U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

The role of BEM in decarbonizing the U.S. buildings sector

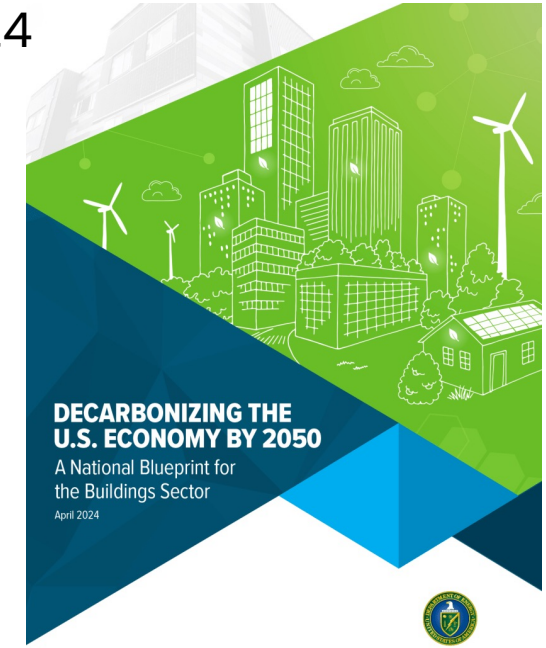
CalBEM 2024 keynote address

November 21, 2024

Eric Wilson
U.S. Department of Energy (on detail from National Renewable Energy Laboratory)

A people-centered strategy for catalyzing and scaling U.S. building decarbonization

April 2024



Everyone deserves to live in a safe and health home with access to affordable, clean, and reliable energy

A people-centered strategy for catalyzing and scaling U.S. building decarbonization

The Building Decarbonization Blueprint:

- Sets national goals for U.S. buildings sector decarbonization in line with economy-wide climate goals
- Outlines coordinated federal actions and support for state, local, and tribal stakeholders
- Serves as a guidepost for program planning and coordination
- Centers benefits to people and communities

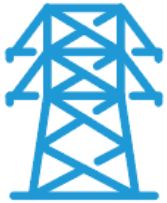
Everyone deserves to live in a safe and health home with access to affordable, clean, and reliable energy

The U.S. is pursuing ambitious national climate mitigation goals

GREENHOUSE GAS EMISSIONS REDUCTIONS

50-52% reduction by 2030 vs. 2005 levels

Net-zero emissions economy-wide by 2050



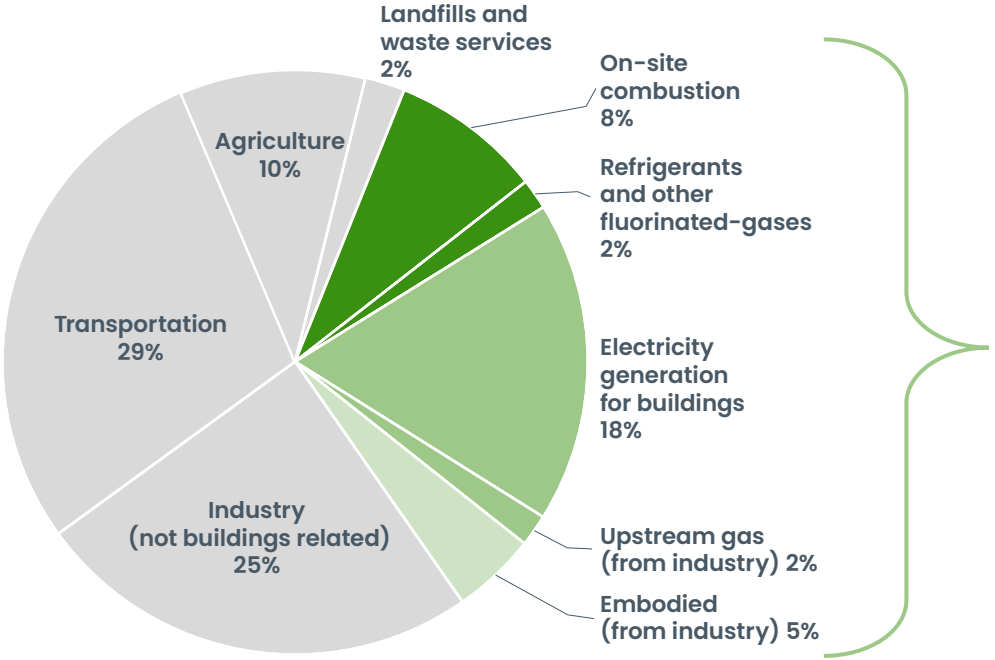
POWER SYSTEM DECARBONIZATION

100% clean electricity by 2035

ENERGY JUSTICE

40% of benefits from federal climate and clean energy investments flow to disadvantaged communities

Buildings are a critical pillar of economy-wide decarbonization



Buildings are over 1/3 of total U.S. GHG emissions[1]

[1] Source: U.S. EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, 2021 data, internal DOE analysis. Uses 100-year CO2 equivalencies.

Buildings impact our everyday lives in many ways

90% of people's time
is spent in buildings, which provide shelter and keep us safe

$374 billion is spent annually on building energy costs

2.2 million people
are already employed in jobs related to energy efficiency

2X air pollution from gas appliances in buildings vs. gas power plants

34 million households
experienced energy insecurity

1 in 5 households
were behind on a monthly energy bill payment

1 in 3 Americans live in a community facing climate, health, and economic burdens

[1] Sources to be added

An ambitious but achievable vision for the buildings sector in 2050

Reduce U.S. building GHG emissions 65% by 2035 and 90% by 2050 vs. 2005

- while enabling net-zero emissions economy-wide and
- centering equity and benefits to communities.

An ambitious but achievable vision for the buildings sector in 2050

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STRATEGIC OBJECTIVES

Increase building energy efficiency
Reduce onsite energy use intensity in buildings 35% by 2035 and 50% by 2050 vs. 2005

Accelerate on-site emissions reductions
Reduce onsite GHG emissions in buildings 25% by 2035 and 75% by 2050 vs. 2005

Transform the grid edge
Reduce electrical infrastructure costs by tripling demand flexibility potential by 2050 vs. 2020

Minimize embodied life cycle emissions
Reduce embodied emissions from building materials and construction 90% by 2050 vs. 2005

An ambitious but achievable vision for the buildings sector in 2050

Reduce U.S. building GHG emissions 65% by 2035 and 90% by 2050 vs. 2005
- while enabling net-zero emissions economy-wide and
- centering equity and benefits to communities.

CROSS-CUTTING GOALS

Equity – Advance energy justice and benefits to disadvantaged communities

Affordability – Reduce energy burden and technology costs so all can benefit

Resilience – Increase the ability of communities to withstand and recover from stresses

STRATEGIC OBJECTIVES

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Minimize embodied life cycle emissions
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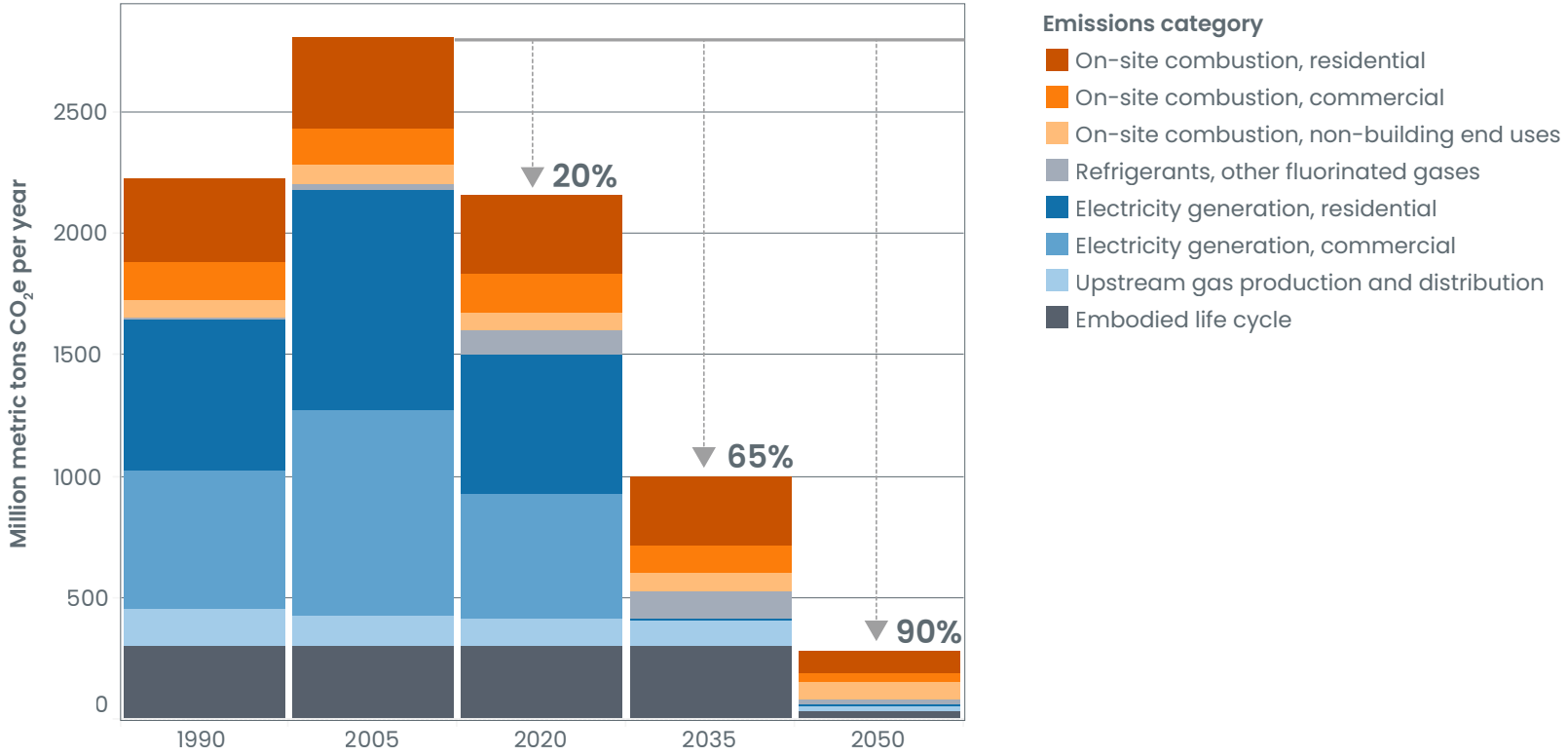
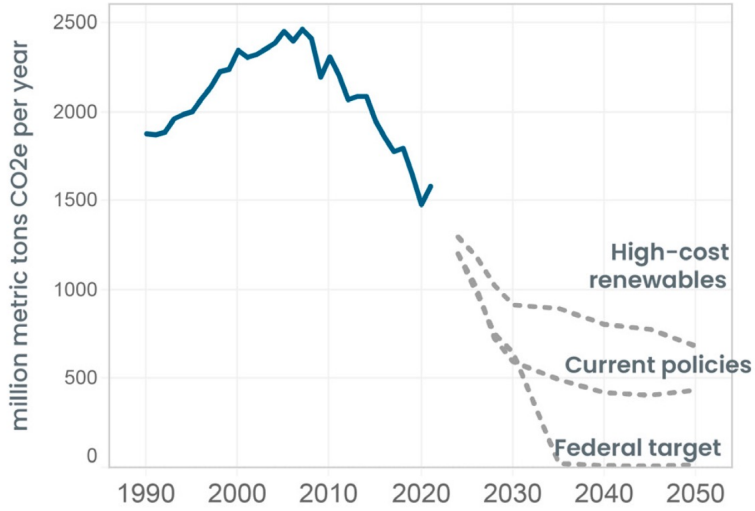
The Blueprint's emissions goals are ambitious

