



# Building Electrification and Decarbonization

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PRESENTED BY: PAE

FEB 29, 2024



[pae-engineers.com](http://pae-engineers.com)

# Introductions



**Tony Marino**



**Chelsea Guenette**



**David Mead**

## AGENDA



**About PAE**



**Why Decarbonize? / Methods to Success**



**Code Implications**



**Existing Building Challenges**



**Overall System Solutions**



**Architectural Integration**



**Whole Life Carbon**



**Building Portfolio Strategies**



**Q&A**





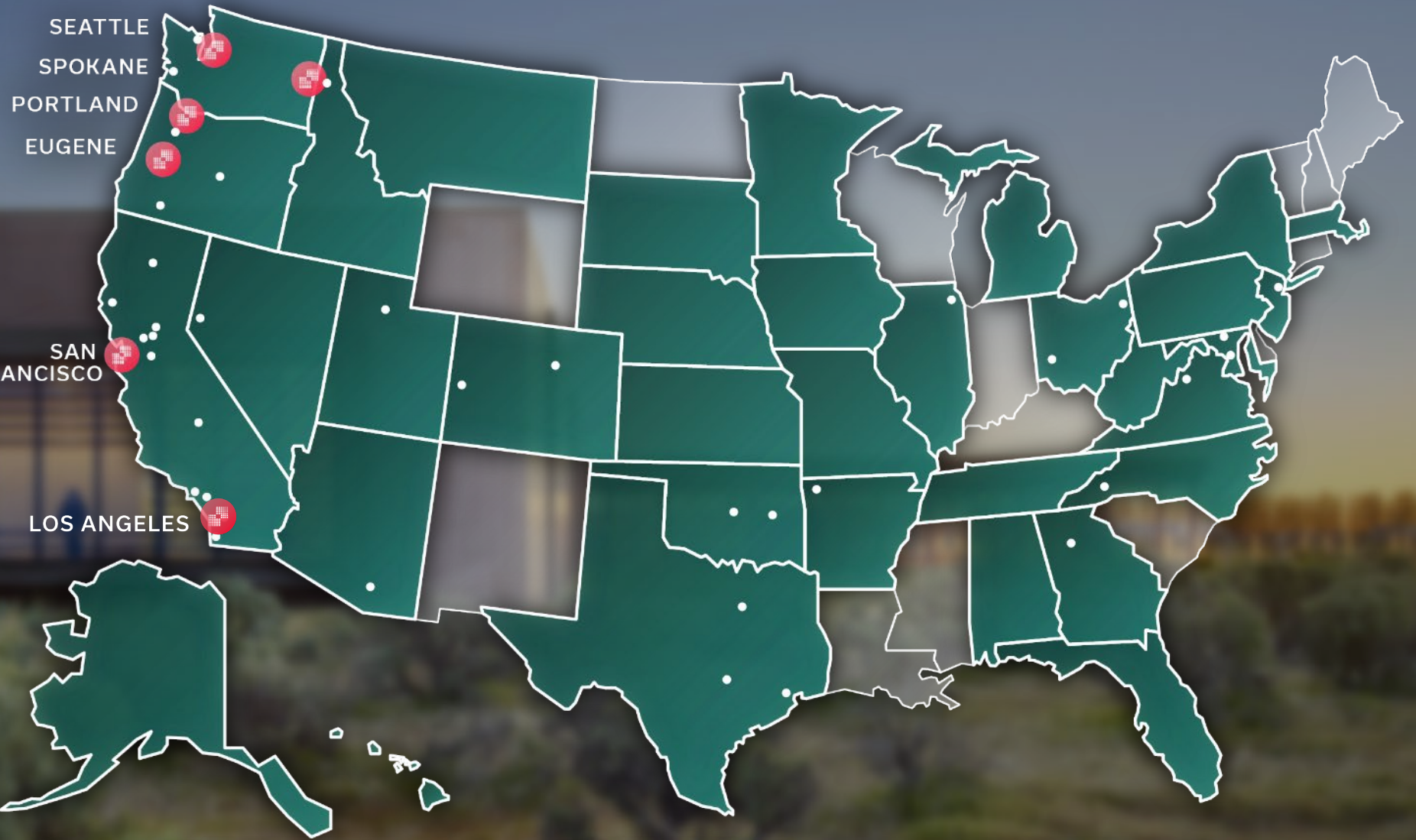
**365**  
STAFF



**6**  
OFFICES




**56**  
YEARS



 OUR WORK

 OUR PEOPLE

 OUR OFFICES

Wanapum Heritage Center & Museum | Mattawa, WA

# Our Services

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Nike World Headquarters | Beaverton, OR



Mechanical



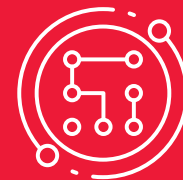
Electrical



Plumbing



Analysis  
and Modeling



Technology



Commissioning



Architectural  
Lighting

# Key Markets



**Commercial Office**



**Residential and Hospitality**



**Cultural and Spiritual**



**Government**



**Healthcare**



**Higher Education**



**K-12**



**Aviation**



**Mission Critical**



**District Planning**



**Laboratories**



**Sports and Recreation**

# Leaders in Sustainable Design



PAE Living Building | Portland, OR

**20**

**LIVING BUILDINGS**

5 ACHIEVED | 15 PURSUING

**11**

**CARBON NEUTRAL**

3 ACHIEVED | 8 PURSUING

**44**

**NET ZERO ENERGY**

11 ACHIEVED | 33 PURSUING

**11**

**PASSIVE HOUSE**

5 ACHIEVED | 6 PURSUING

**95**

**LEED PLATINUM**

52 ACHIEVED | 43 PURSUING

**86**

**ALL ELECTRIC**

43 ACHIEVED | 43 PURSUING

# Learning Objectives

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**1**

Why building electrification is key to a carbon neutral future

**2**

How to overcome all-electric design barriers, including Washington's energy code

**3**

Understand building technologies used in all-electric buildings

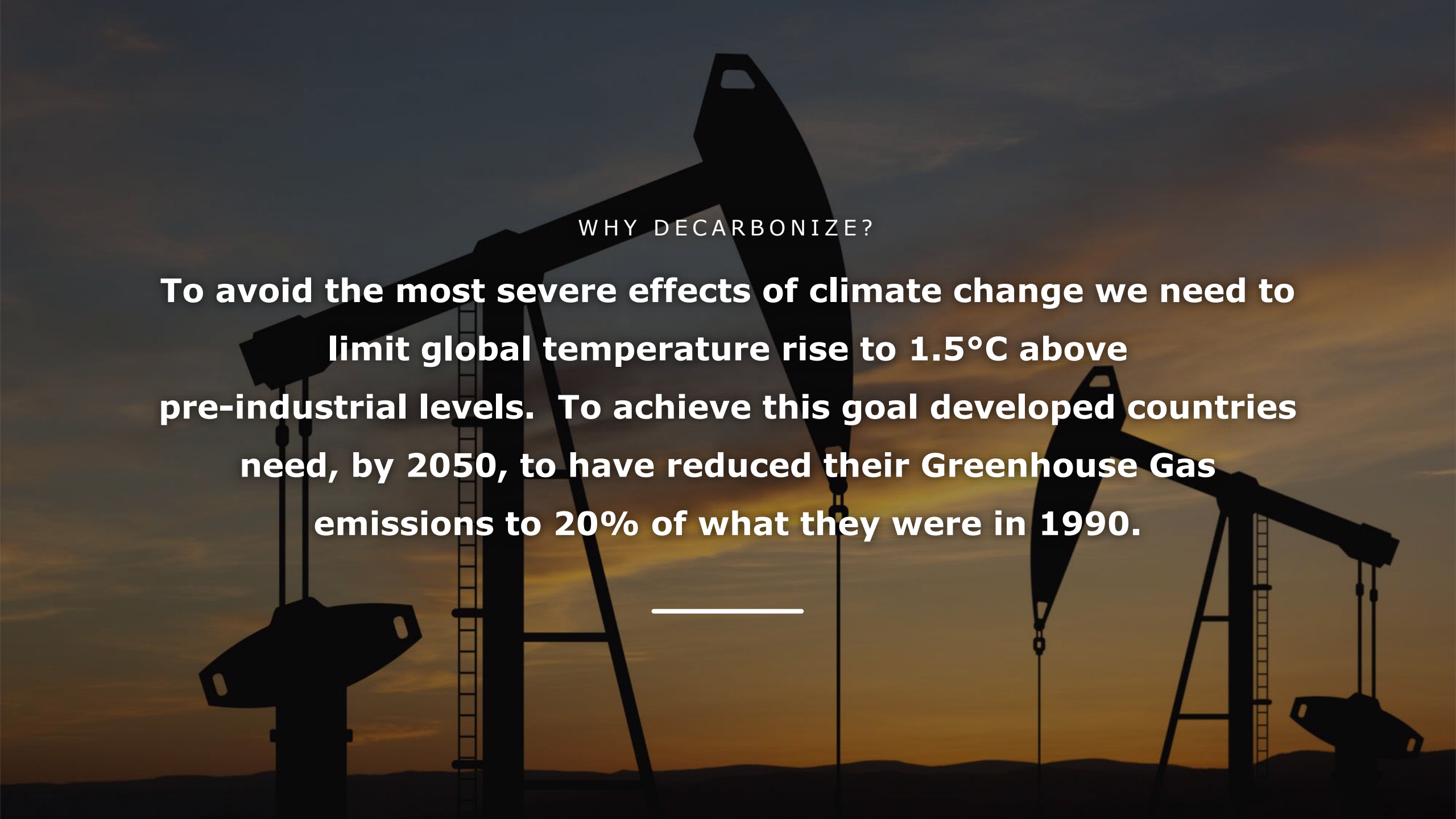
**4**

Embodied carbon considerations





# Why Decarbonize?

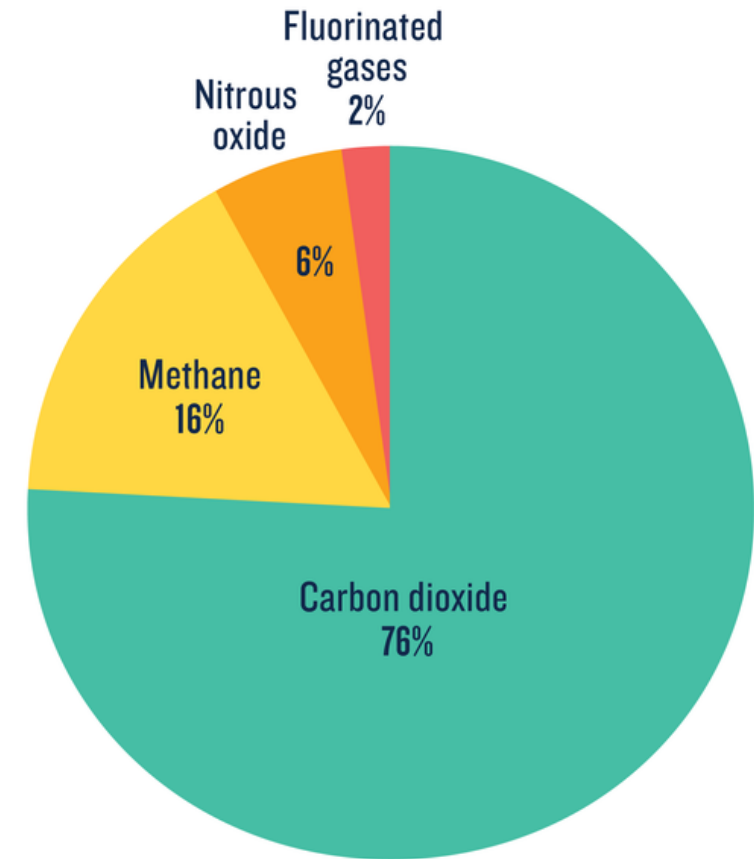
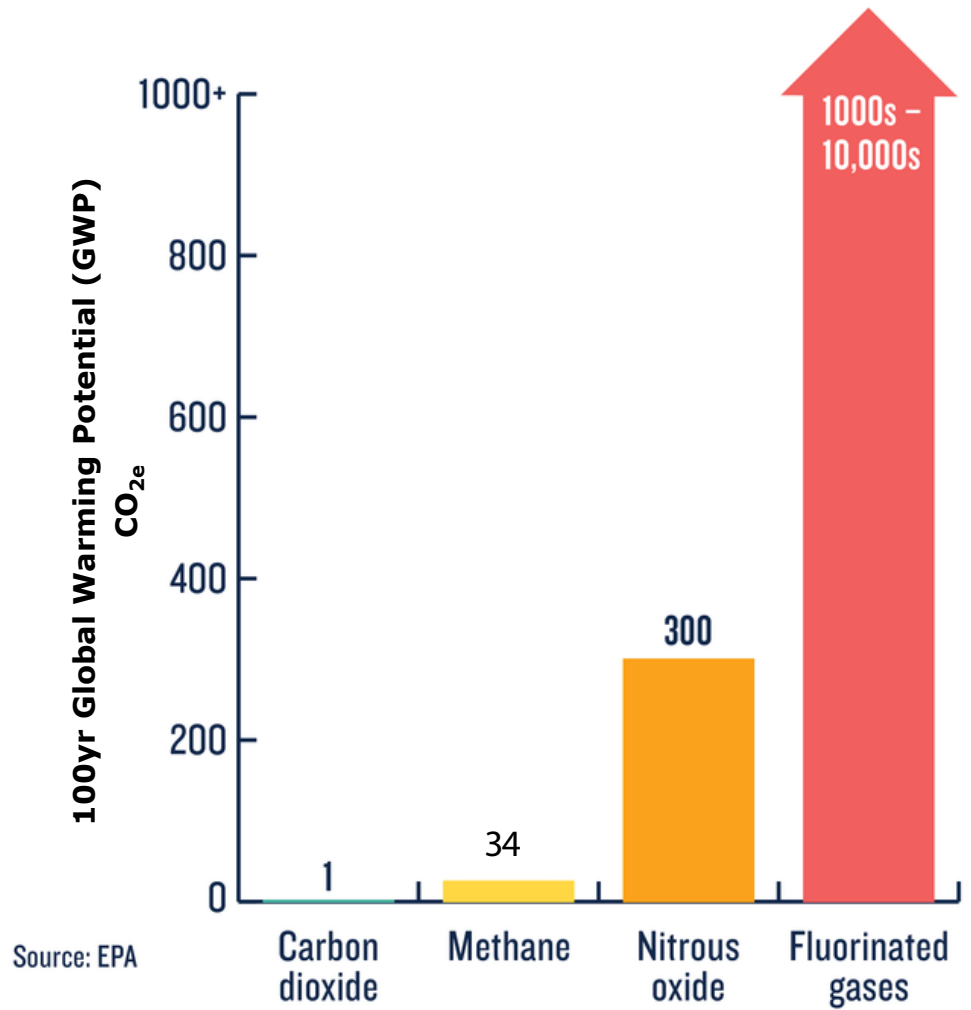
The background of the slide features several black silhouettes of oil pumpjacks (jack-o'-lanterns) against a warm, orange and yellow sunset sky. The pumpjacks are positioned at various heights and angles, creating a sense of depth and industrial activity. The overall mood is somber and urgent, reflecting the theme of decarbonization.

## WHY DECARBONIZE?

**To avoid the most severe effects of climate change we need to limit global temperature rise to 1.5°C above pre-industrial levels. To achieve this goal developed countries need, by 2050, to have reduced their Greenhouse Gas emissions to 20% of what they were in 1990.**

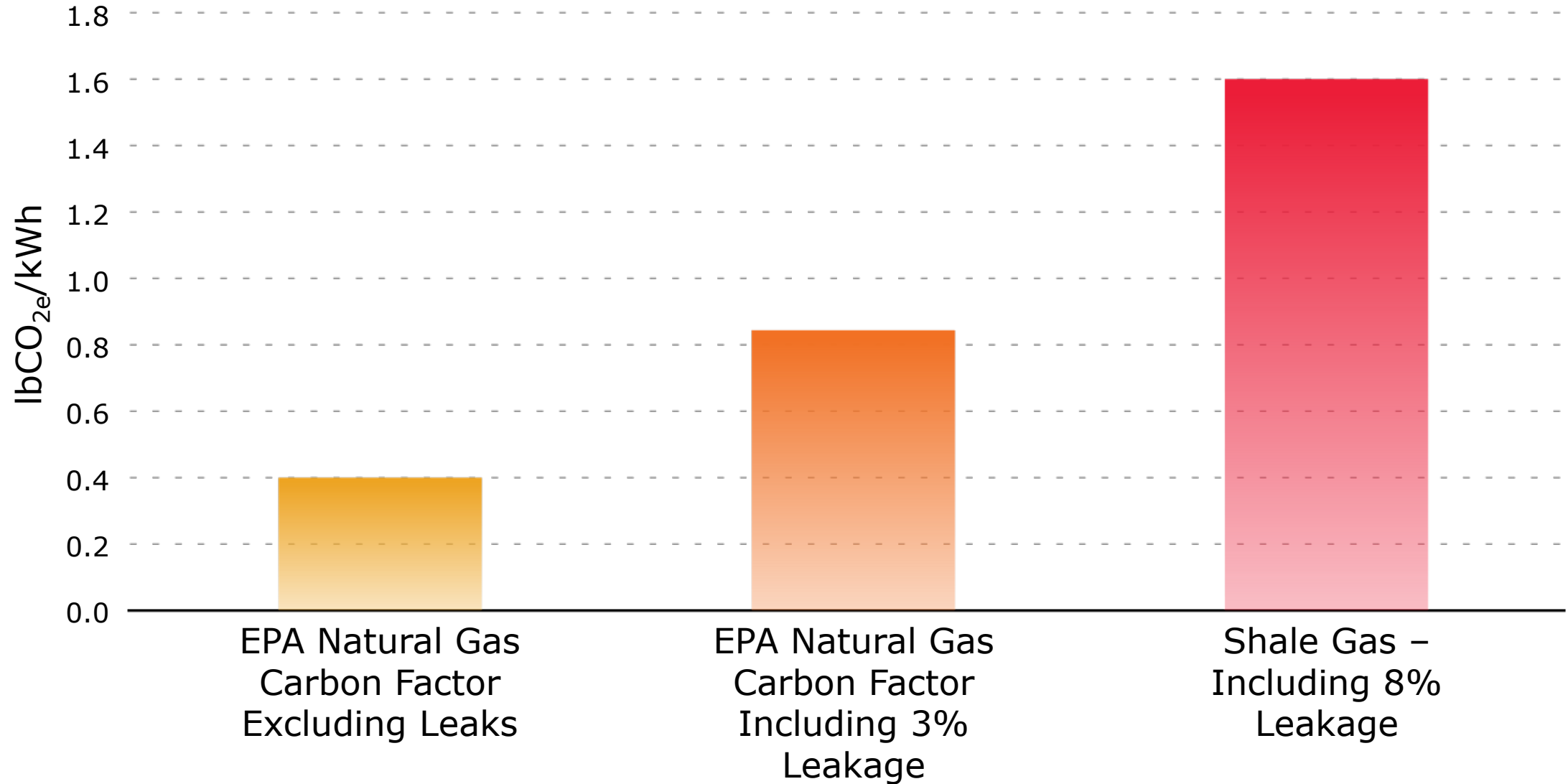
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# Greenhouse Gases | CO<sub>2</sub> Equivalent (100 yr GWP)



**Carbon dioxide equivalent (CO<sub>2</sub>e)** - the amount of CO<sub>2</sub> which would have the equivalent global warming impact.

