or several floor at a time - Low carbon impact (Fossil Fuel free)
Con	- Requires additional infrastructure work for future condition - Not fossil fuel free today	- Highest first cost - Higher annual energy costs due to electric rate - Requires large rooftop MER - Infrastructre change would require major cost to replace all distribution and coils	- Need for outdoor air on floor complicates phasing - Need for heat rejection on floor impacts façade (louver areas per floor) - Higher annual energy costs due to electric rate	- Need for outdoor air on floor complicates phasing - Higher annual energy costs due to electric rate - Not fossil fuel free today
Recommended for further analysis?	Yes	Yes	No unless stacking is possible	No unless stacking is possible

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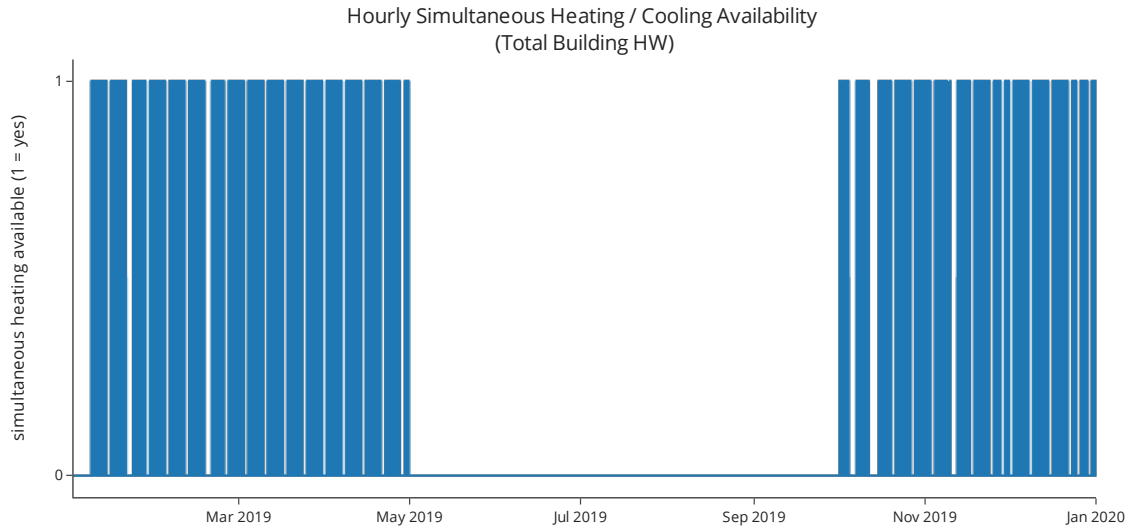
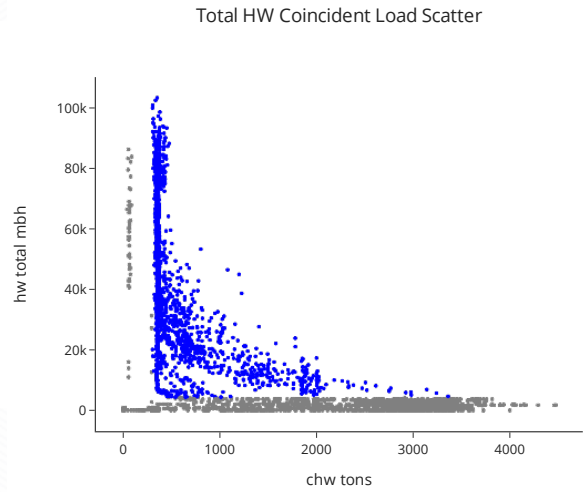
Heat Recovery Strategies

Thermal Storage

- Normal Operation: Typical chiller arrangement with a cooling tower.
- Winter Operation: Recover heat from the condenser side as a heating source.





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Thank You!

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