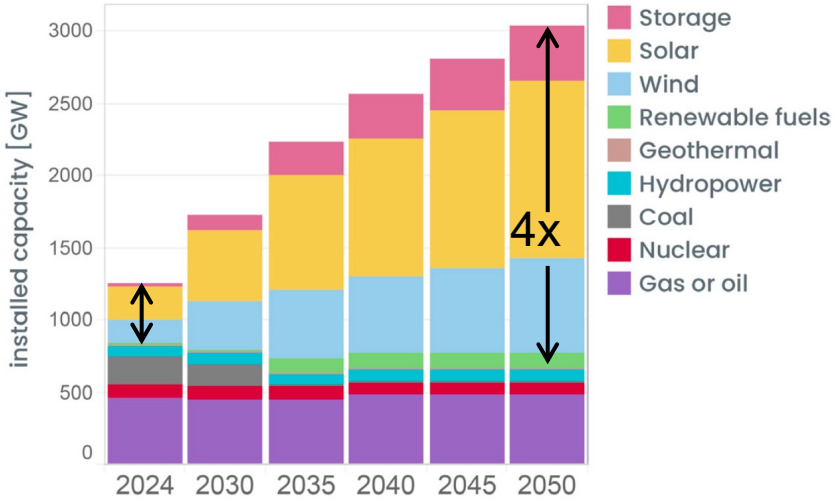


The power sector is rapidly changing

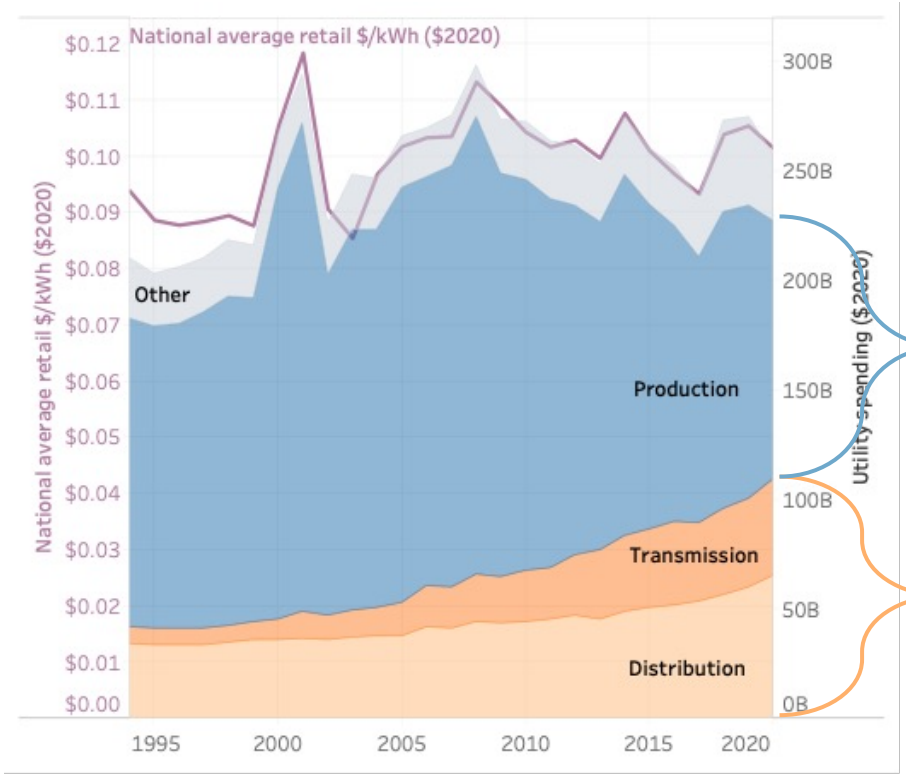
Historical and projected power emissions
for a range of future grid scenarios



Projected generation capacity
for 100% clean electricity by 2035 target



The cost of **delivering** electricity may soon surpass the cost of **producing** it



Between 2010 and 2020…

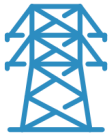
power production costs decreased 32%

electricity delivery costs increased 65%

Source: EIA. Today in Energy. “Major U.S. utilities spending more on electricity delivery, less on power production” November 23, 2021. https://www.eia.gov/todayinenergy/detail.php?id=50456

Buildings engage multiple pillars of economy-wide decarbonization

Building upgrades **improve lives** by increasing high-quality jobs, economic security, equity, health, and community resilience



Limit scale of required electricity infrastructure needed under deep grid decarbonization

Enable fast, secure, and interactive distributed energy resources like EVs, onsite generation, and storage

Support convenient, efficient, and clean mobility options through building codes, zoning, and urban planning

Accelerate demand for low-embodied carbon material manufacturing to reduce life cycle emissions

A wide range of technical solutions and potential emissions impacts

Emissions scope and source (% buildings emissions)		Energy efficiency	Efficient electrification	Grid edge resource managment	Low GWP refrigerants	Low embodied carbon construction
1	On-site fuel combustion (24%)	☁☁	☁☁☁			
	Refrigerants, other HFCs (5%)				☁	
2	Electricity generation (52%)	☁☁☁		☁☁		
	Upstream gas*(~5%)	☁	☁			
3	Embodied life cycle (~14%)					☁☁