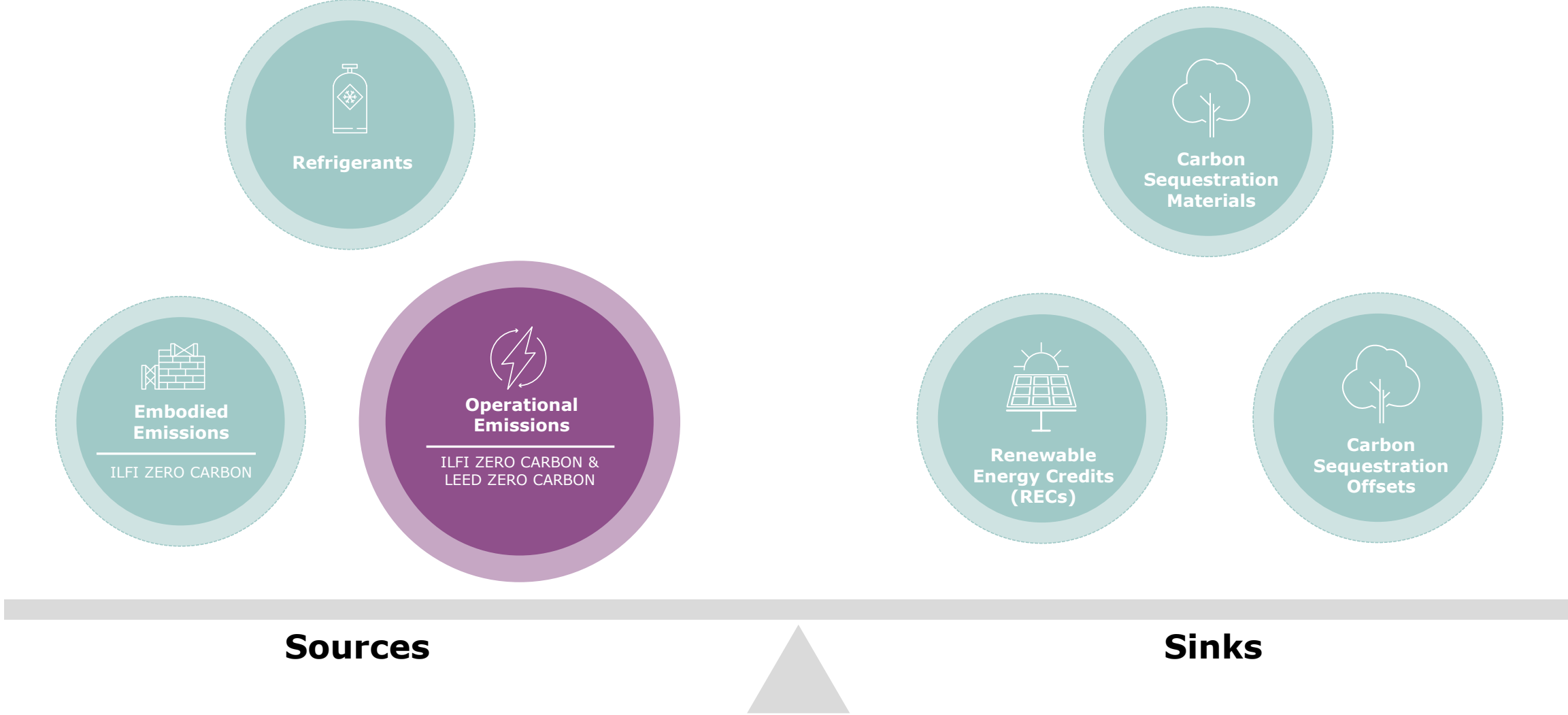
# Greenhouse Gases | THE IMPACT OF METHANE (NATURAL GAS) LEAKAGE (20 Yr GWP)



# Carbon Balance | EMISSIONS AND OFFSETS

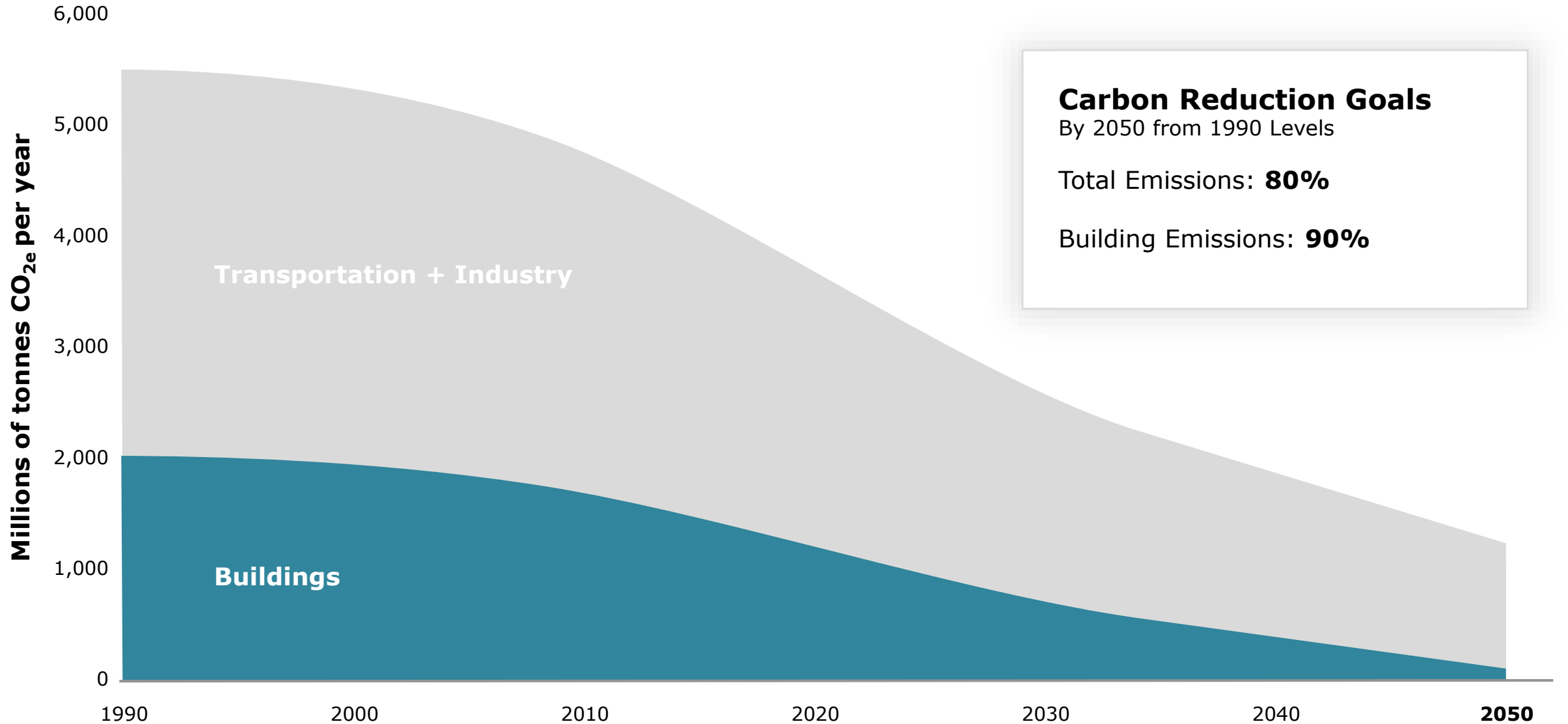


# Carbon Balance | OPERATIONAL CARBON



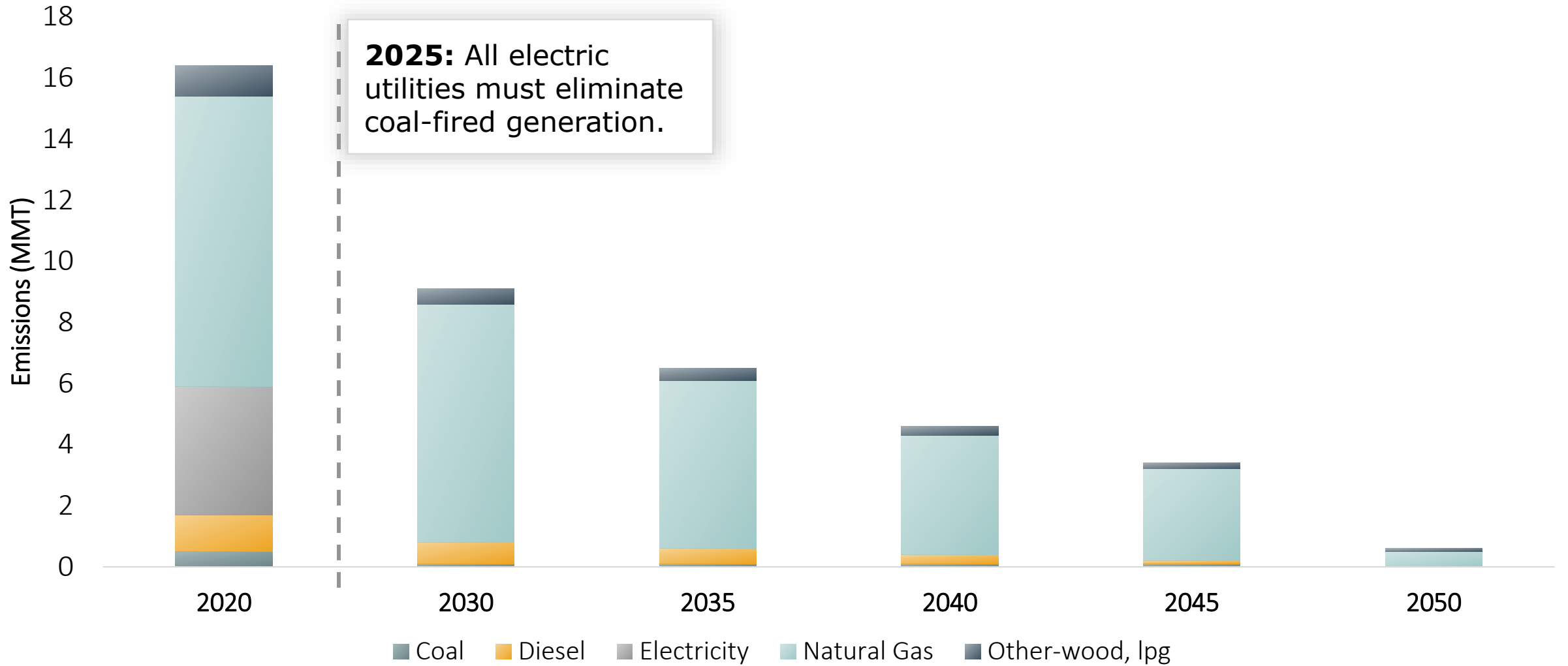
# US Greenhouse Gas Emissions

NRDC PATHWAY TO 2050



# Washington State Clean Energy Transformation Act *(SB 5116, 2019)*

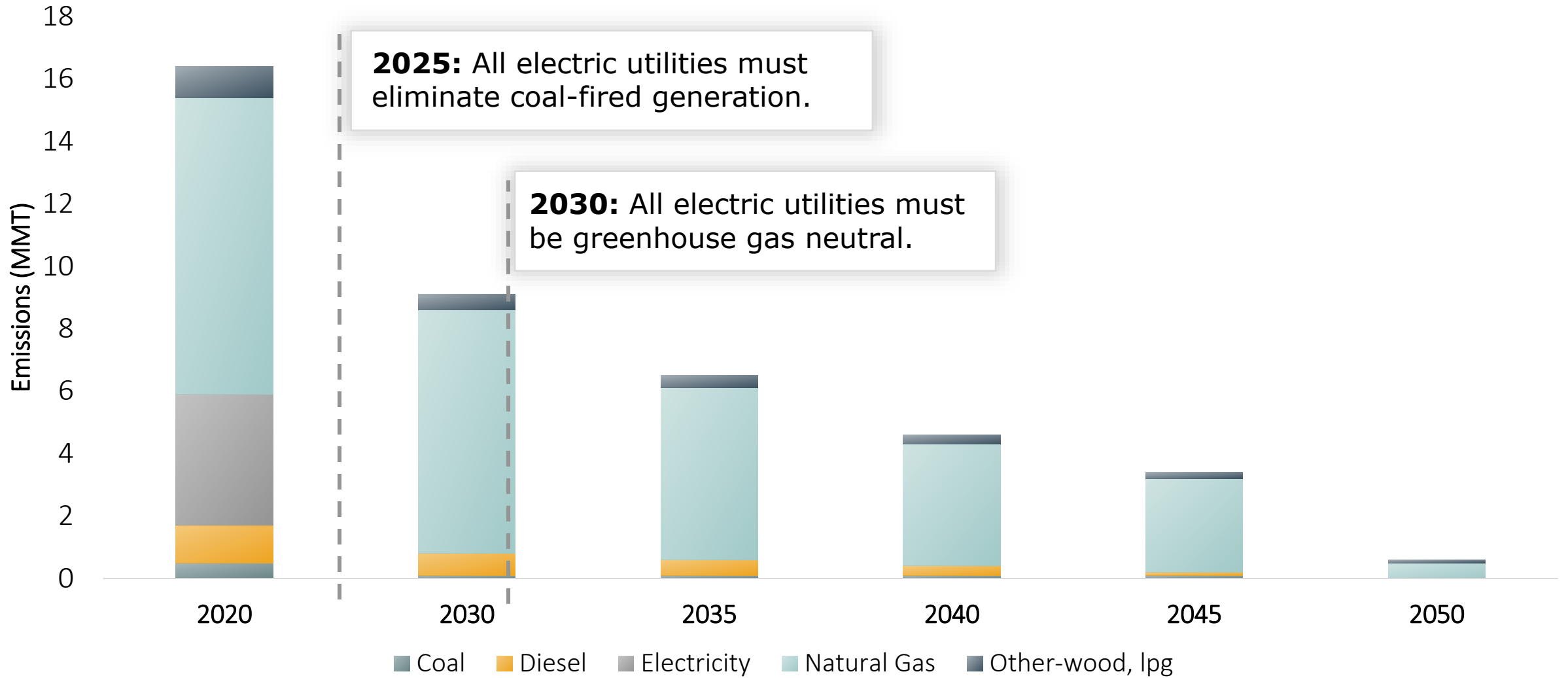
## Building Emissions by Fuel Type





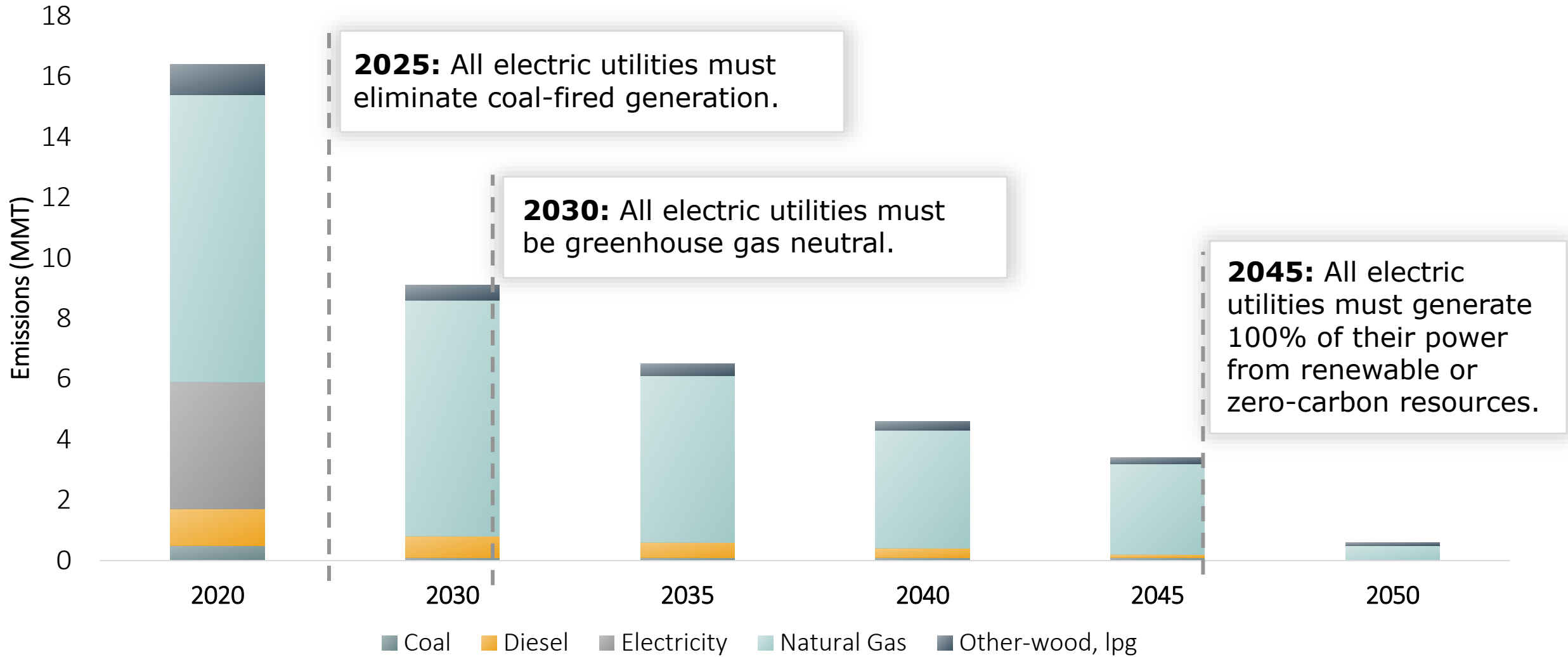
# Washington State Clean Energy Transformation Act *(SB 5116, 2019)*