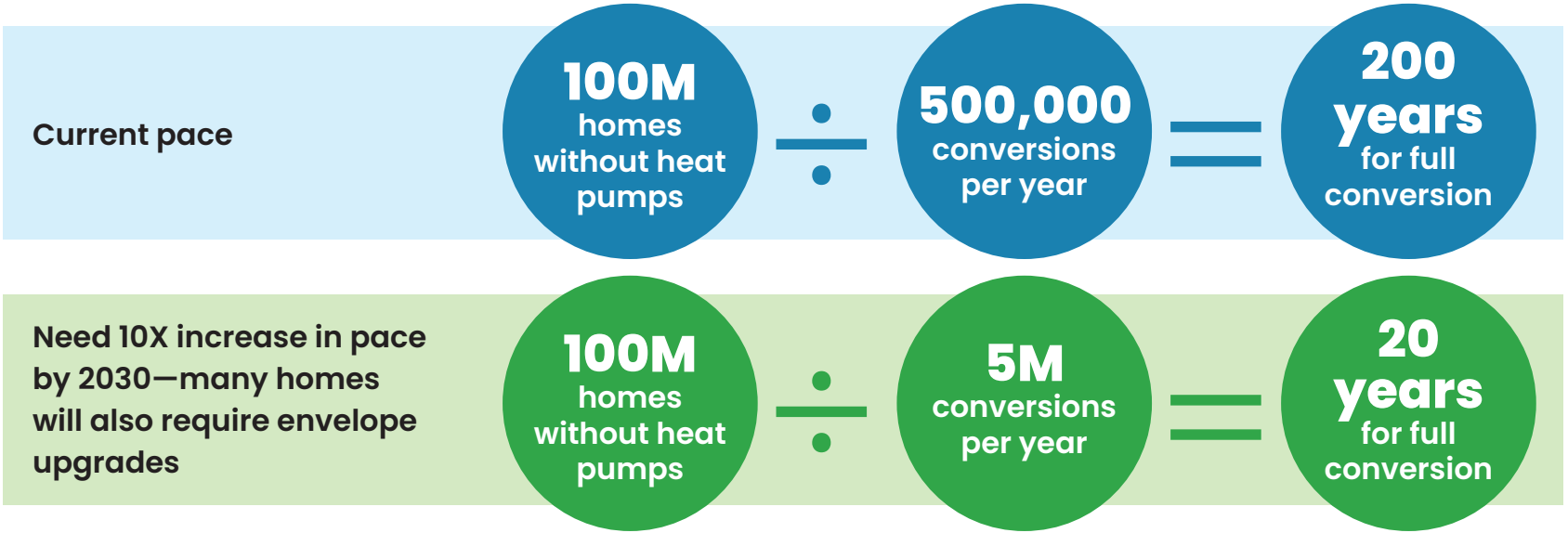
☁ Lower emissions reductions potential

☁☁ Moderate emissions reduction potential

☁☁☁ Higher emissions reduction potential

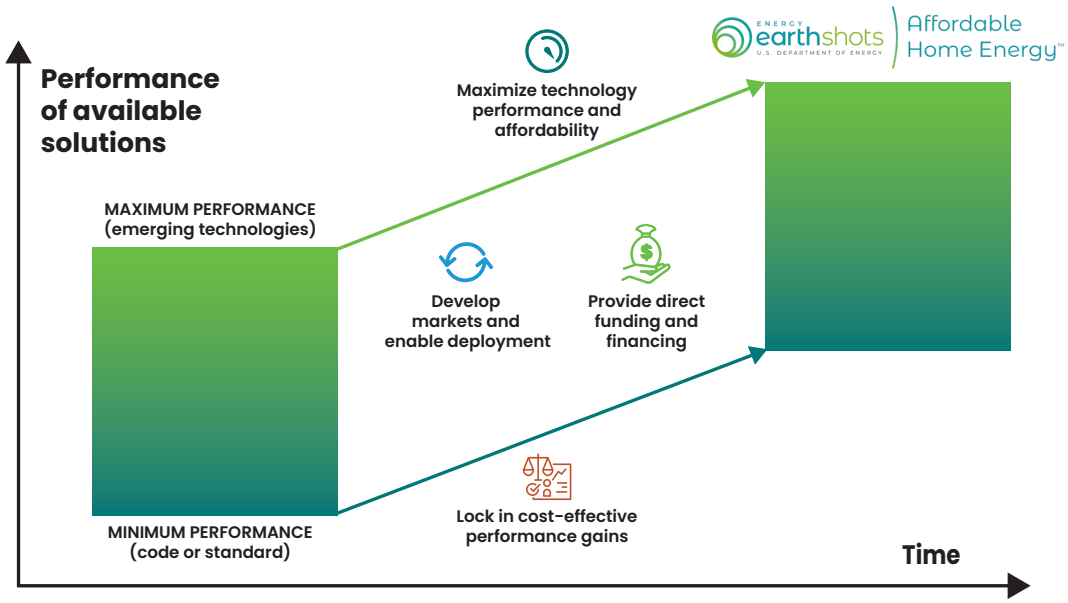
Rapid deployment of solutions at scale is urgently needed

Example: Residential space heating



The Blueprint outlines a three-stage transition to a low-carbon buildings sector

- **By 2030: Catalyze the transition**
- **2030-2040: Adapt and scale**
- **2040-2050: Complete the transition**
- Coordinate federal actions across the full federal toolbox
- Identifies RDD&D activities over the next decade that are critical for the success of future stages



Federal support can accelerate state, local and tribal leadership

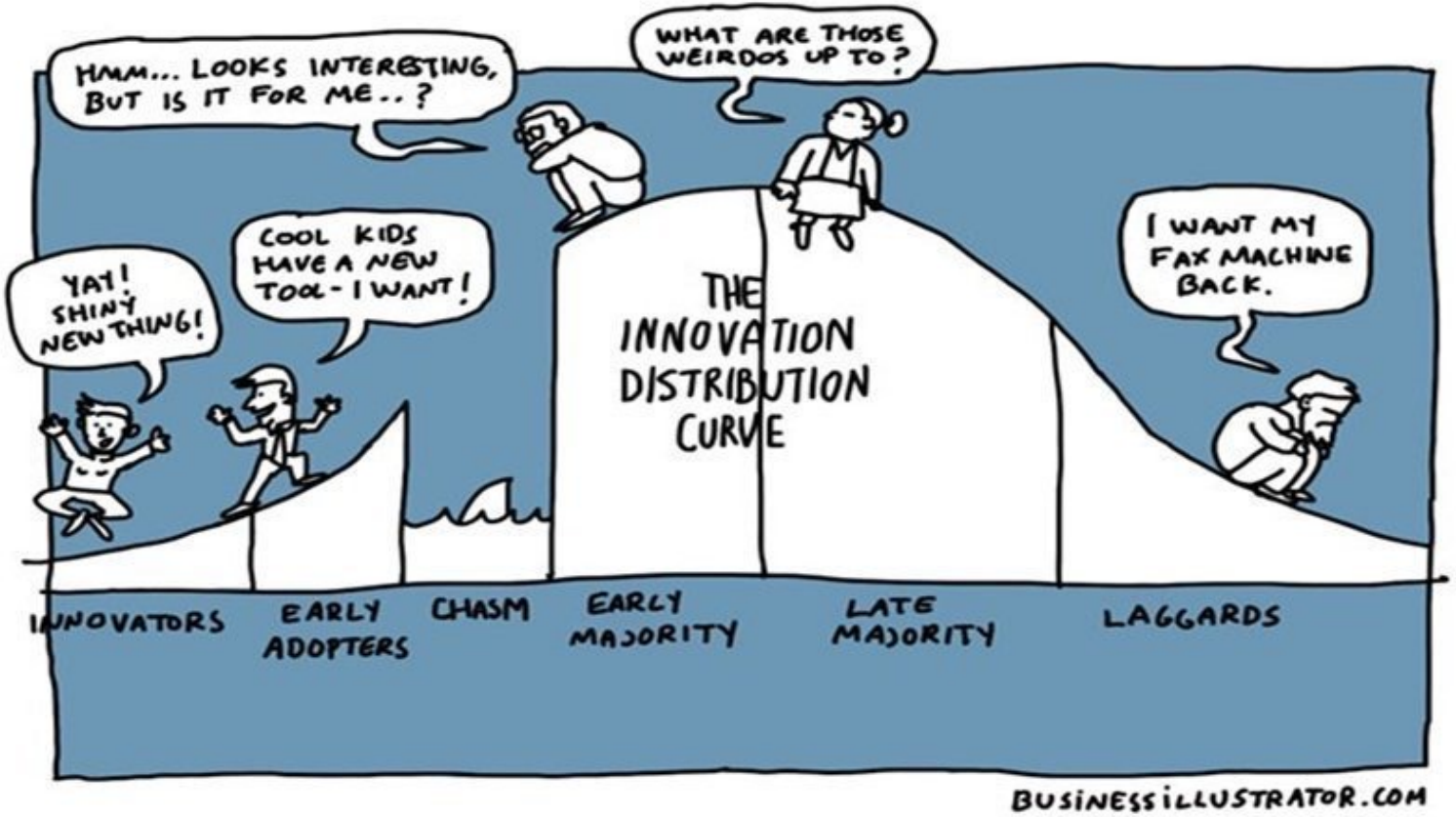
Fund investments in building decarbonization

Set codes, standards, and other requirements

Lead policy to enable greater investments

Part 2

The evolving role of Building Energy Modeling


HMM... LOOKS INTERESTING, BUT IS IT FOR ME..?
WHAT ARE THOSE WEIRDOS UP TO?
YAY! SHINY NEW THING!
COOL KIDS HAVE A NEW TOOL - I WANT!
THE INNOVATION DISTRIBUTION CURVE
I WANT MY FAX MACHINE BACK.
INNOVATORS
EARLY ADOPTERS
CHASM
EARLY MAJORITY
LATE MAJORITY
LAGGARDS
BUSINESSILLUSTRATOR.COM

BEM decision maker ecosystem

Decision maker
Homeowners and small businesses
Organizations with large building portfolios
State and local jurisdictions
Utilities and regulators

BEM decision maker ecosystem

Decision maker	Traditional BEM use cases
 Homeowners and small businesses	• Custom home design
 Organizations with large building portfolios	• Design guidance for new buildings • HVAC system sizing
 State and local jurisdictions	• Energy code analysis
 Utilities and regulators	• Energy efficiency potential studies

BEM decision maker ecosystem

Decision maker	Traditional BEM use cases	Emerging BEM use cases
 Homeowners and small businesses	• Custom home design	• Remote assessments and heat pump quote generation
 Organizations with large building portfolios	• Design guidance for new buildings • HVAC system sizing	• Design guidance for districts and thermal energy networks • Existing building performance standard compliance • Design tools for embodied GHG
 State and local jurisdictions	• Energy code analysis	• Program design guidance for states, cities, utilities • Evaluating public health and distributional impacts
 Utilities and regulators	• Energy efficiency potential studies	• Utility load forecasting • Utility rate design

Technology, market, and policy milestones related to BEM

Objective 1: Increase building energy efficiency	
by 2035	**by 2050**
• >75% of building contractor education and training programs include energy efficiency skills as a graduation requirement. • Building energy disclosure requirements are adopted in states and jurisdictions representing >50% of people in the United States and include point-of-sale/rental disclosure requirements for homes.* • Zero-energy or equivalent codes and BPS are each adopted in states and jurisdictions representing >25% of people in the United States. • 3% annual efficient envelope retrofit rate for existing residential and 2% for existing commercial are achieved and maintained or exceeded thereafter. • At least 75% of new buildings are constructed at or above the latest model energy code performance levels. • More than 50% of all homes and businesses have automated control platforms that reduce energy waste and enable flexibility.	• Building energy disclosure requirements adopted in states and jurisdictions representing >75% of people in the United States and include point-of-sale/rental disclosure requirements for homes. • Zero-energy or equivalent codes and BPS are adopted in states and jurisdictions representing >50% of people in the United States. • All federal buildings meet stringent energy use intensity (EUI) targets.** • All primary electric resistance space and water heating is replaced by heat pumps. • More than 75% of all homes and businesses have automated control platforms that reduce energy waste and enable flexibility.

Technology, market, and policy milestones related to BEM

Objective 3: Transform the grid edge	
by 2035	**by 2050**
• Commercially available low-power appliances and smart controls enable full electrification without upgrades to behind-the-meter electrical infrastructure. • Widespread availability of appliances with integrated battery storage adds flexibility and resilience without utility interconnection and permitting requirements. • Standardized communications and cybersecurity protocols increase customer confidence in device security. • 50% of commercial and 25% of residential electricity customers are offered incentives for flexible use of their HVAC and/or water heating equipment; incentives reflect new revenue streams such as virtual power plants and distribution grid value. • Utilities in areas representing at least 25% of people in the United States conduct integrated resource, transmission, and distribution planning that accounts for building efficiency and demand response and regularly apply these resources as non-wires alternatives.	• More than 75% of installed HVAC and lighting equipment in homes and businesses is network connected and supports flexible control. • More than 90% of residential and commercial customers are offered incentives for flexible use of their HVAC and/or water heating equipment. • Utilities in areas representing at least 50% of people in the United States conduct integrated resource, transmission, and distribution planning that accounts for building efficiency and demand response and regularly apply these resources as non-wires alternatives.

Technology, market, and policy milestones related to BEM

Objective 4: Minimize embodied life cycle emissions	
by 2035	**by 2050**
• A data-driven 2050 target for reduction in U.S. buildings sector embodied carbon emissions has been established, along with an extensive stock-scale inventory of material life cycle emissions from annual U.S. building construction and renovation. • Whole-building modeling and design tools include standardized embodied carbon calculations for building material components. • Model building codes and green building rating systems limit embodied carbon emissions for larger building types and encourage focus on circular economy practices for building construction and/or renovation.	• Model building codes and green building rating systems limit embodied carbon emissions for all building types. • All new building envelope designs extend the service lifetimes of envelope components by enabling disassembly, reuse, and recycling. • All new building and retrofit designs use lower embodied carbon alternatives to concrete and steel, including mass timber construction. • Bio-based insulation and other carbon-negative building materials are widely used in building construction and renovation.§ • U.S. cement manufacturing greenhouse gas (GHG) emissions decrease to near zero, while cement production increases by 46%.§§ • U.S. steel industry GHG emissions decrease to near zero, while steel production increases by 12%.‡

Federal support can accelerate state, local and tribal leadership

Fund investments in building decarbonization

- Deploy BIL/IRA programs
- Enable and deploy innovative financing
- Oversee utility programs

- Tailored technical assistance (TA) and data for program design and implementation
- Fund low-interest financing

Set codes, standards, and other requirements

- Enact/enforce building codes and performance standards
- Enact state-level appliance and procurement standards

- Model code development input
- TA for code/standards adoption and enforcement
- Lead-by-example on codes and procurement standards

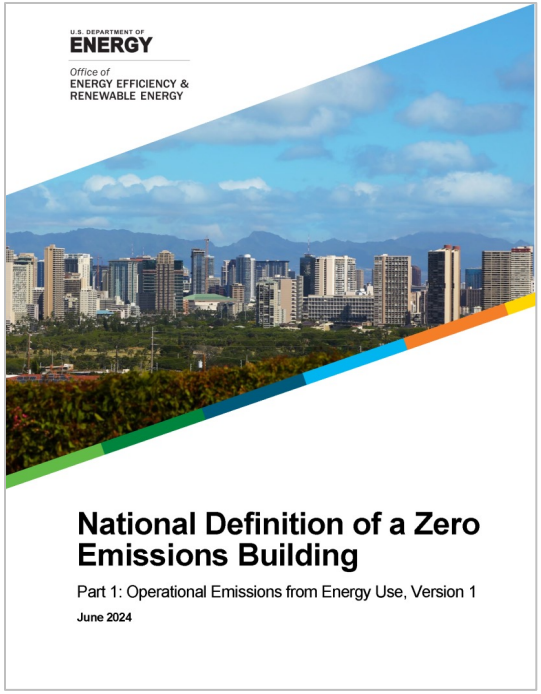
Lead policy to enable greater investments

- Utility regulation and reforms
- Energy efficiency and clean heat standards

- TA to support utility decision-making, planning, and compliance assessments

Part 3
Resources for modelers

National Definition of a Zero Emissions Building



June 2024

Gives modelers a consistent definition for projects to follow

1. Energy efficient.
2. Free of on-site emissions from energy use.
3. Powered solely from clean energy.

Public and private entities can use to demonstrate climate and clean energy leadership

DOE BTO Guidance on GHG Emissions Factors

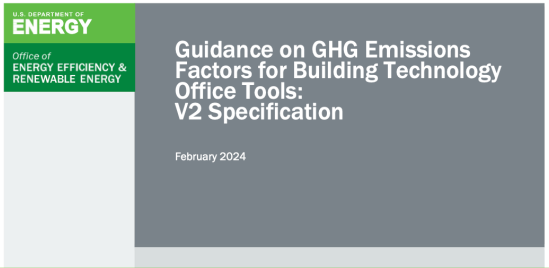
Standardized guidance
on GHG emission calculations

For BTO tool developers,
but may be useful to others

Multiple applications
1. GHG inventories and reporting
2. Measure impact assessments

Multiple time frames
- Historical vs. future
- Annual vs. hourly resolution

DOE BTO Guidance on GHG Emissions Factors



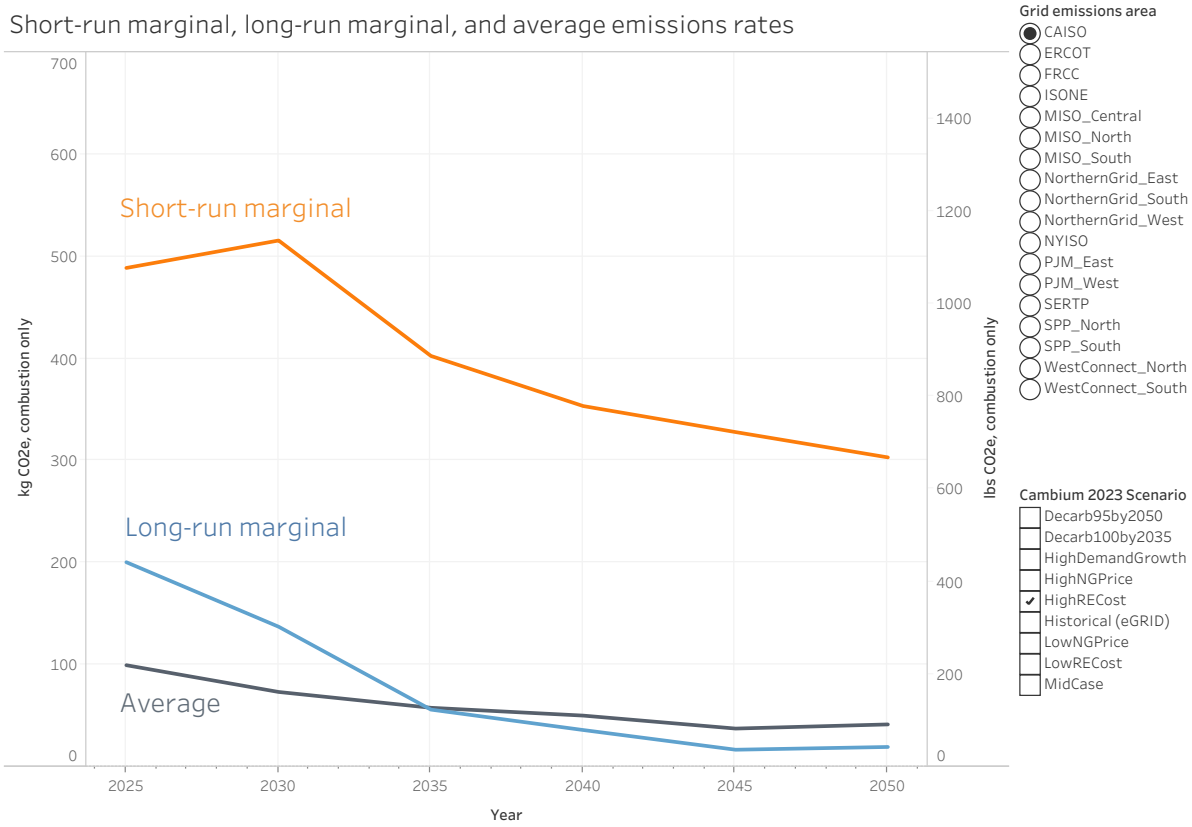
Standardized guidance
on GHG emission calculations