## Building Emissions by Fuel Type



# Washington State Clean Energy Transformation Act *(SB 5116, 2019)*

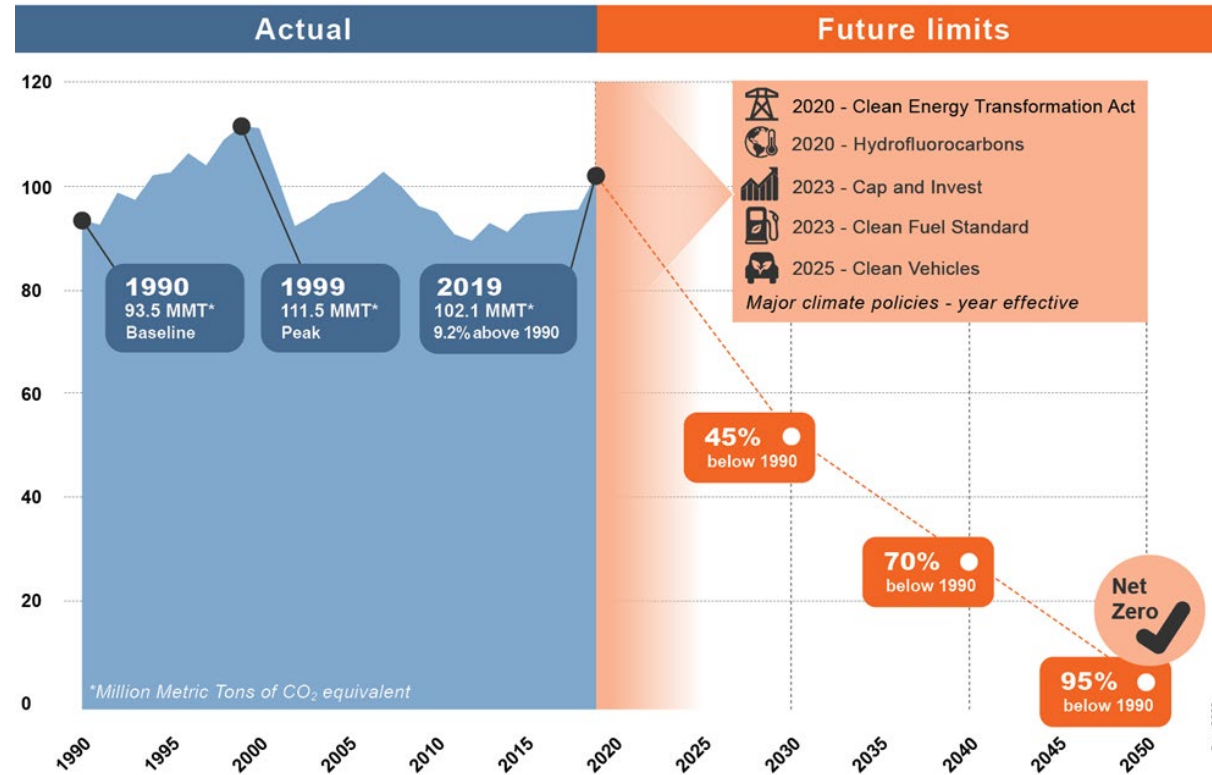
## Building Emissions by Fuel Type





# Code Implications

# Tracking Washington's Greenhouse Gases



Source: <https://ecology.wa.gov/Air-Climate/Reducing-Greenhouse-Gas-Emissions/Tracking-greenhouse-gases/GHG-inventories>

## What does the Energy Code Target?

- Energy efficiency
- Decarbonization
- Electrification
- Demand flexibility

### ALIGNS WITH...

- WA Climate Commitment Act (NET-ZERO BY 2050)
- Clean Buildings Act
- Washington 2021 State Energy Strategy

# Existing Building Alterations in Seattle

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- Change in Space Conditioning or Change in Occupancy
  - Envelope upgrade of impacted building areas
  - C406 Additional Efficiency Packages
- Full Substantial Alteration
  - Seismic upgrade
  - Envelope upgrade of entire building
  - C406 Additional Efficiency Packages



# What is a Substantial Alteration?

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Remodeling or additions that **substantially extend the useful physical and/or economic life of the building** or a significant portion of the building, other than typical tenant remodeling

- Repair of a building with a damage ratio of 60% or more
- Re-occupancy of a building that has been substantially vacant for more than 24 months in occupancies other than group R-3



# New Code Adoptions

2021 Washington State Energy Code – March 15<sup>th</sup> 2024

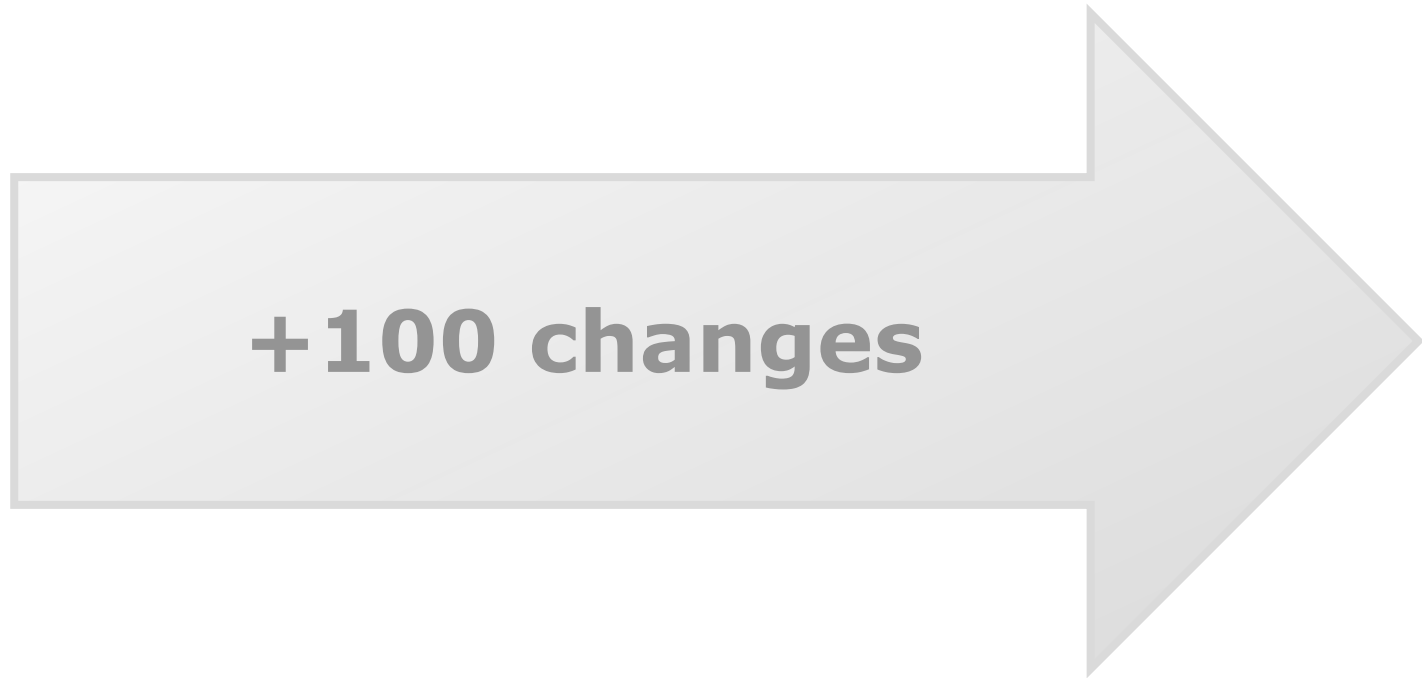
2021 Seattle Energy Code – July 1<sup>st</sup> 2024



**WSEC  
2018  
SEC**

**+100 changes**

**WSEC  
2021  
SEC**



# High Impact Energy Code Changes



**Space Heating**

C403.1.4



**Renewable  
Energy**

C411



**Heat Pump  
Domestic  
Water Heating**

C404



**Energy Efficiency  
and Load  
Management**

C406



**Building  
Performance**

C407



**Air  
Leakage**

C402.5



**Glazed  
Assembly  
Performance**

C402.4



**Exterior  
Lighting Power  
Allowances**

C405



# Fossil Fuel Compliance Path

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## Fossil Fuel Compliance Path Additional C406 Credits

OCCUPANCY GROUPS	R-1	R-2	B	E	M	OTHER
Baseline Credits	54	41	42	48	74	49
Fossil fuel space heating additional credits	+7	+24	+101	+38	+111	+56
Fossil fuel service water heating additional credits	+198	+212	+27	+17	+79	+107



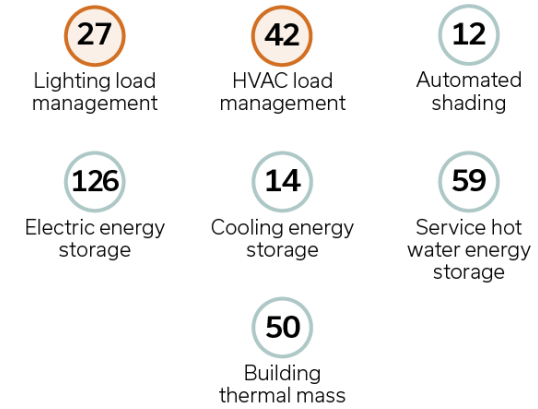
# C406 Washington State Energy Code

## C406

### Energy Efficiency | REQUIRES 42 CREDITS



### Load Management | REQUIRES 27 CREDITS



NOTE: LOAD MANAGEMENT CREDITS ARE NOT REQUIRED FOR TI PROJECTS

#### LEGEND

- Shell + Core
- Shell + Core and TI
- POPULAR CREDITS
- Shell + Core
- Shell + Core and TI

NOTE: ABOVE IS FOR B OCCUPANCY. CREDIT REQUIREMENTS VARY BY OCCUPANCY.

### Credit Requirements by Occupancy

OCCUPANCY GROUPS	R-1	R-2	B	E	M	Other
New Building Energy Efficiency	54	41	42	48	74	49
Building Additions Energy Efficiency	27	20	21	23	36	21
New Building Load Management	12	15	27	15	13	26

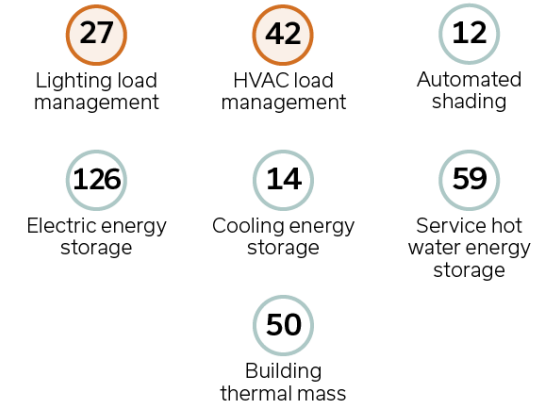
# C406 with Fossil Fuel Heating System

# C406 with Fossil Fuel Heating System

### Energy Efficiency | REQUIRES 143 CREDITS



### Load Management | REQUIRES 27 CREDITS



NOTE: LOAD MANAGEMENT CREDITS ARE NOT REQUIRED FOR TI PROJECTS

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- Shell + Core and TI
- POPULAR CREDITS
- Shell + Core
- Shell + Core and TI

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# WA Clean Buildings Act

# WA Clean Buildings Act Timeline

Bill signed into law



MAY 7, 2019

Building owners notified of compliance schedule



JULY 1, 2021

NOVEMBER 1, 2020



EUI targets published

JULY 2021-26



Voluntary incentive program

## MANDATORY COMPLIANCE FOR COMMERCIAL BUILDINGS...

220,000sf and bigger



JUNE 1, 2026

50,000sf and bigger



JUNE 1, 2028

JUNE 1, 2027



90,000sf and bigger

*\*Standard to be updated July 1, 2029 and every fifth year thereafter.*

# How to Comply for Mandatory Requirements

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## 3 OPTIONS FOR COMPLIANCE



Exemption



Hitting target EUI



Investment Criteria

# Choose Not to Comply?



Pay this every  
**5 years!**

50,000 ft<sup>2</sup> Building pays **\$80,000**

100,000 ft<sup>2</sup> Building pays **\$155,000**

150,000 ft<sup>2</sup> Building pays **\$230,000**

250,000 ft<sup>2</sup> Building pays **\$380,000**

An architectural rendering of a modern university campus. The scene features a central courtyard with a paved walkway, green spaces, and several tall, slender evergreen trees. People are depicted walking and interacting in the courtyard. In the background, there are several multi-story buildings. One building is constructed of light-colored brick with a grid of windows. Another building is taller and features a prominent glass facade with a dark frame. The sky is blue with scattered white clouds. The overall atmosphere is bright and active.

# Building Emissions Performance Standard

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# What's the Timeline for Compliance?

## Seattle Building Emissions Performance Standard (BEPS)

2022 - 2026	2027 - 2030	2031 - 2035	2036 - 2040	2041 - 2045	2046 - 2050	
Policy Development / Support Program	Verify Energy & Emissions, Plan, and Start Reductions	Nonresidential Emissions Targets			Net-Zero Targets	
		Multifamily Emissions Targets*			Net-Zero Targets	
Director's Rule Mid-2024-2025	Support & Early Adopter Incentives	*Extension for affordable housing & human services until 2036-2040 to meet targets.				

## State of WA Clean Buildings Performance Standard

2026 - 1 <sup>st</sup> Energy Targets Commercial >50K	2031 >> Future Energy Targets - To be Determined by Rule Commercial & Multifamily >20K
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# Existing Buildings



# 419 Occidental

SEATTLE, WA

## → QUICK STATS

<b>OWNER</b>	City of Seattle
<b>ARCHITECT</b>	SHED Architecture & Design
<b>PROGRAM</b>	Commercial
<b>PAE SCOPE</b>	Mechanical, Electrical, Plumbing
<b>DELIVERY</b>	Design Build
<b>SIZE</b>	99,440 sf



LEED Platinum

1901

Building Built



PV Array

7

Stories



Historic Renovation



HOTEL WEST

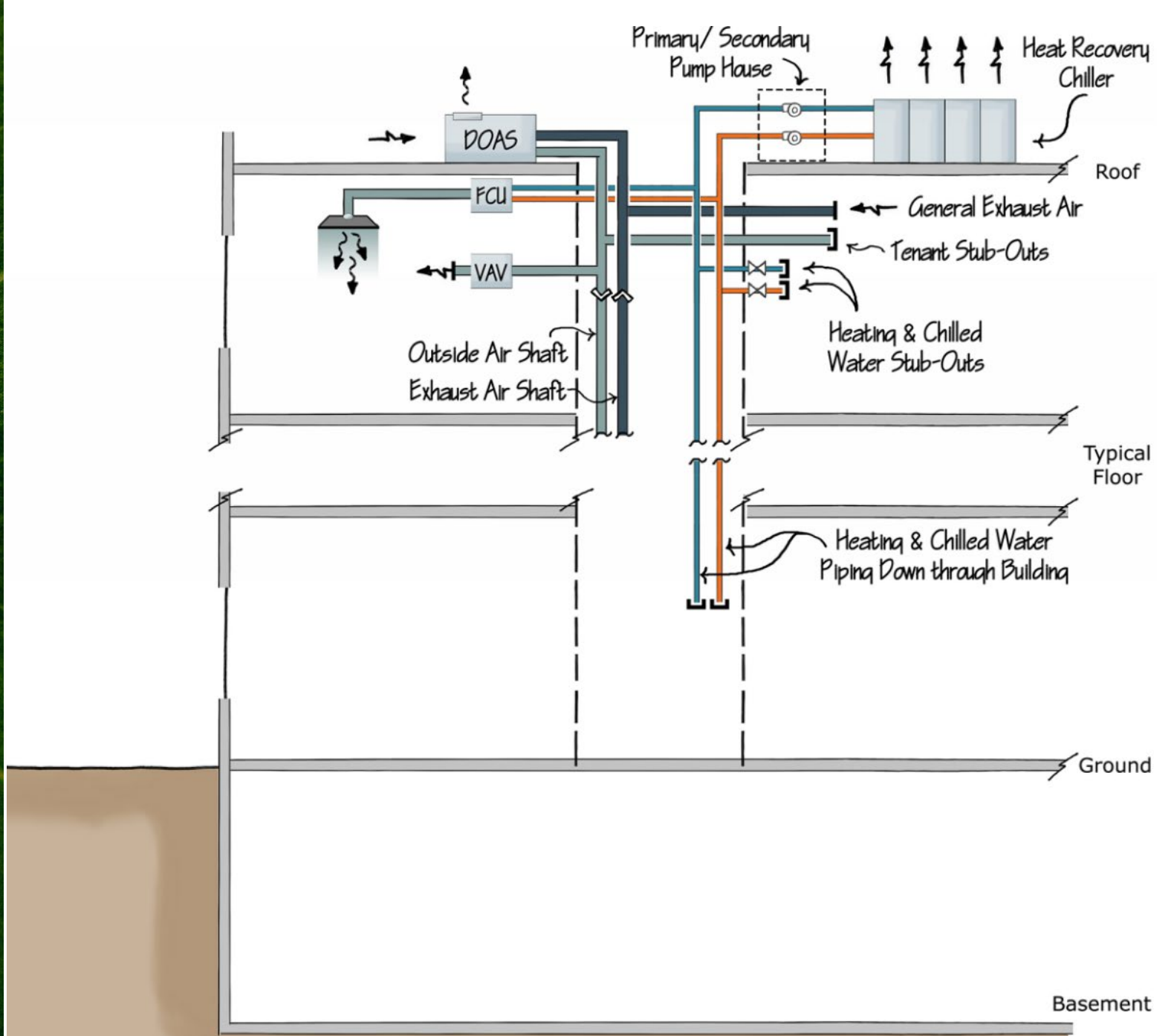
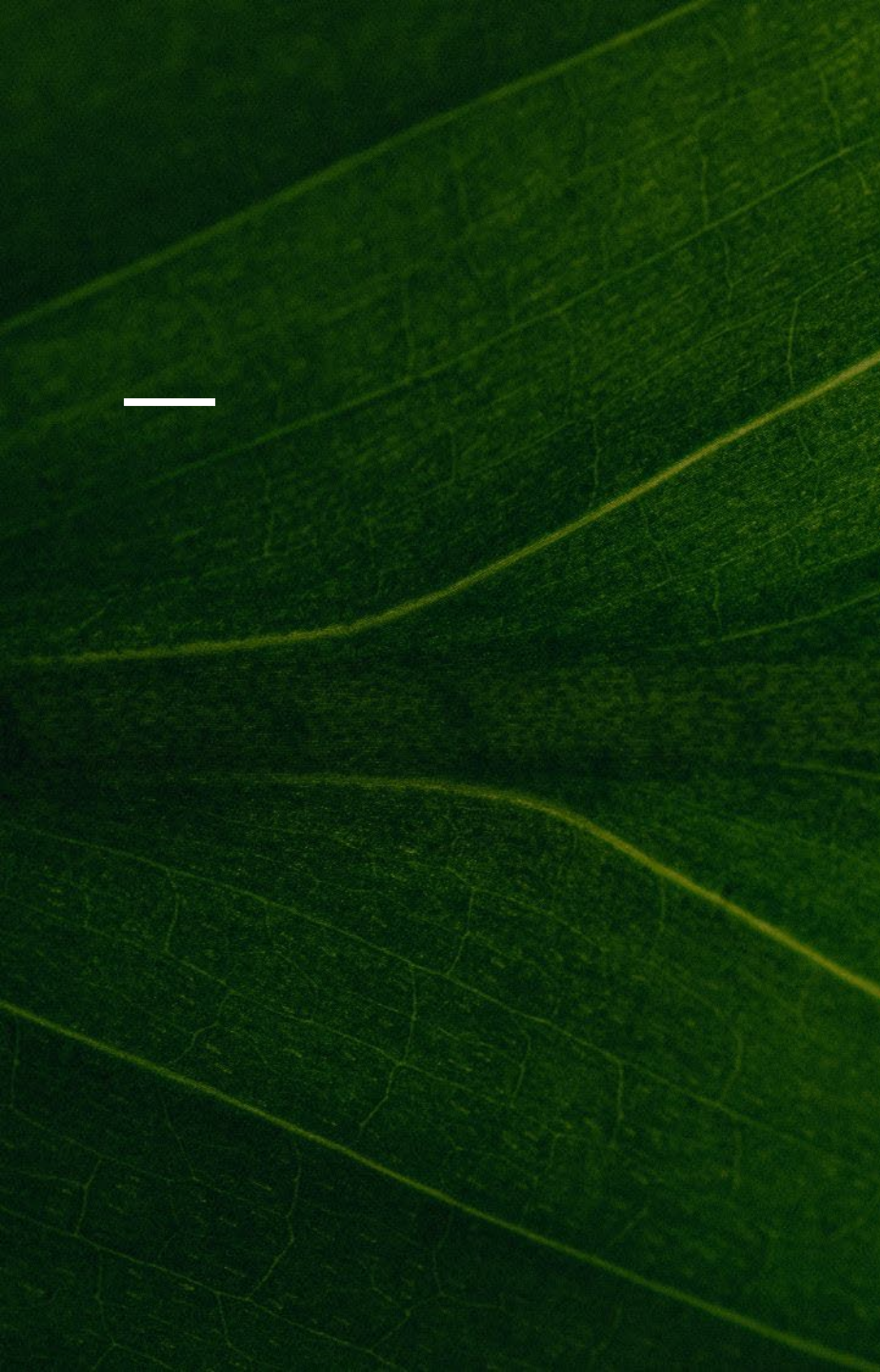
115

BORZE

BORZE

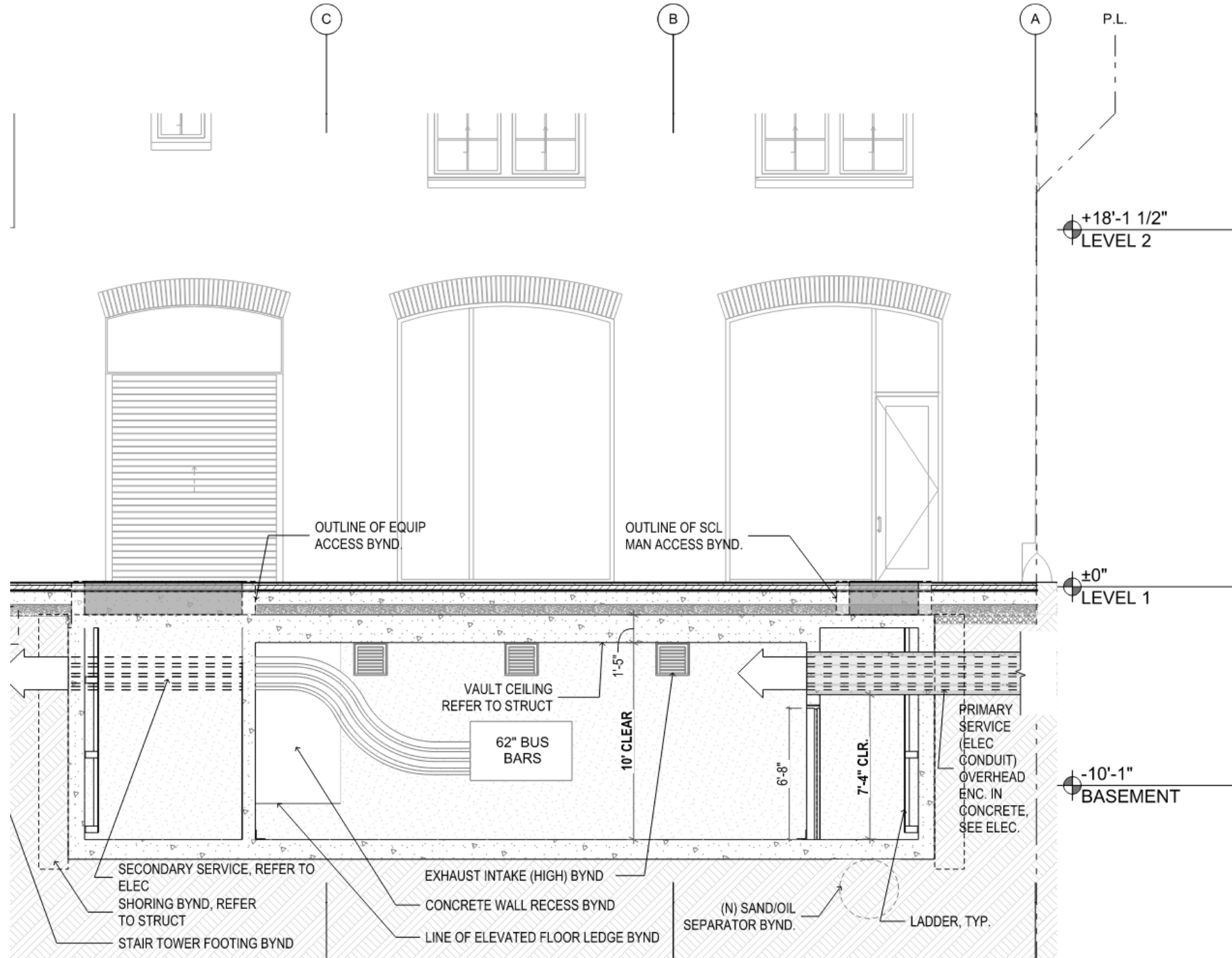
KASOOK books







# SCL Vault



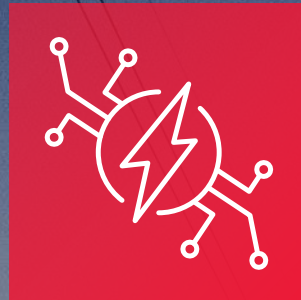


# Electrical Service Negotiation

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Electrical service is often 2-4 times larger than a "typical" building