For BTO tool developers,
but may be useful to others

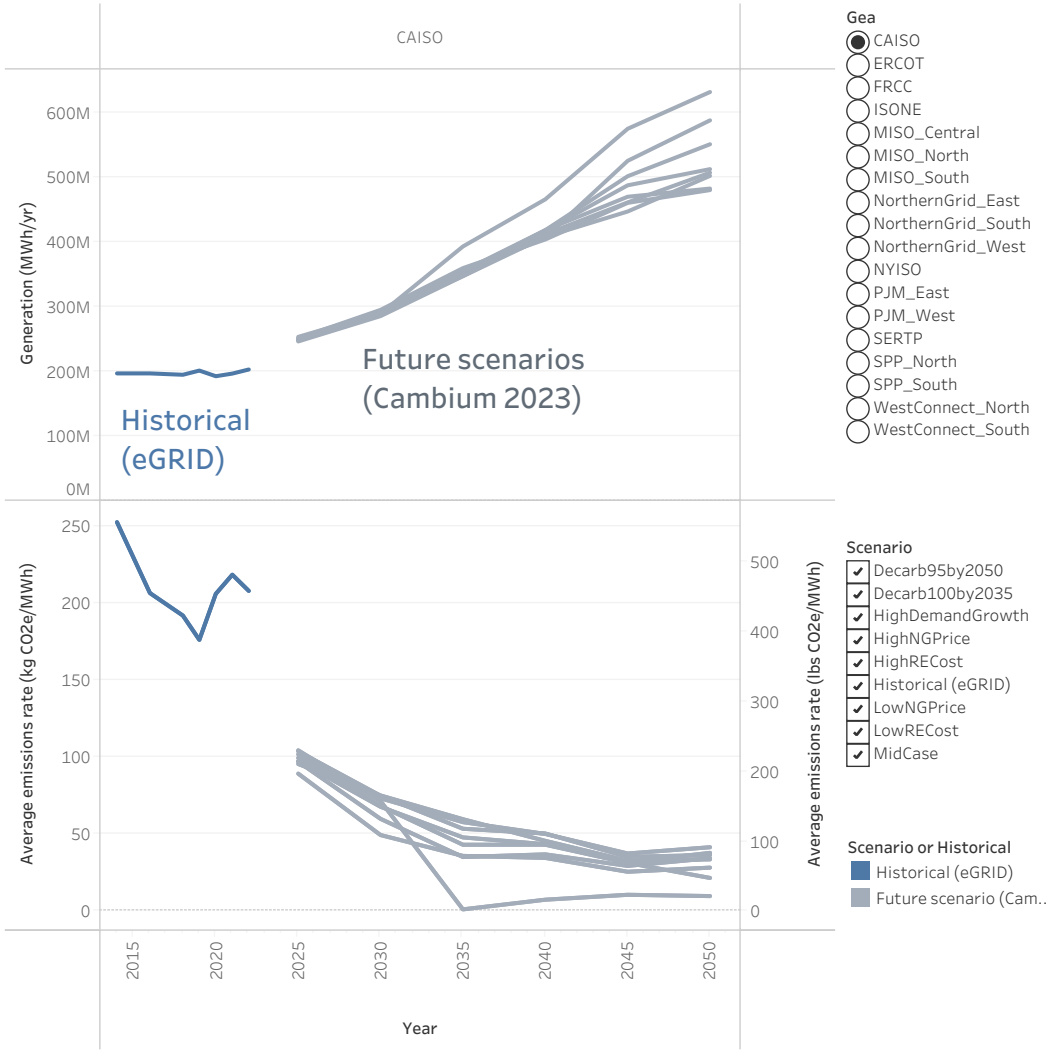
Table 1: Recommended Type and Source of Electricity Emissions Rate, Depending on the Application and Time Resolution of Available Electricity Use Data

Application Type	Time Frame	Time Resolution	Recommended Type	Recommended Source
GHG Accounting and Benchmarking	Historical	Annual	Average	eGRID
	Future	Annual	Average	Cambium
		Hourly	Average	Cambium
Measure Impact Assessments	Future	Annual	Long-run marginal	Cambium
		Hourly	Long-run marginal	Cambium

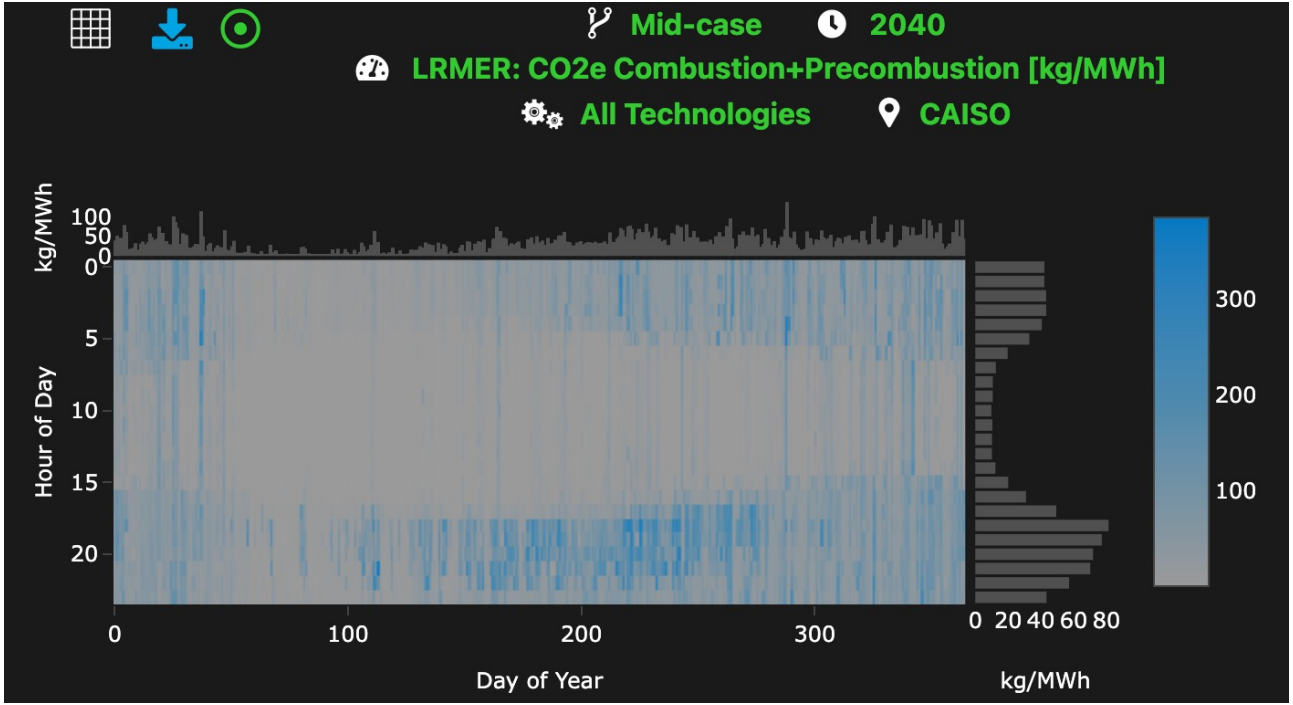
2x difference between short-run and long-run marginal



For decisions about the future, use future projections of emissions intensity



Use hourly emissions rates if available



Buildings Annual Technology Baseline (B-ATB)

(draft dataset coming soon)

Machine-readable dataset

Curated and regularly updated

Technology and labor costs

Equations for all major building energy technologies

Future cost trajectories

to 2050 under different scenarios

E.g., for early stage design

where actual cost data is not yet available

Buildings Sector GHG Segmentation Dashboard

bit.ly/buildingspathways

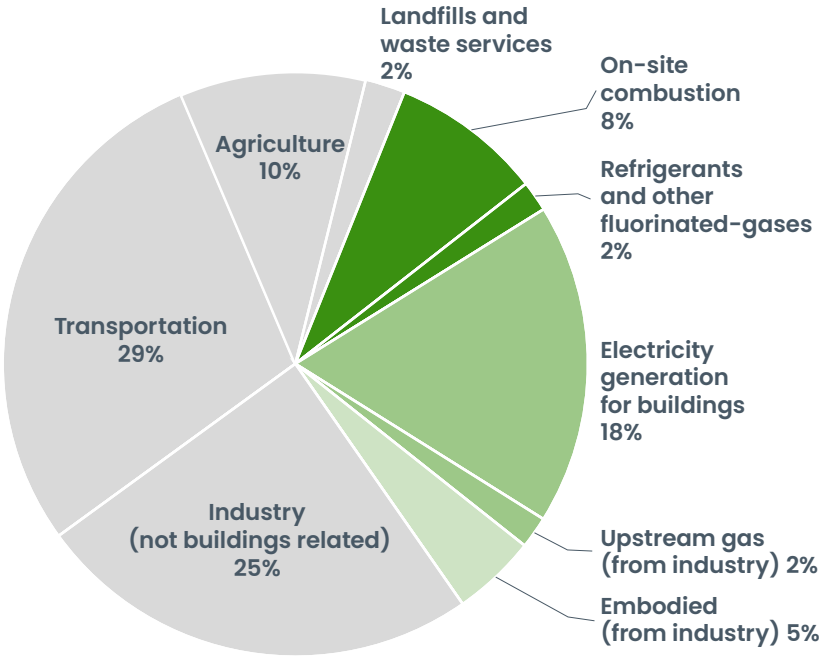
Interactive dashboard

visualizing all buildings sector GHG and energy segments

Future projections

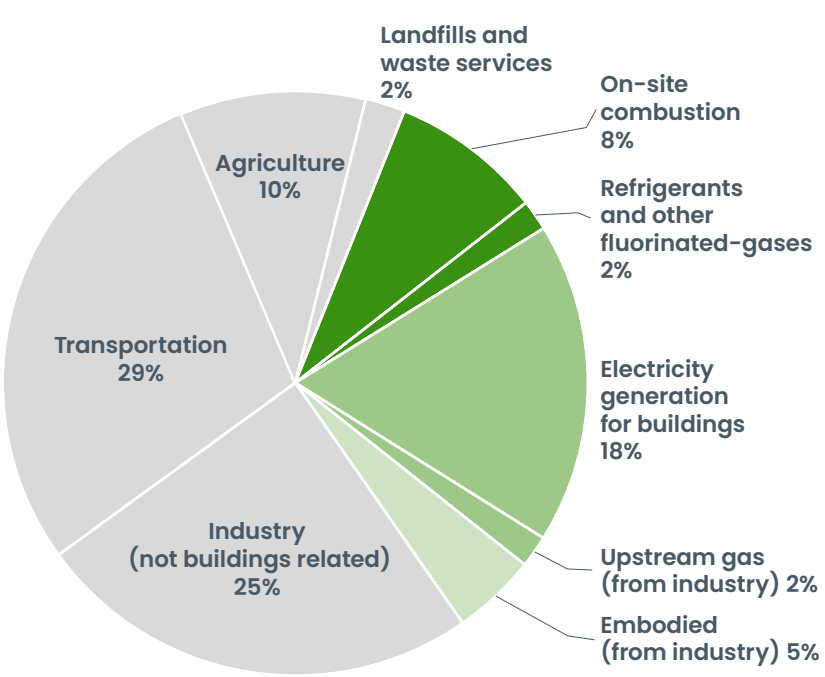
of GHG, energy, and peak demand through 2050 under different scenarios