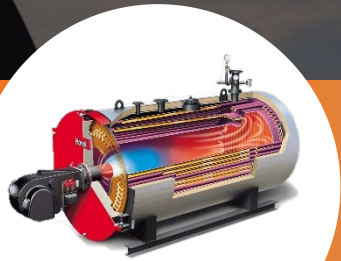


# All-Electric Technologies

# TRADITIONAL GAS FUELED

# ELECTRIC

**Space Heating**



Gas Boiler



Air-Source Heat Pump



VRF

**Domestic Hot Water**



Gas-Fired Water Heater



Air-Source Heat Pump



Water-Source Heat Pump

**Cooking**



Gas Oven



Convection/Combi Oven



Induction Cooking

# Gas vs All-Electric Cooking

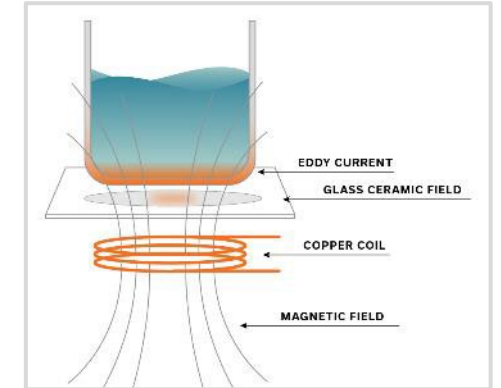
## Gas



## Electric Conduction



## Electric Induction



Gas emissions  
from combustion

No gas emissions  
from combustion

No gas emissions  
from combustion



~40%  
Efficiency

~70%  
Efficiency

~75%  
Efficiency



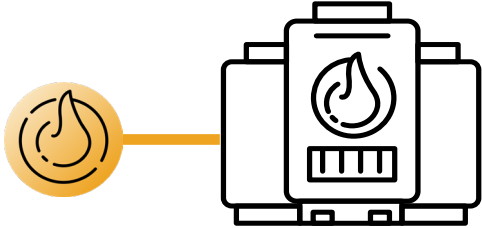
8 minutes to  
boil 0.75L water

7 minutes to  
boil 0.75L

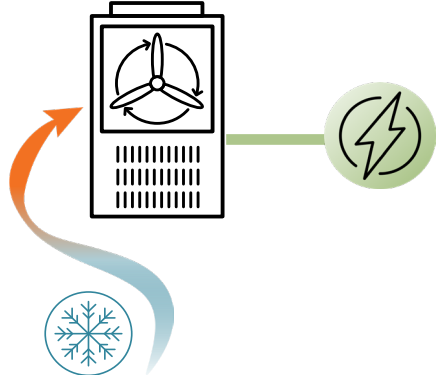
4 minutes to  
boil 0.75L water

# Gas Boilers vs Heat Pumps

**Gas Boiler**  
MAX EFFICIENCY  
~96%



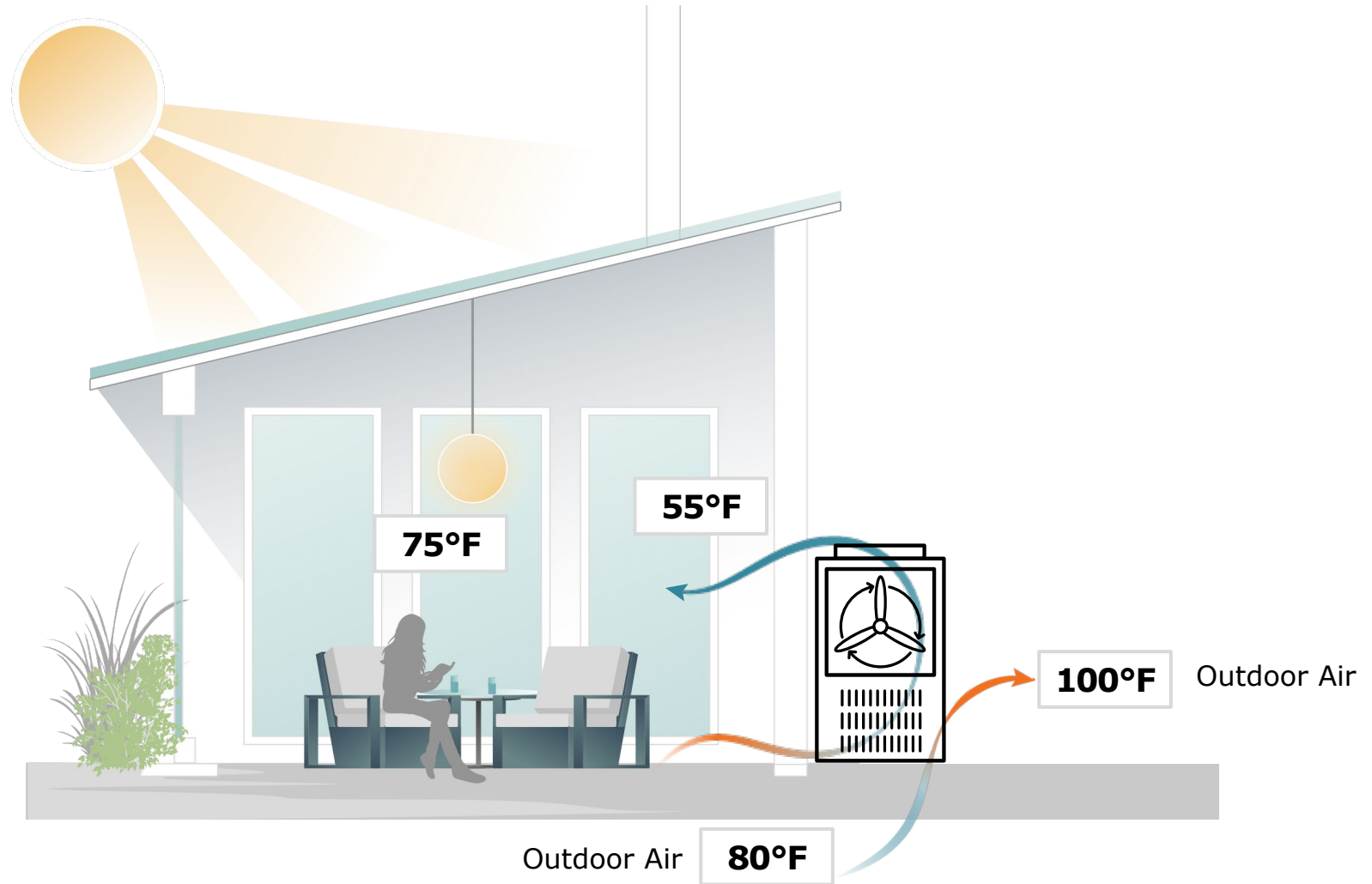
**Heat Pump**  
MAX EFFICIENCY  
>500%



# Heat Pump Applications

Chiller Application | COOLING A SPACE

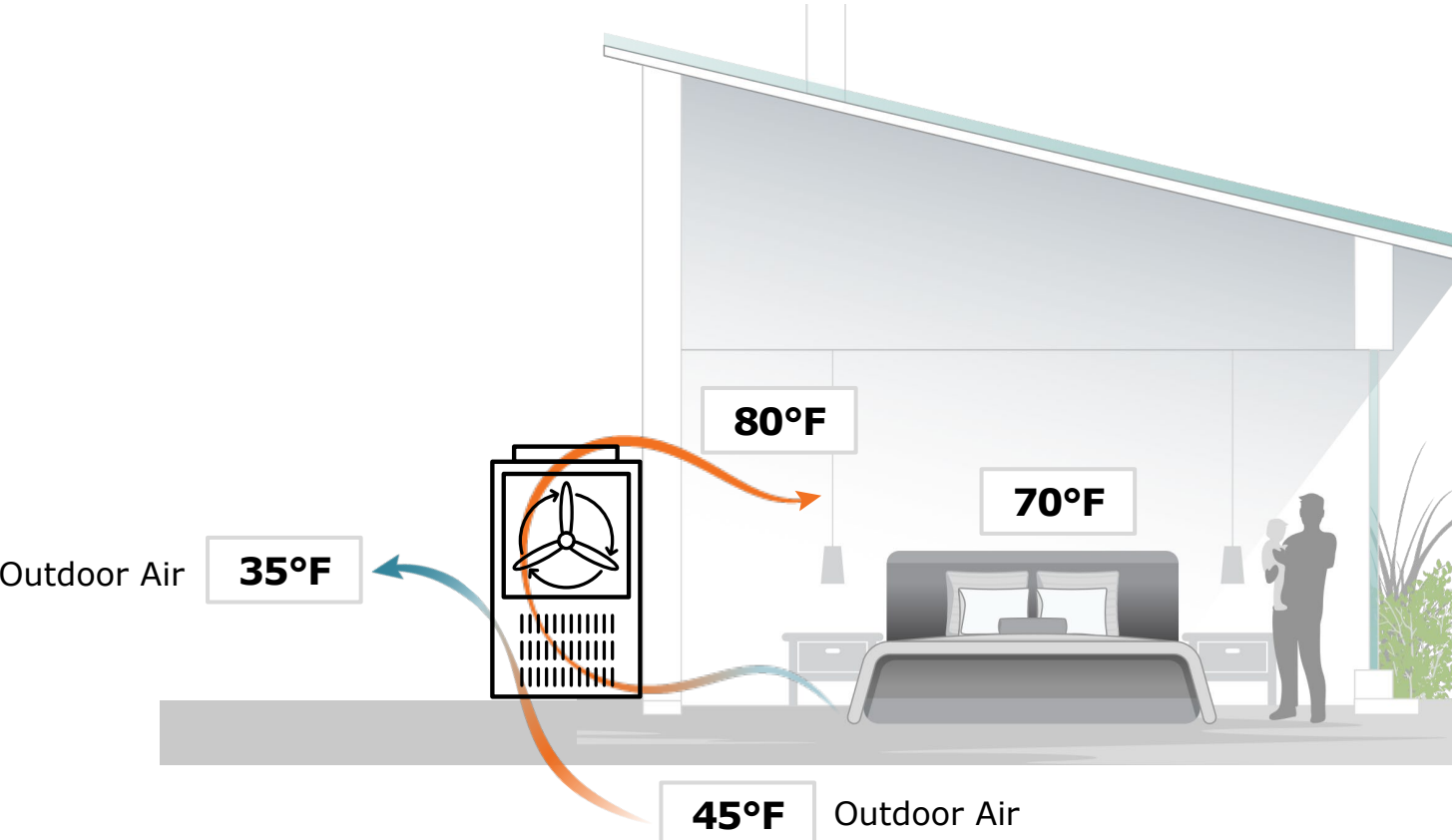
COEFFICIENT OF PERFORMANCE  
~ 3



# Heat Pump Application

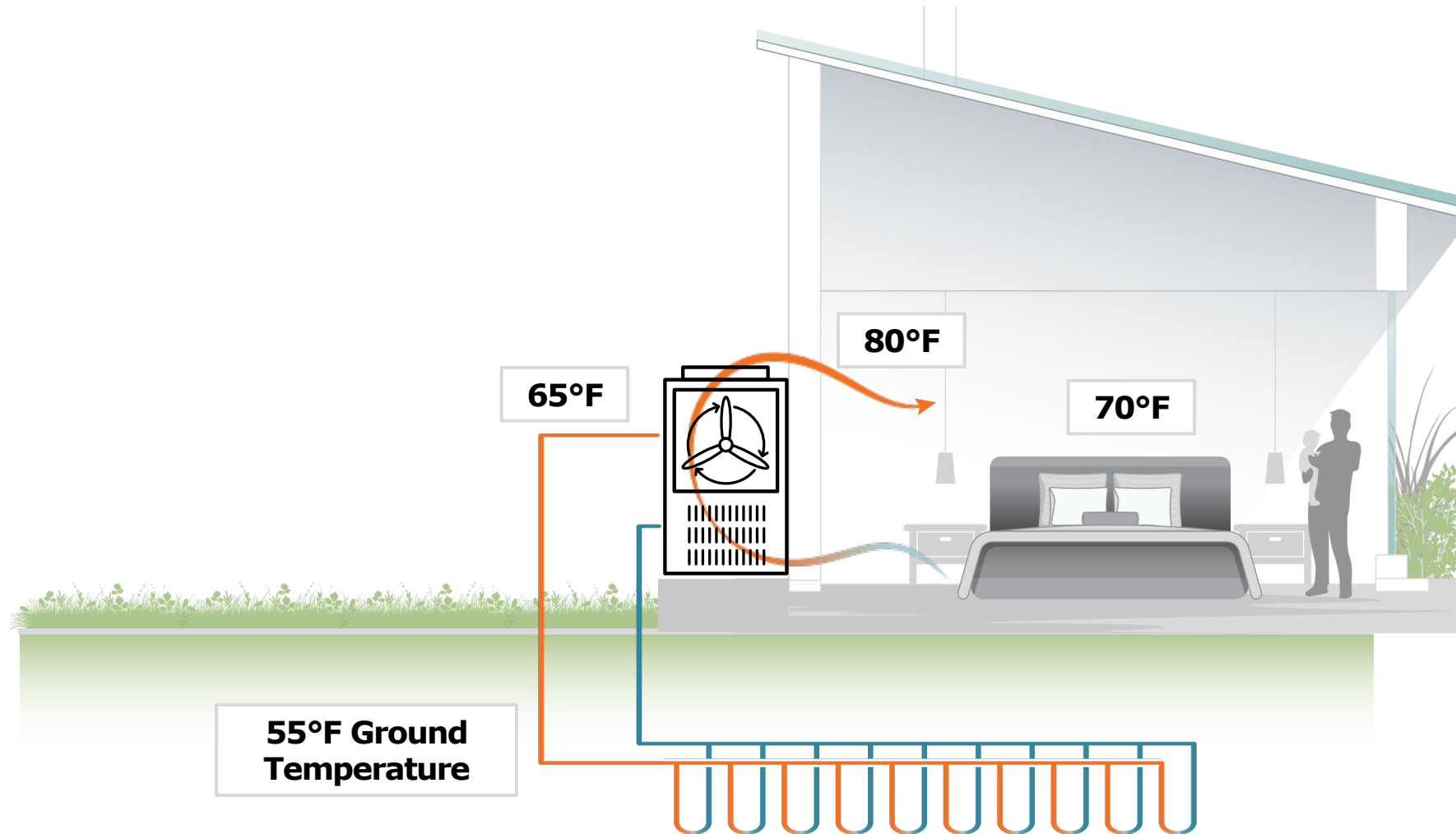
COEFFICIENT OF PERFORMANCE  
~ 3

## Heat Pump Application | WARMING A SPACE



# Adding Geo-Exchange

Geo-Exchange Heat Pump Application | WARMING A SPACE

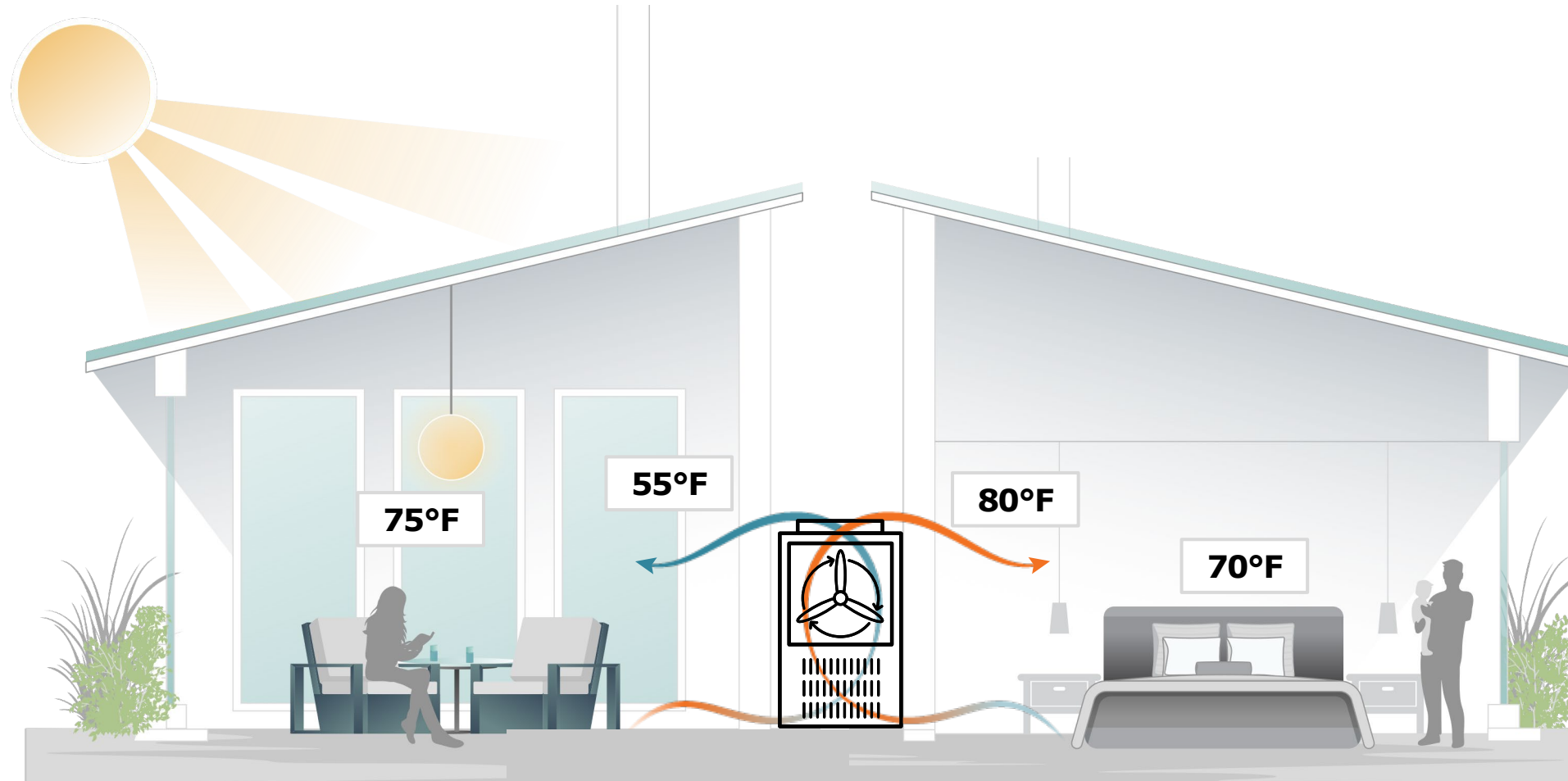




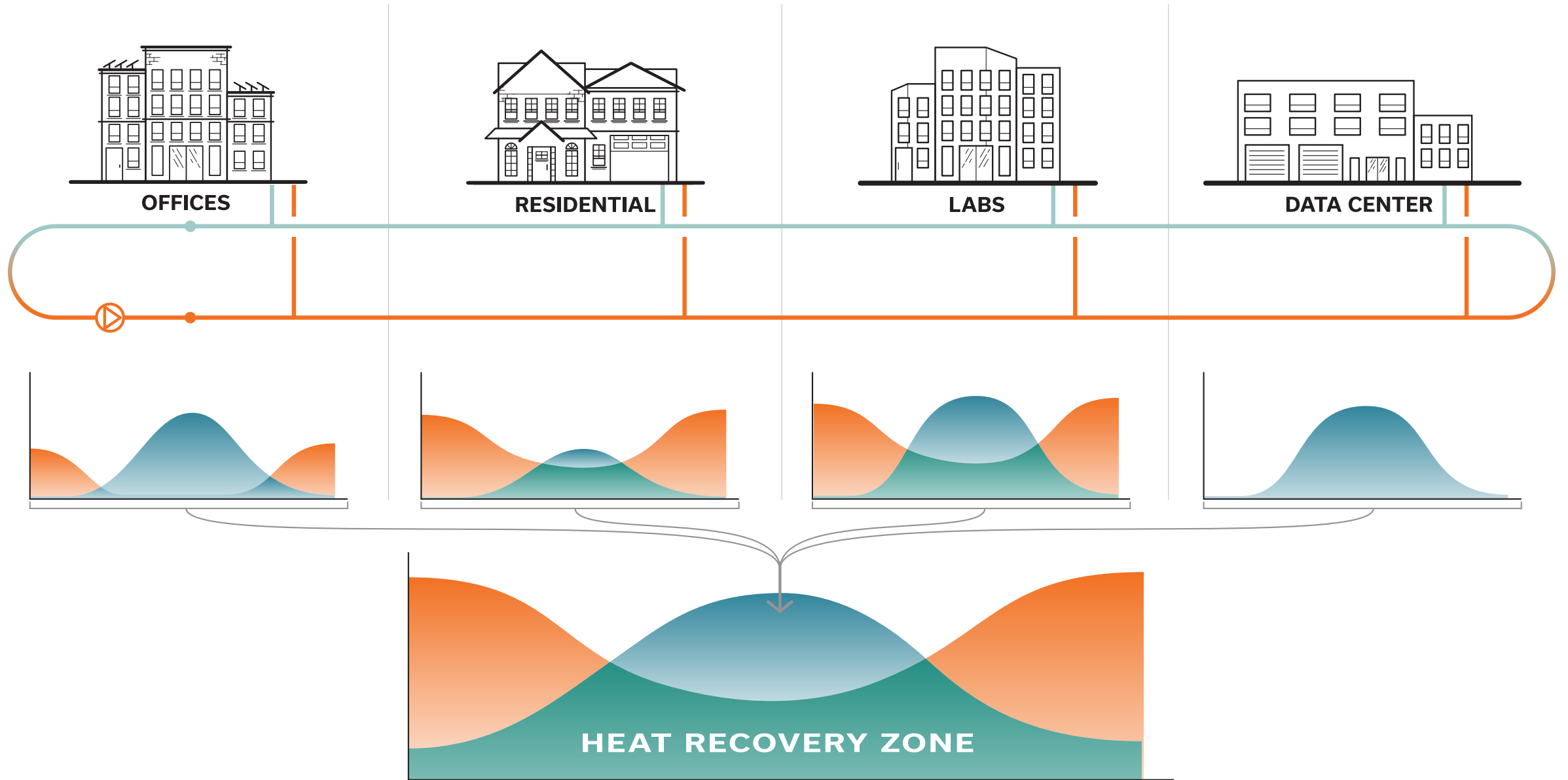
# Heat Recovery Application | SIMULTANEOUS HEATING + COOLING

## Heat Recovery

COEFFICIENT OF PERFORMANCE  
~ 7

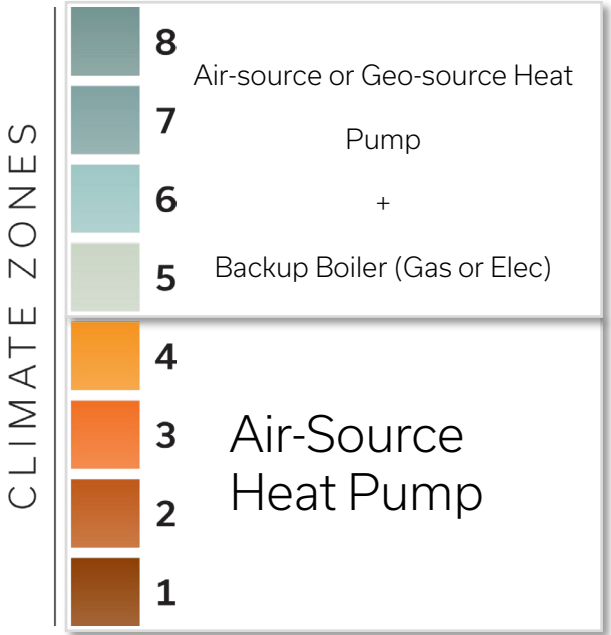
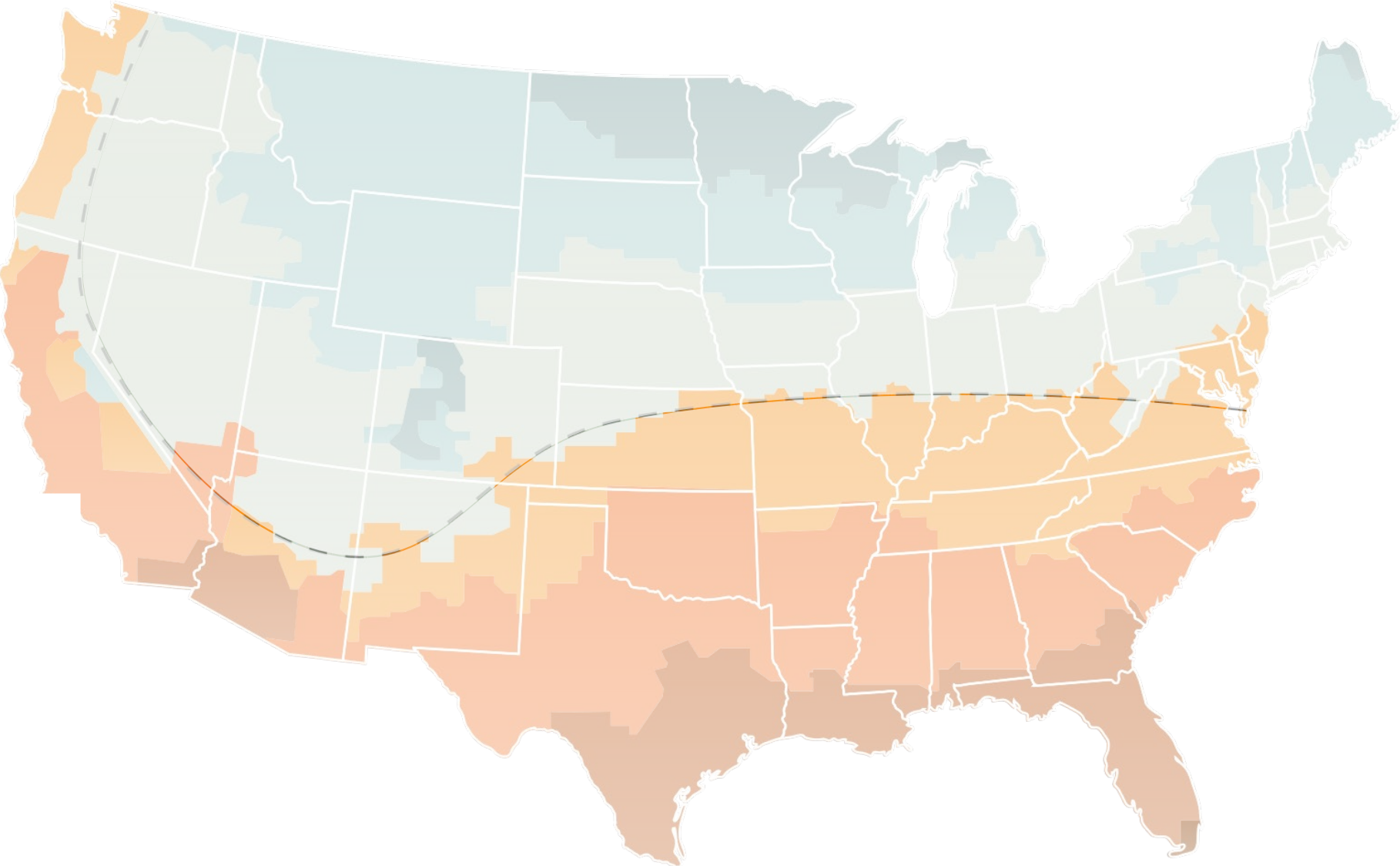


# District Systems | ENERGY SYNERGIES



# Heat Pump

TECHNOLOGY AND CLIMATE



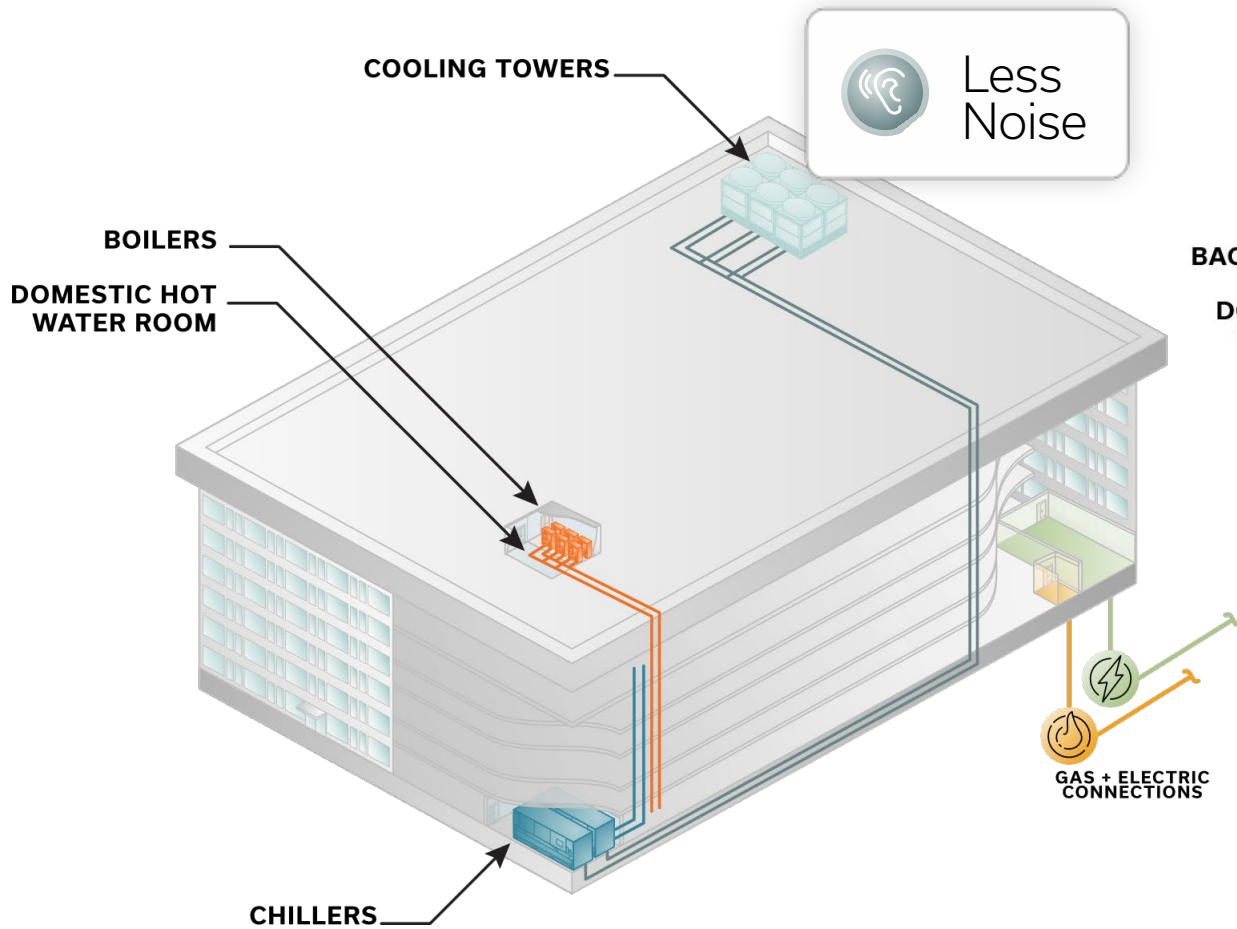
# Future Heat Pump Technology

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- CO2 Heat Pumps
  - Historically Limited to Domestic Hot Water
  - High Supply Water Temperatures
  - Low Ambient Air Operation
  - Commercial size variable capacity operation for heating hot water systems
    - Currently at a cost premium, but can replace traditional condensing boilers and non-condensing boiler systems.
    - No upgrade to distribution and coils

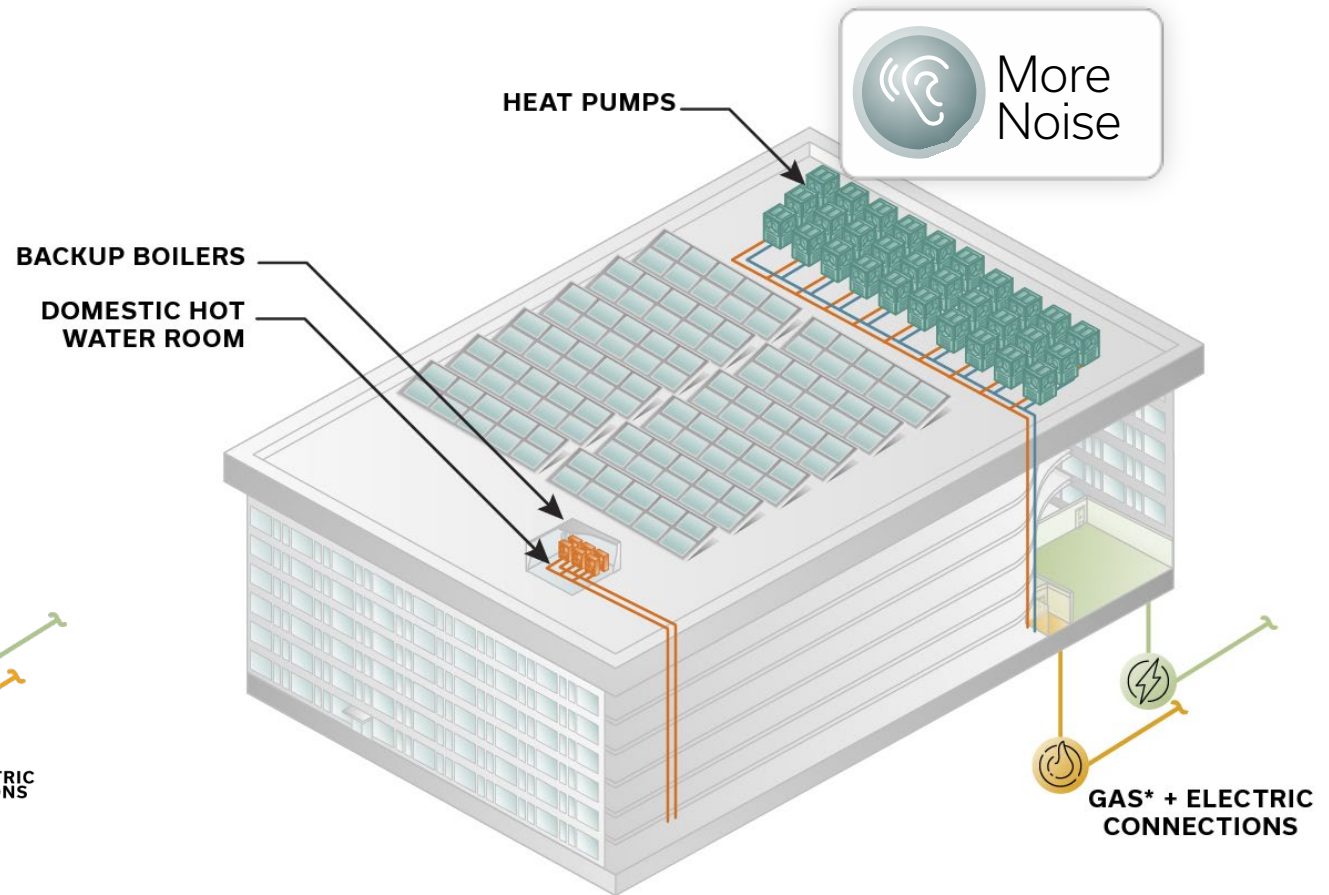


# Architectural Considerations



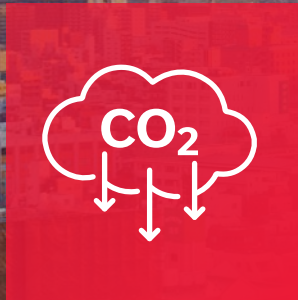
**Traditional Boiler + Chiller**

WARM + COLD CLIMATES



**All Electric HVAC System**

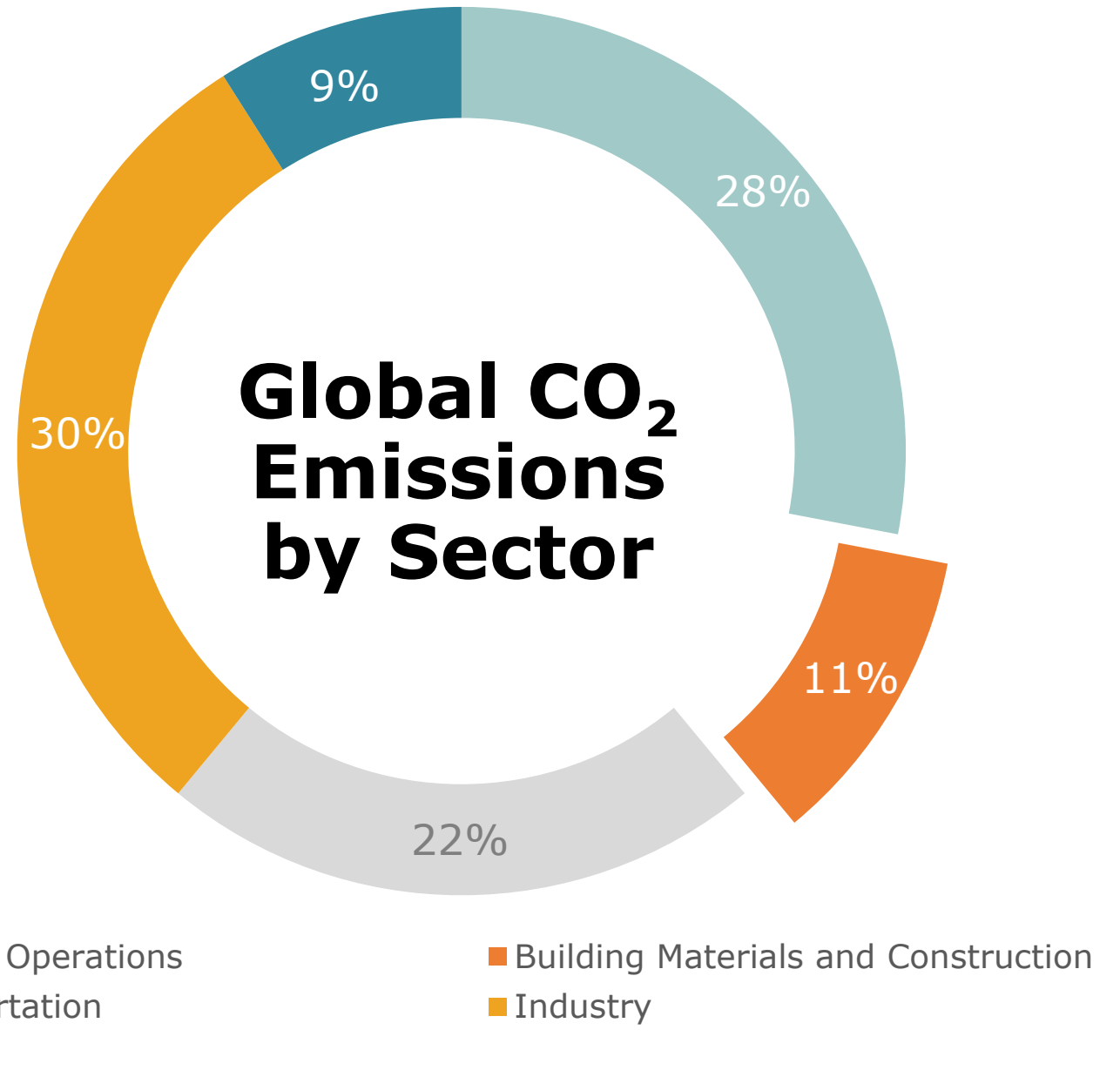
WARM CLIMATE



# Whole Life Carbon

# Embodied Carbon

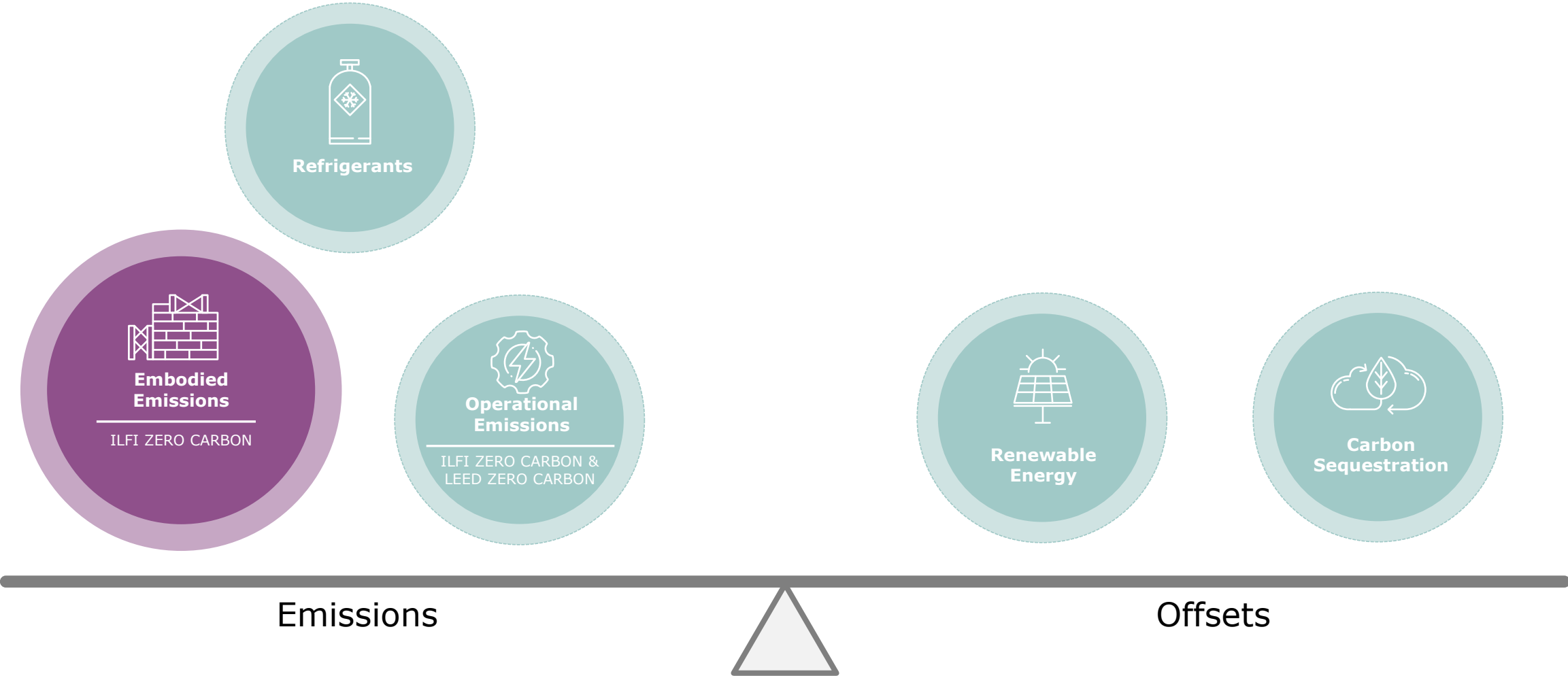
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Source: UN Environmental Global Status Report 2017

# Carbon Balance

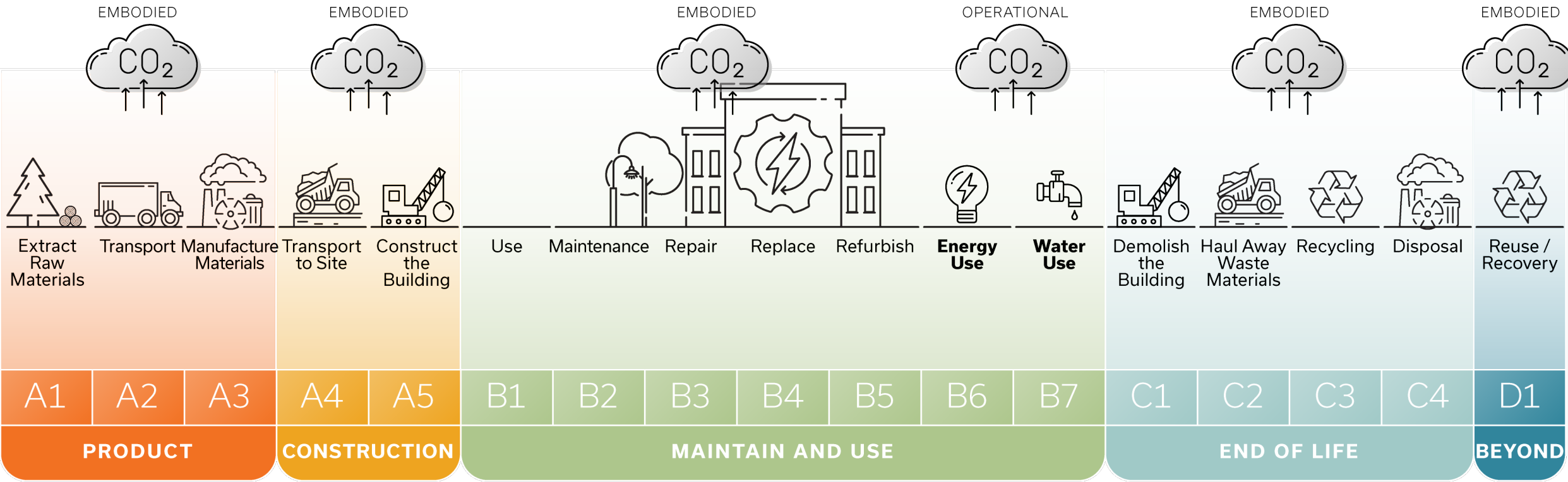
EMBODIED EMISSIONS





# Embodied Carbon

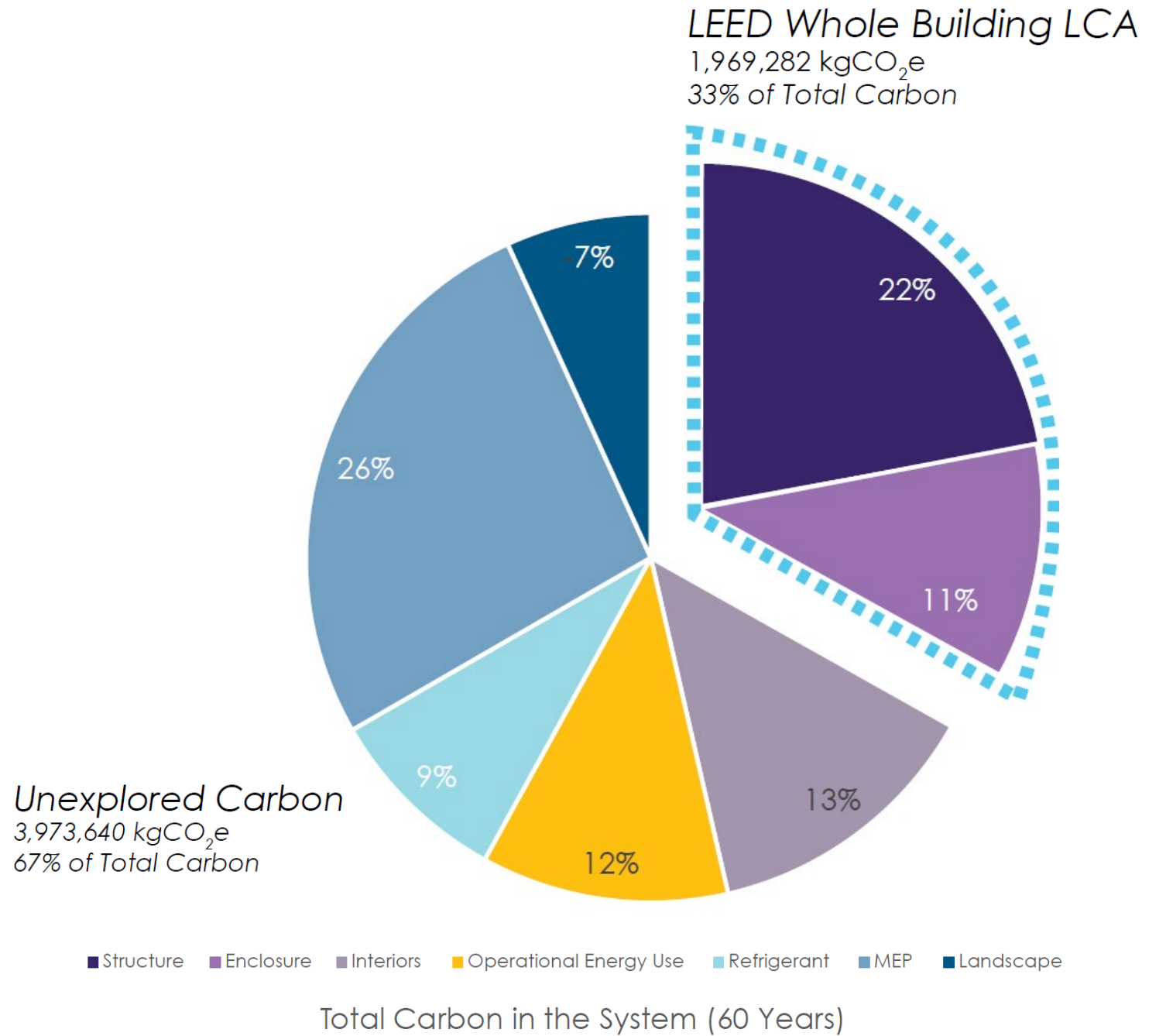
WHAT IS EMBODIED CARBON?