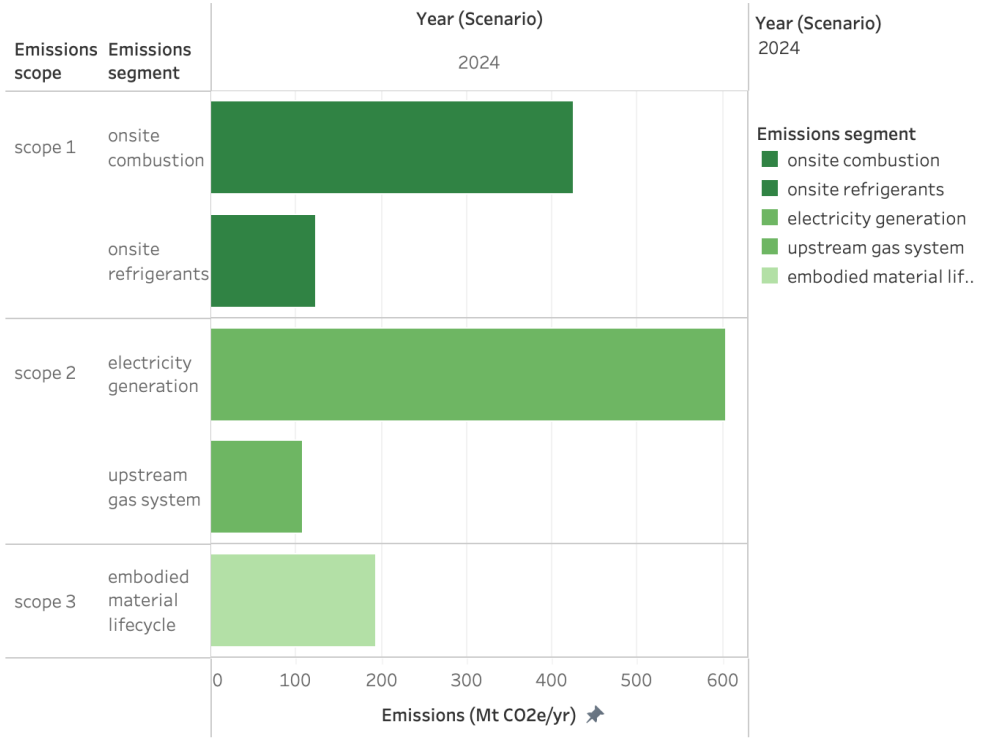
Buildings Sector **Greenhouse Gas (GHG) Segmentation**



[1] Source: U.S. EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, 2021 data, internal DOE analysis. Uses 100-year CO2 equivalencies.

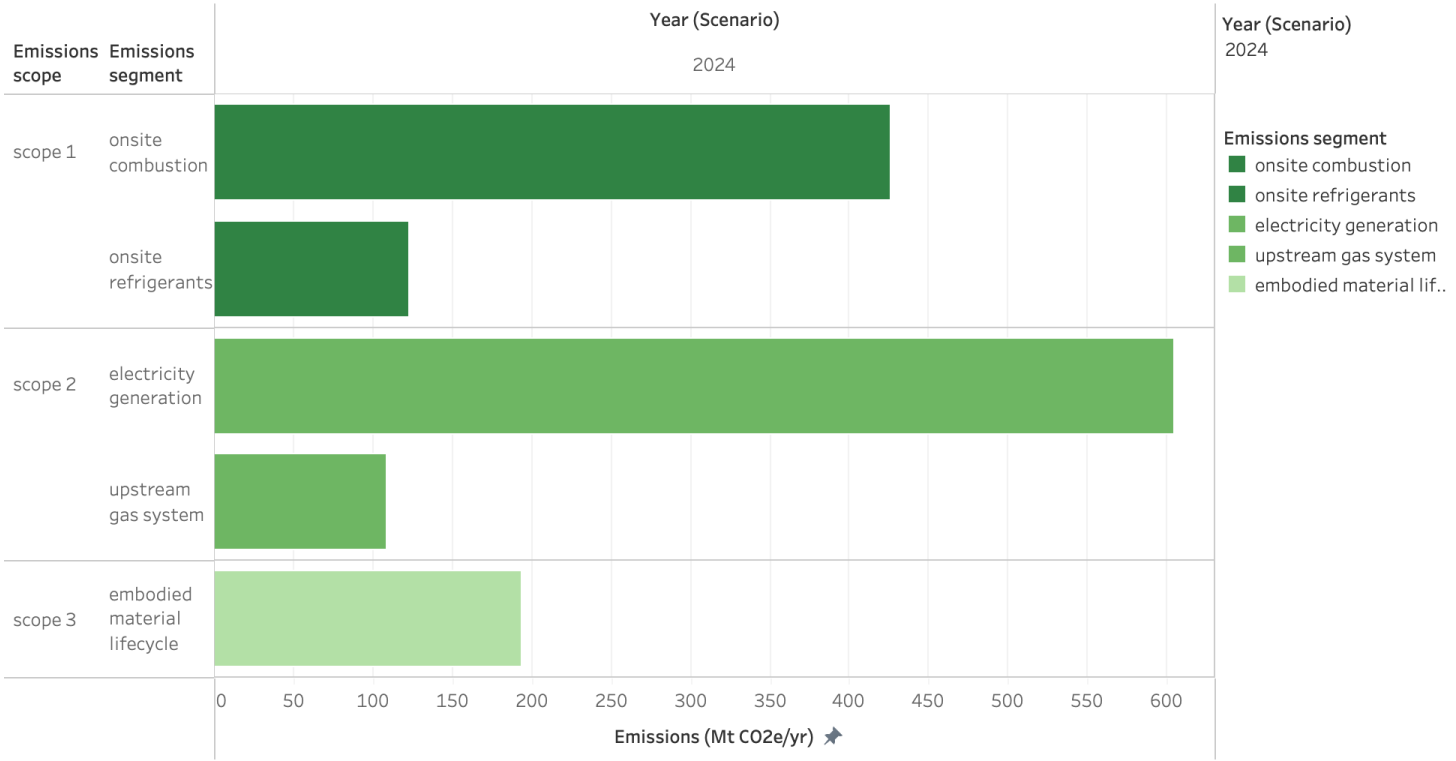
Buildings Sector **Greenhouse Gas (GHG) Segmentation**



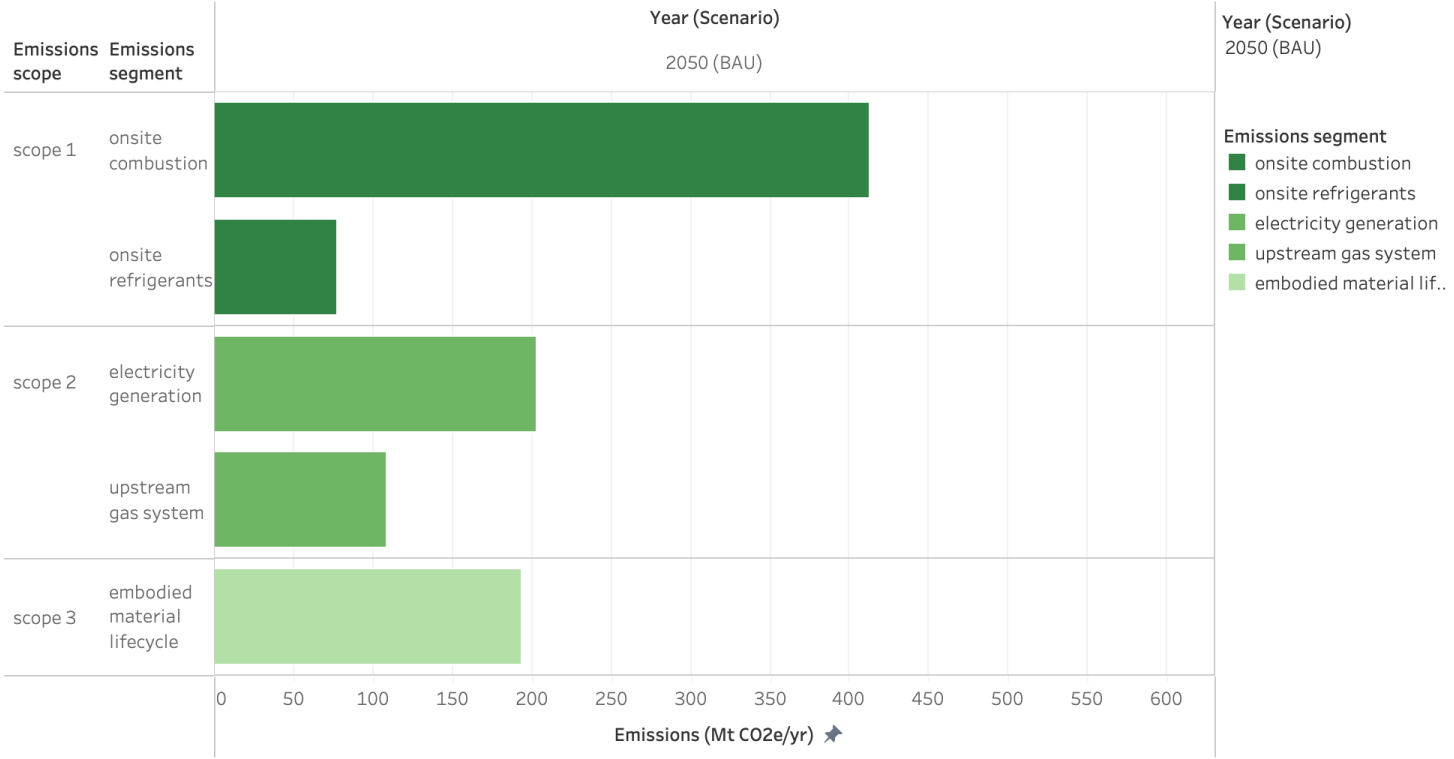


[1] Source: U.S. EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, 2021 data, internal DOE analysis. Uses 100-year CO2 equivalencies.