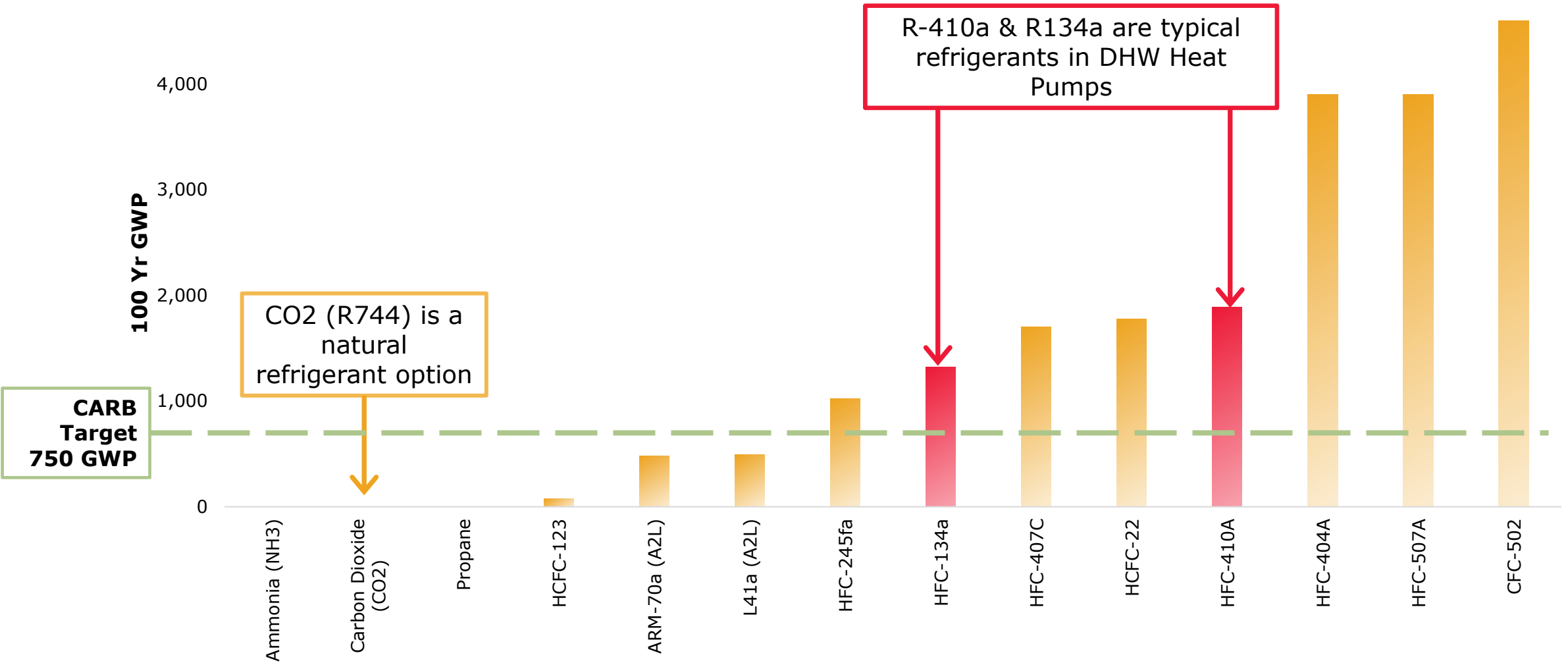
Source: New Buildings Institute

# Lessons Learned

UW TOTAL CARBON STORY

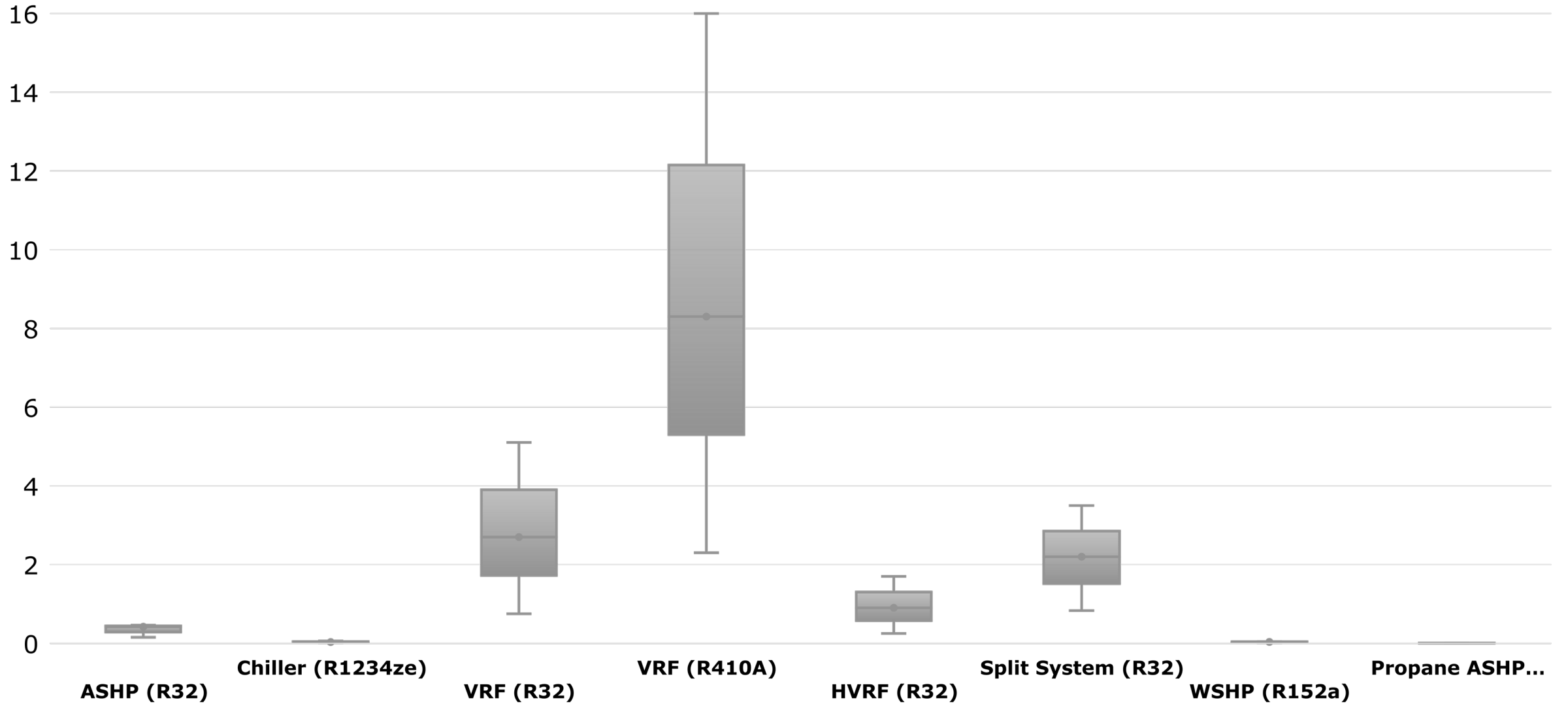


# Refrigerants | GLOBAL WARMING POTENTIAL



# Refrigerants | LEAKAGE IMPACT

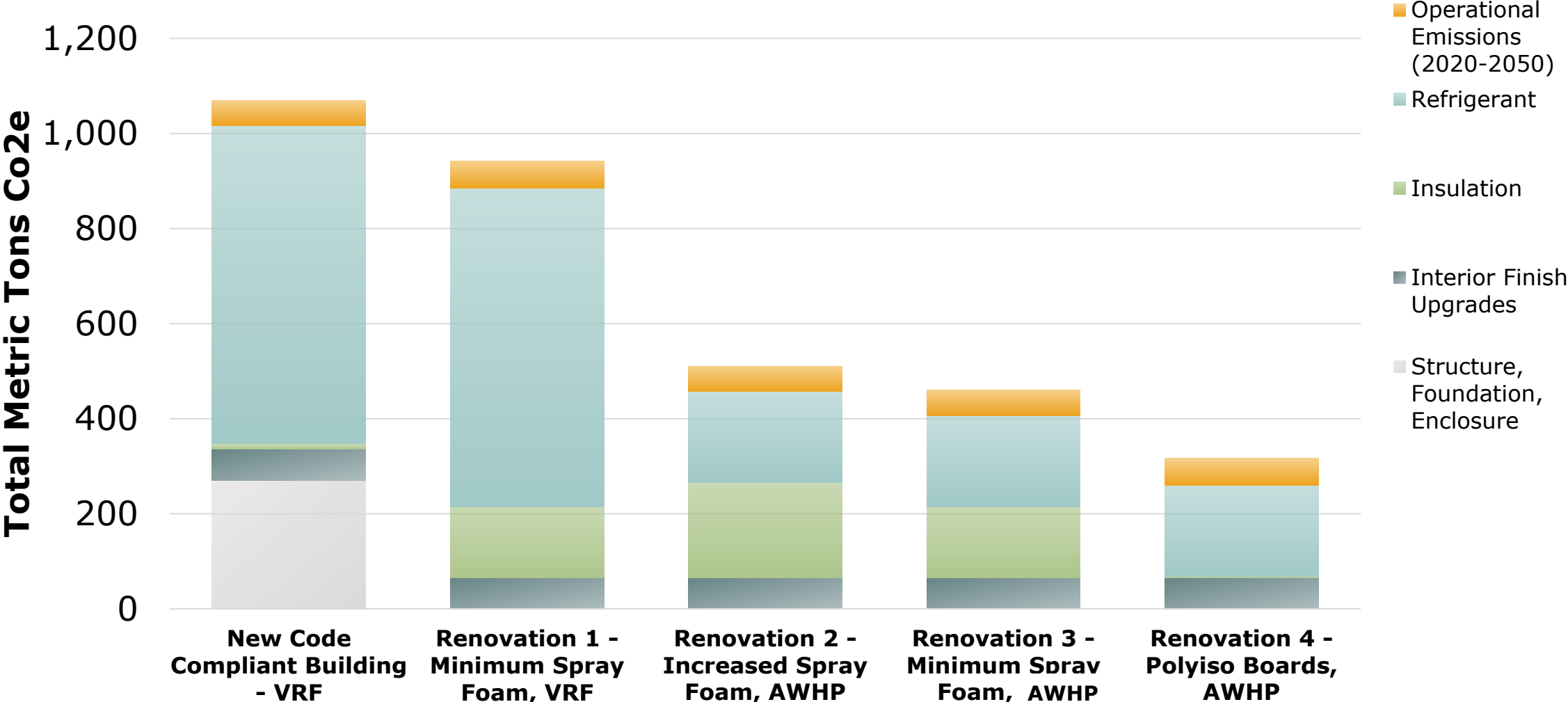
## Leakage Range Emissions (tonnesCO<sub>2e</sub>/kW) Systems Comparison







# Total Carbon Emissions by 2050

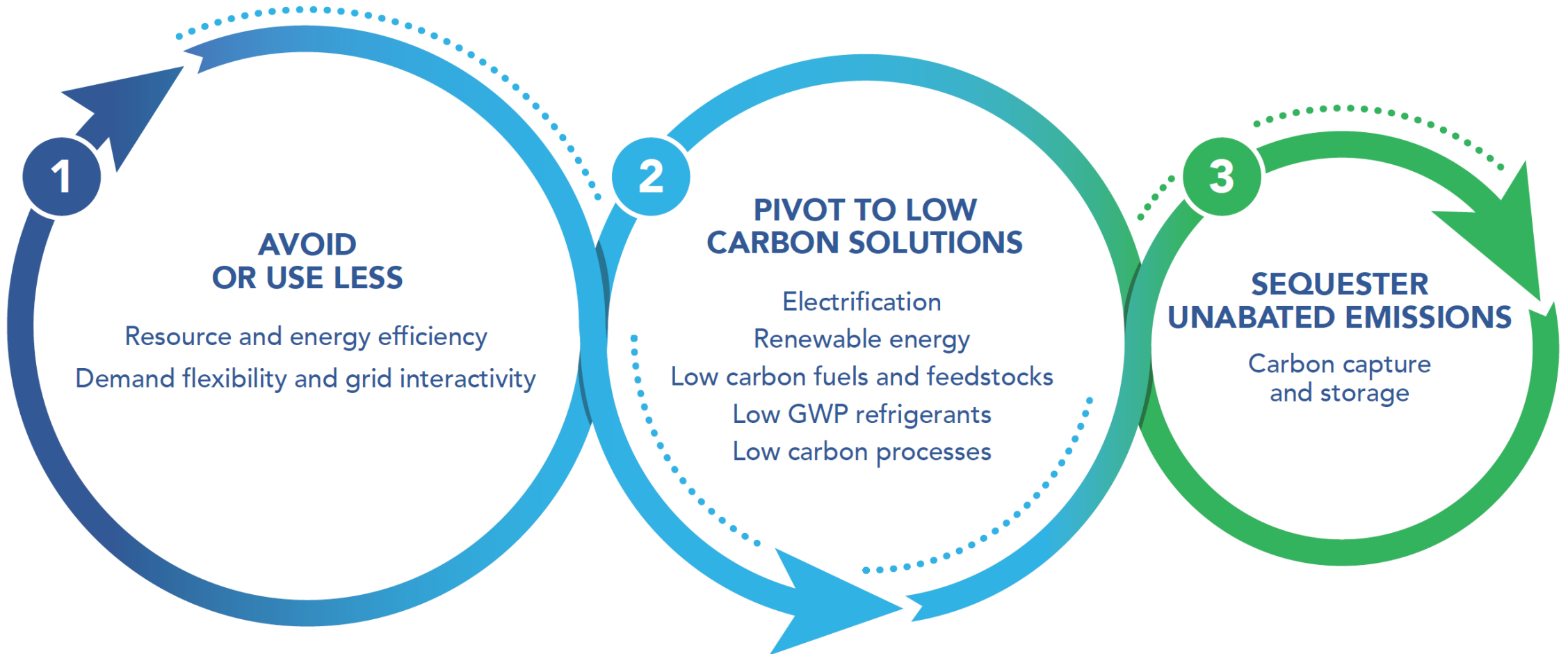




# Building Portfolio Strategies



# Challenge to Organizations Across U.S. Economy



# Challenge to Organizations Across U.S. Economy

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## Portfolio-wide reduction in GHG emissions of *at least* 50% in 10 years

- Reduction includes scope 1 & 2 emissions
- No offsets
- Baseline up to 5-years back from join date
- Focus on absolute targets
- Pursue an energy efficiency target that will contribute towards the 50% emissions reduction.
- Sharing of solutions, barriers, and innovations



# Why is a GHG Emissions Reduction Planning Framework needed?



**CLIMATE ACTION PLAN  
OR SUSTAINABILITY PLAN**



**BUILDING-LEVEL EMISSIONS  
REDUCTION AUDIT**

# Why is a GHG Emissions Reduction Planning Framework needed?



**CLIMATE ACTION PLAN  
OR SUSTAINABILITY PLAN**

**GAP!**



**BUILDING-LEVEL EMISSIONS  
REDUCTION AUDIT**

# Why is a GHG Emissions Reduction Planning Framework needed?



**CLIMATE ACTION PLAN  
OR SUSTAINABILITY PLAN**



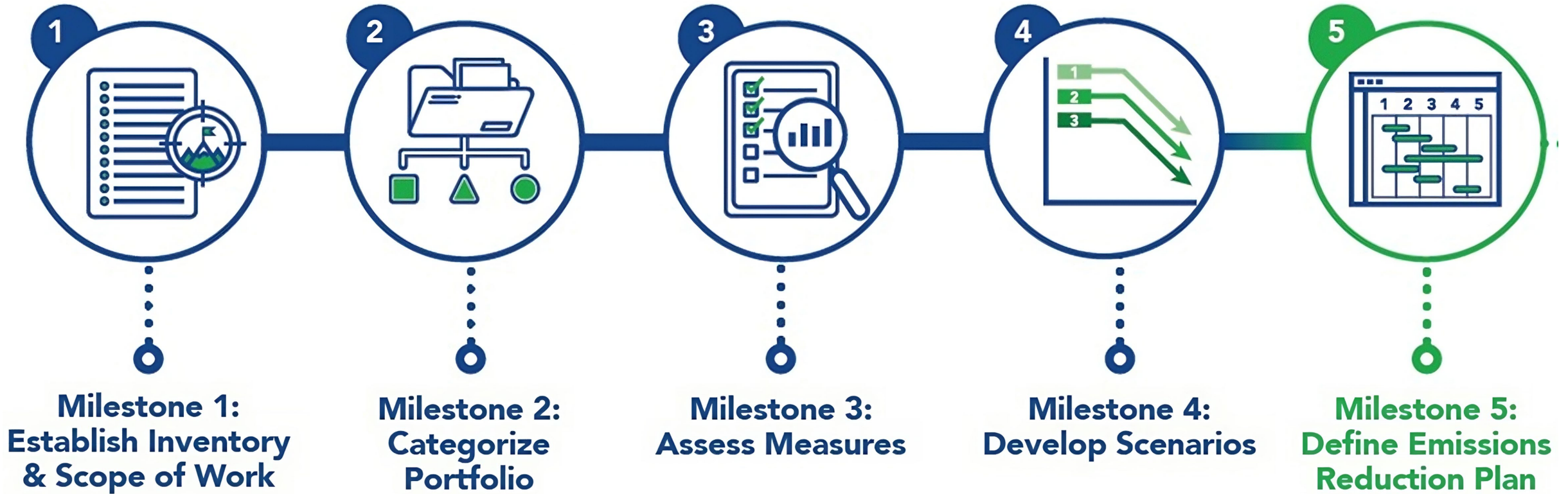
**PORTFOLIO-LEVEL EMISSIONS  
REDUCTION PLAN (ERP)**