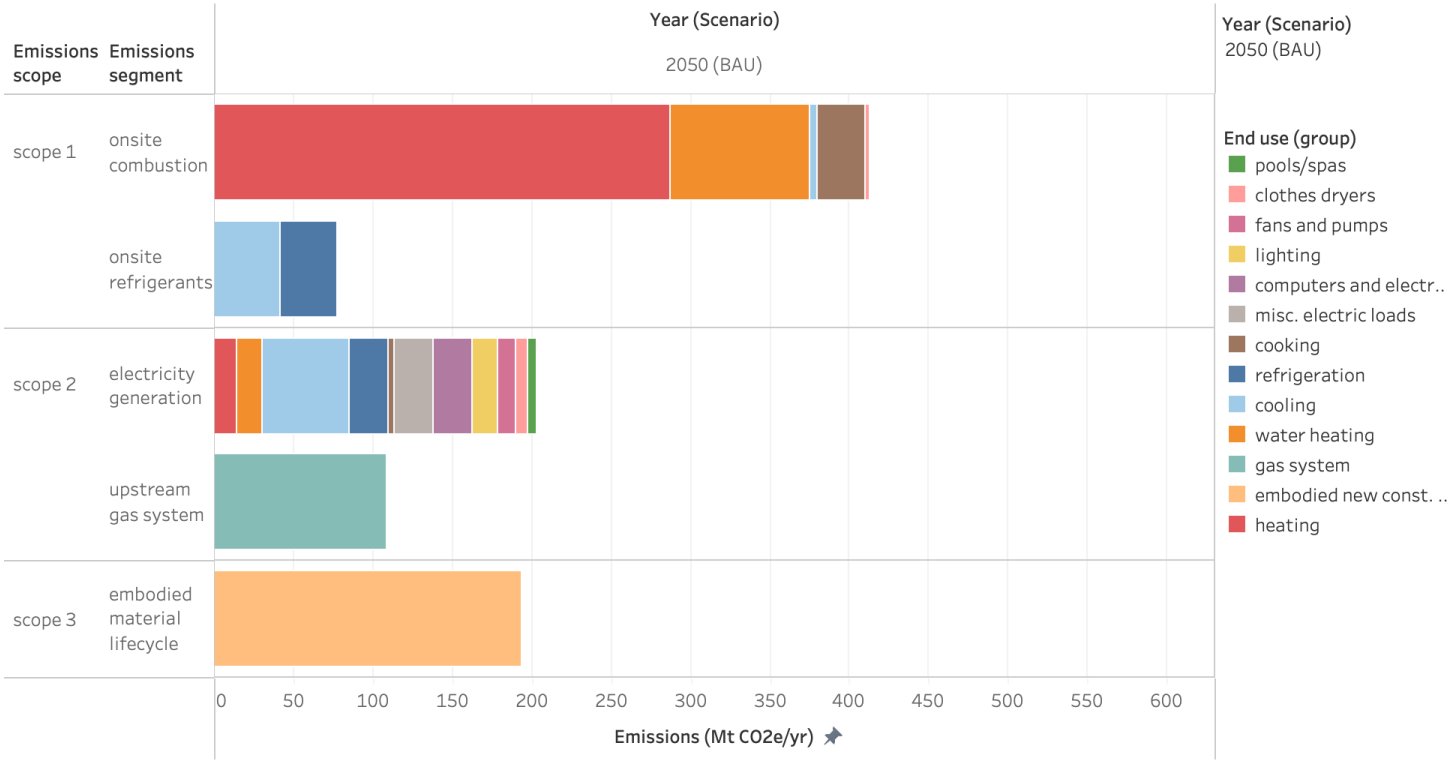
Buildings Sector **GHG Segmentation 2024**



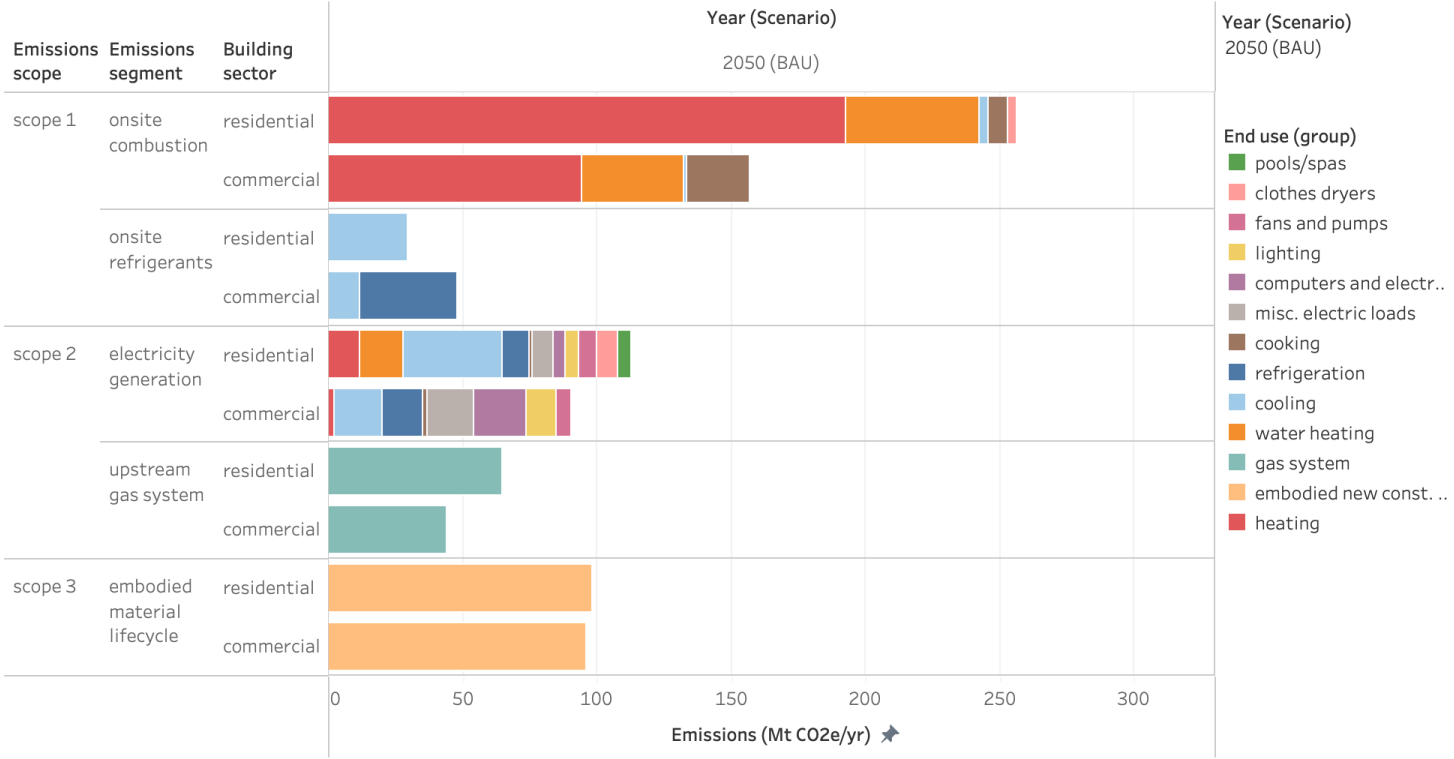
Buildings Sector **GHG Segmentation**
2050 Business-as-usual (BAU)