**BUILDING-LEVEL EMISSIONS  
REDUCTION AUDIT**

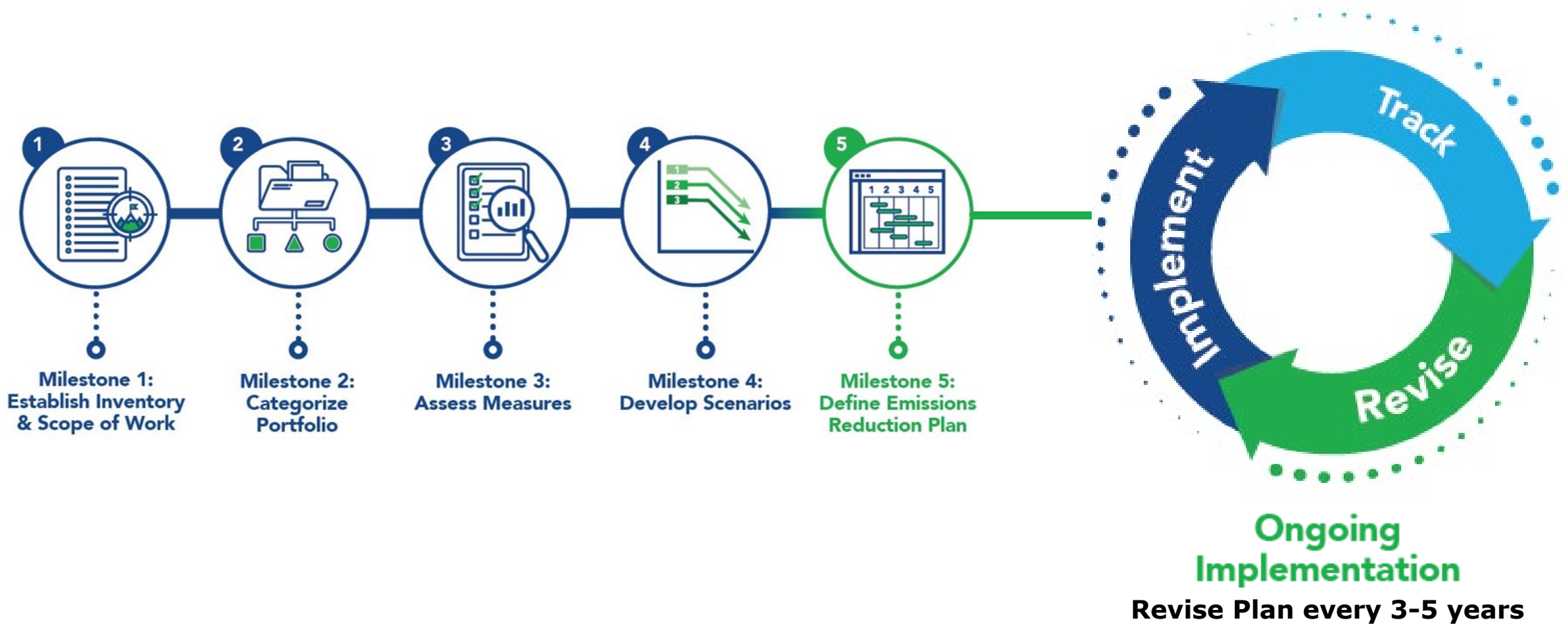
# Framework for Emissions Reduction Planning

5 MILESTONES

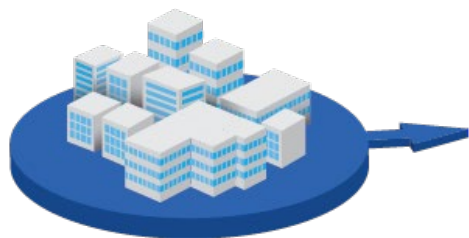


# Framework for Emissions Reduction Planning

ONGOING



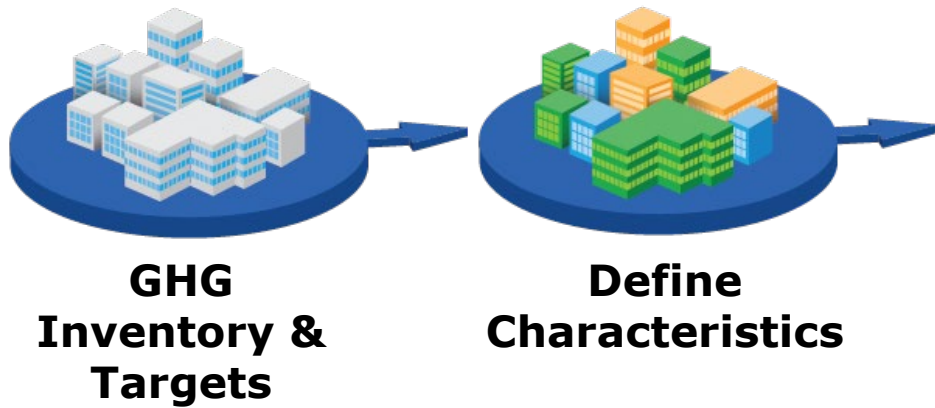
# Scaling Decarbonization to the Portfolio-level



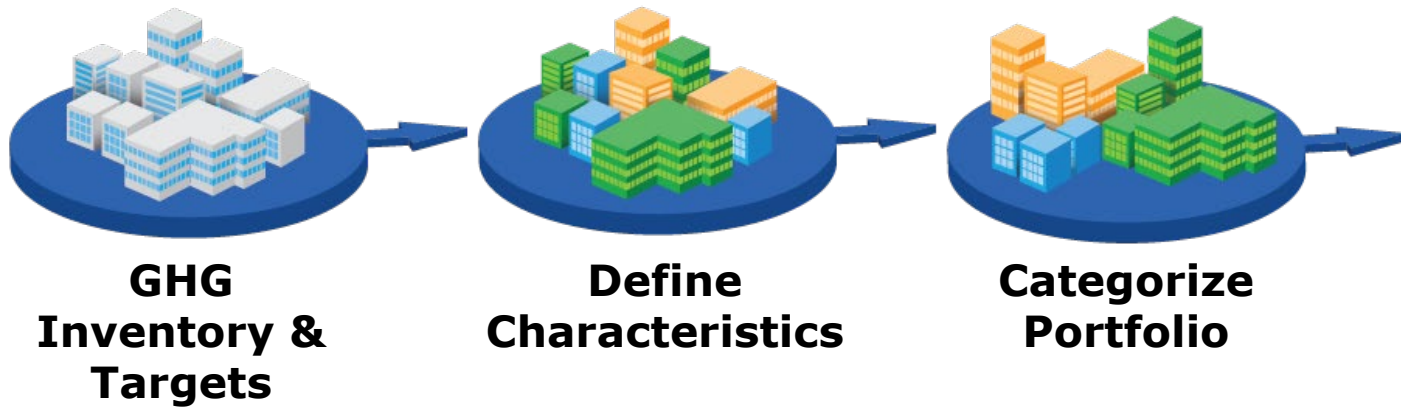
**GHG  
Inventory &  
Targets**



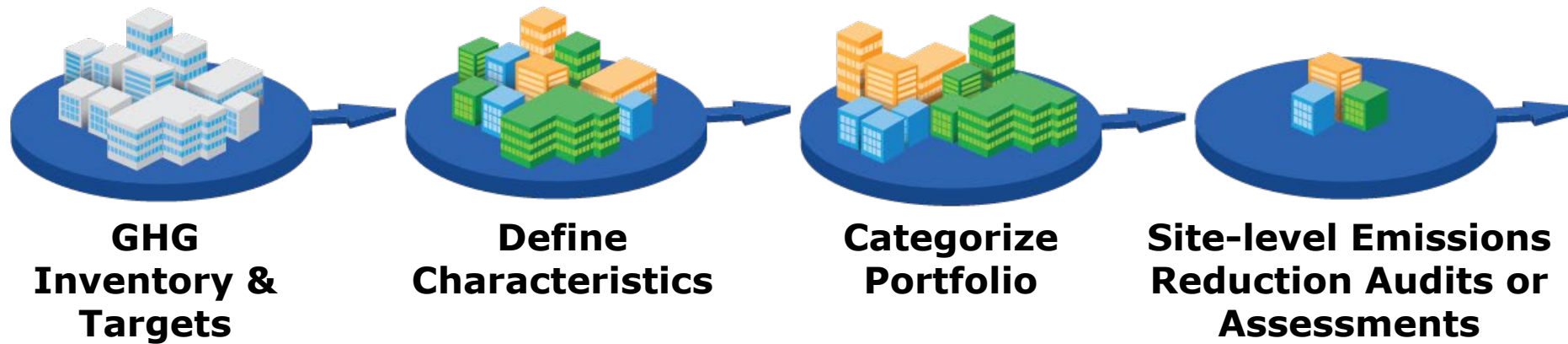
# Scaling Decarbonization to the Portfolio-level



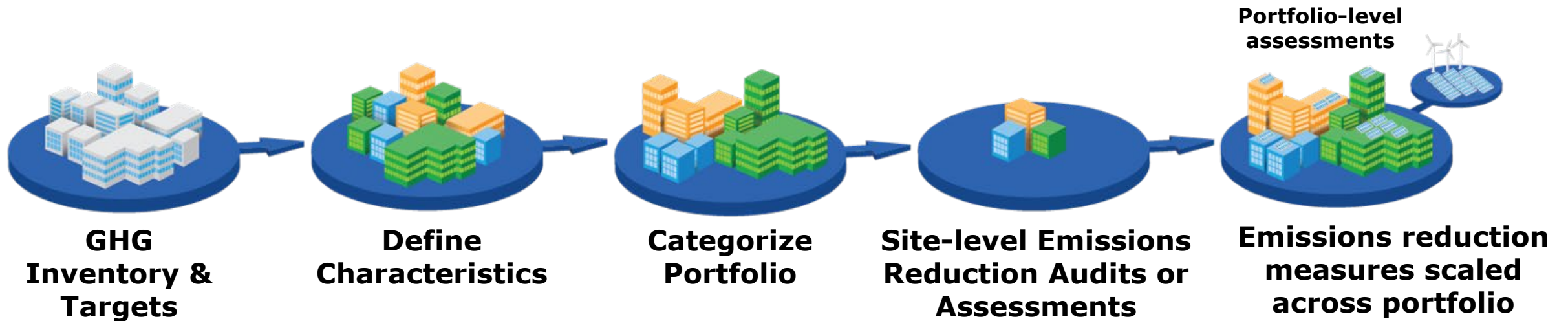
# Scaling Decarbonization to the Portfolio-level



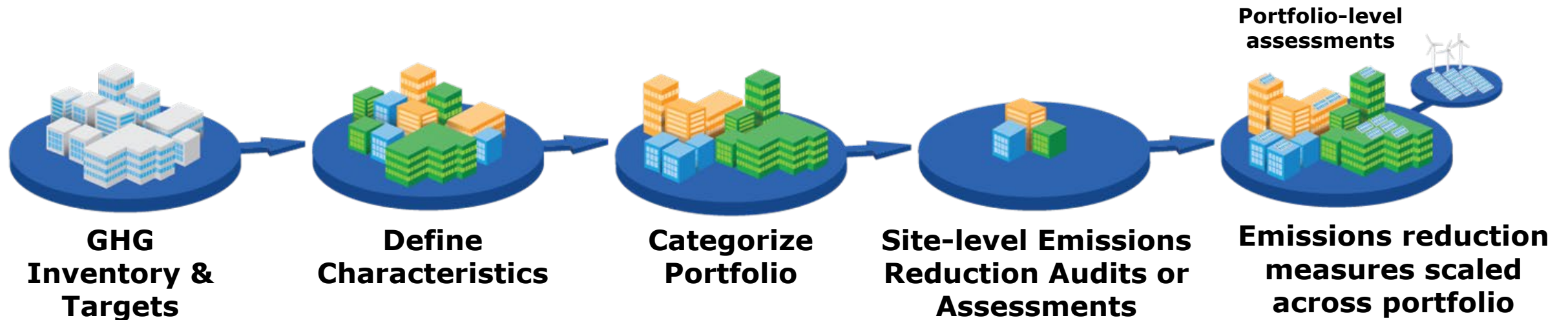
# Scaling Decarbonization to the Portfolio-level



# Scaling Decarbonization to the Portfolio-level



# Scaling Decarbonization to the Portfolio-level



**GOAL:**

A Portfolio-level plan that's based on measures tailored to the types of buildings and plants in the portfolio

# Building-level GHG Emissions Reduction Audits and Portfolio-level Assessments

MILESTONE 3

## ENERGY Conservation Measures (ECMs)

Typical Energy Audit  
Scope



Energy Efficiency & Load Reduction



Electrification / EV Charging



Low / No GWP Refrigerants



On-site Renewable Energy

# Building-level GHG Emissions Reduction Audits and Portfolio-level Assessments

MILESTONE 3

## ENERGY Conservation Measures (ECMs)

Typical Energy Audit  
Scope



**Energy Efficiency & Load Reduction**



**Electrification / EV Charging**



**Low / No GWP Refrigerants**



**On-site Renewable Energy**

# Building-level GHG Emissions Reduction Audits and Portfolio-level Assessments

MILESTONE 3

**ENERGY**  
Conservation Measures  
(ECMs)

Typical Energy Audit  
Scope

**EMISSIONS**  
Reduction Measures  
(ERMs)

GHG Emissions Reduction  
Audit Scope



**Energy Efficiency & Load Reduction**



**Electrification / EV Charging**



**Low / No GWP Refrigerants**







**On-site Renewable Energy**

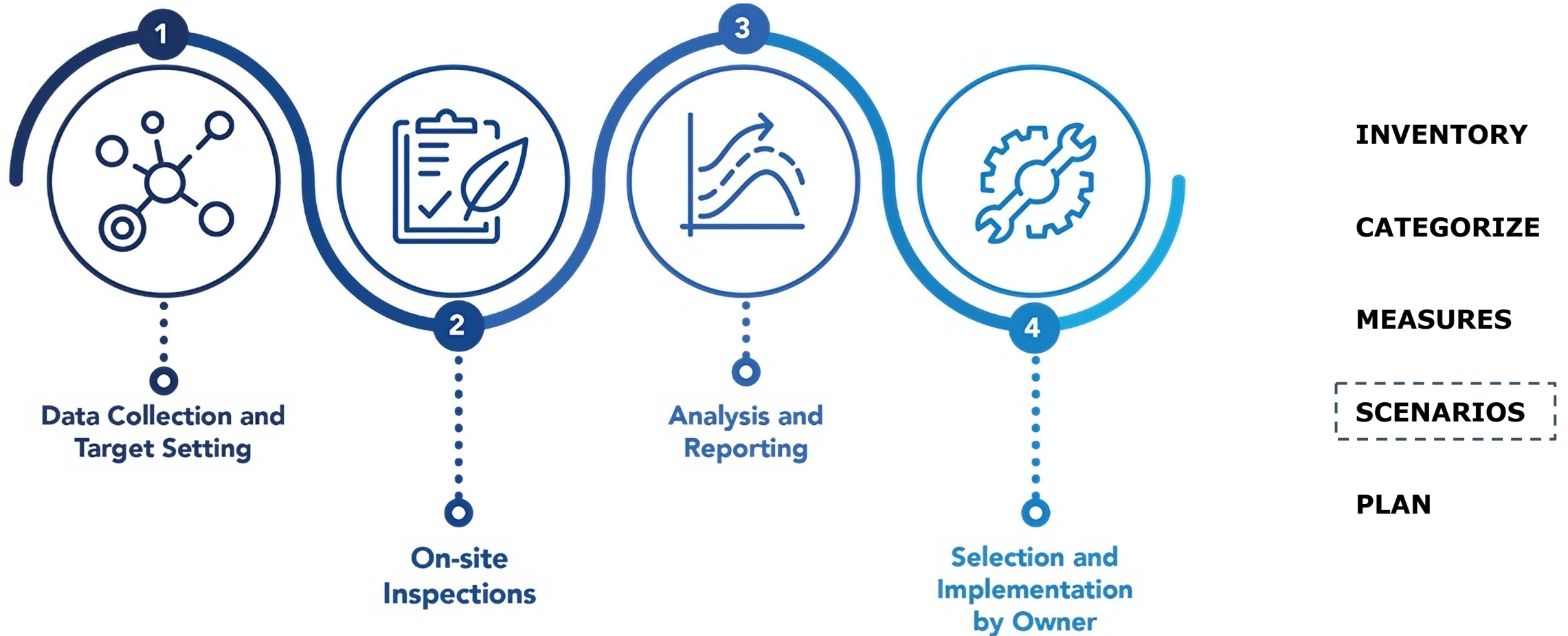



# Building-level GHG Emissions Reduction Audits and Portfolio-level Assessments

MILESTONE 3

		<b>ENERGY</b> Conservation Measures (ECMs)  Typical Energy Audit Scope	<b>EMISSIONS</b> Reduction Measures (ERMs)  GHG Emissions Reduction Audit Scope
	<b>Energy Efficiency &amp; Load Reduction</b>	✓	✓
	<b>Electrification / EV Charging</b>		✓
	<b>Low / No GWP Refrigerants</b>		✓
	<b>On-site Renewable Energy</b>		✓

# Tasks in an Emissions Reduction Audit





# Questions?

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THANK YOU



# Creating a better environment

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