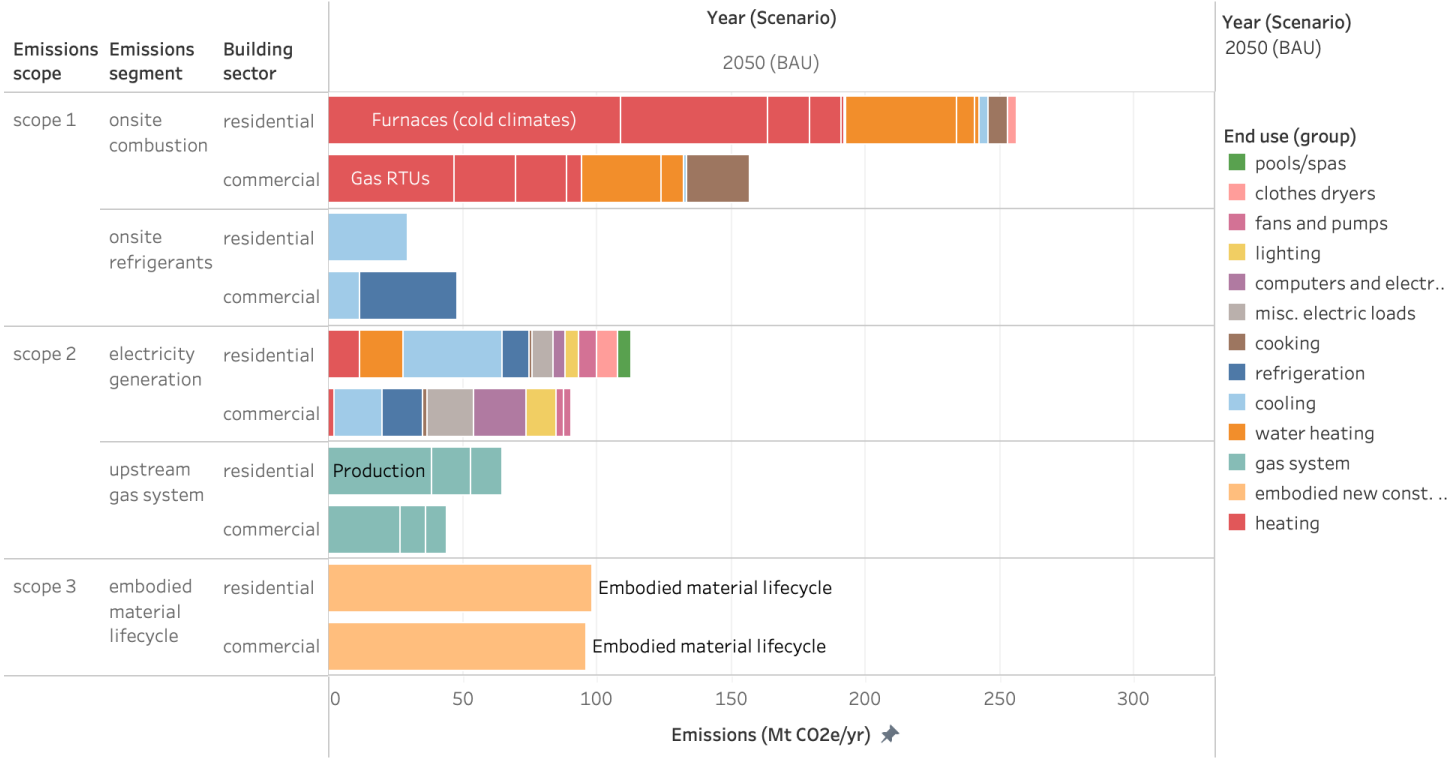
Buildings Sector **GHG Segmentation 2050 BAU by end use**



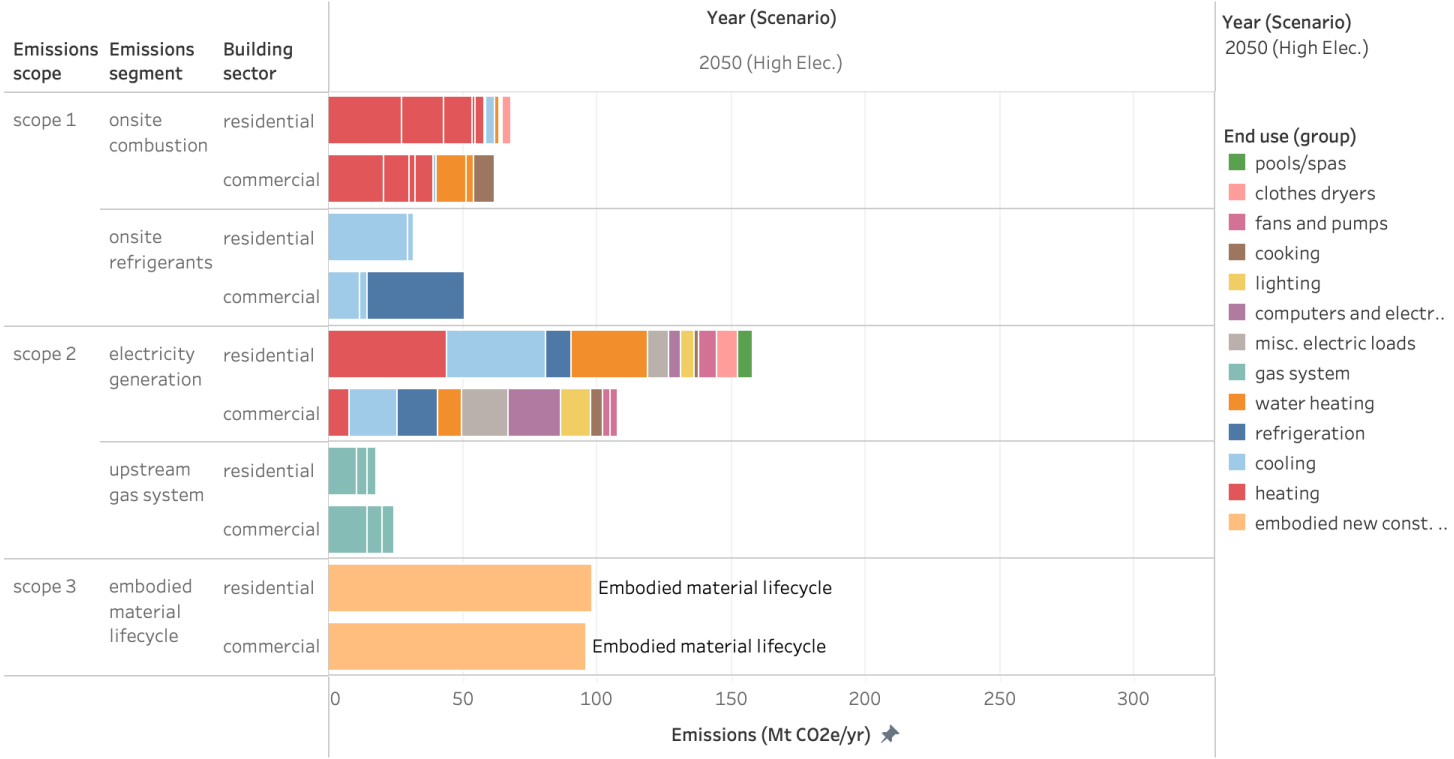
Buildings Sector **GHG Segmentation 2050 BAU by end use and sector**



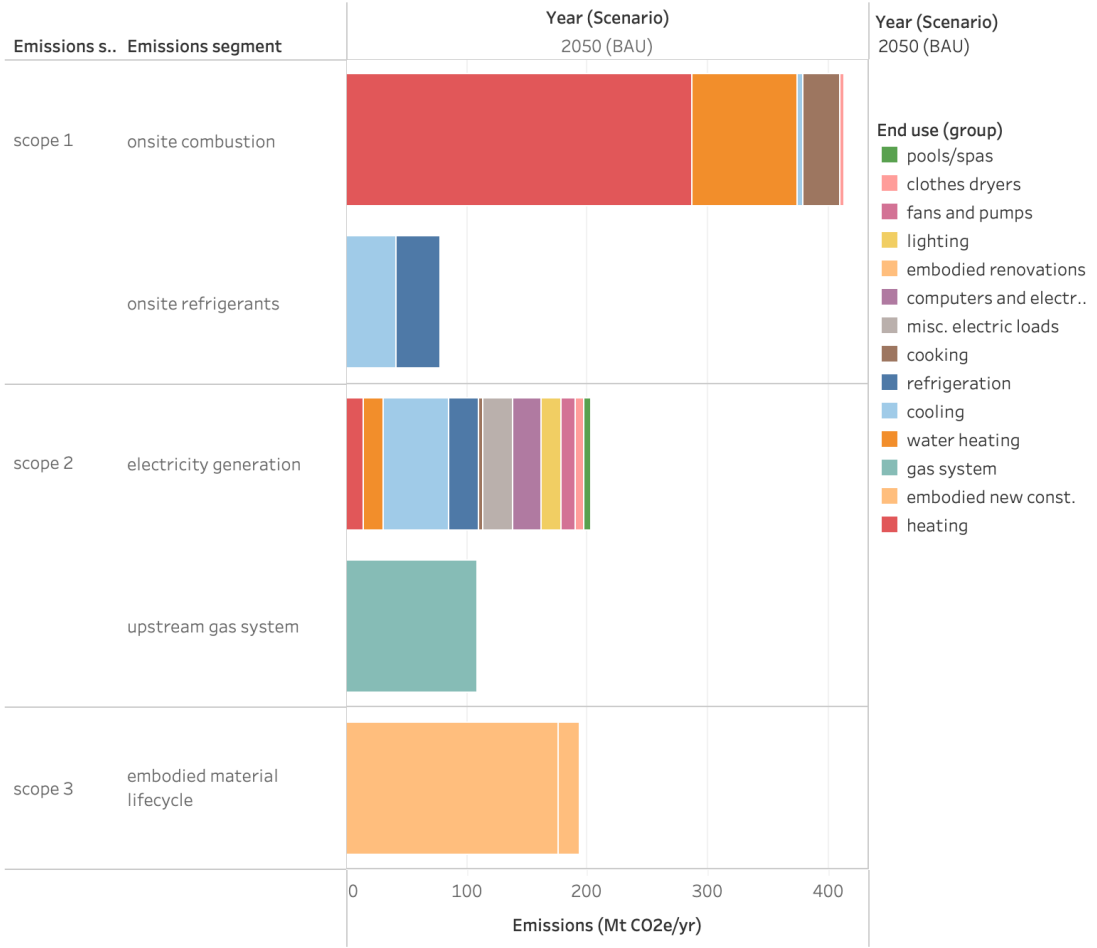
Buildings Sector **GHG Segmentation**
2050 BAU by end use, sector, and equipment



Buildings Sector **GHG Segmentation**
2050 High Electrify by end use, sector and equip.



Heating and cooling are responsible for ~50% of emissions



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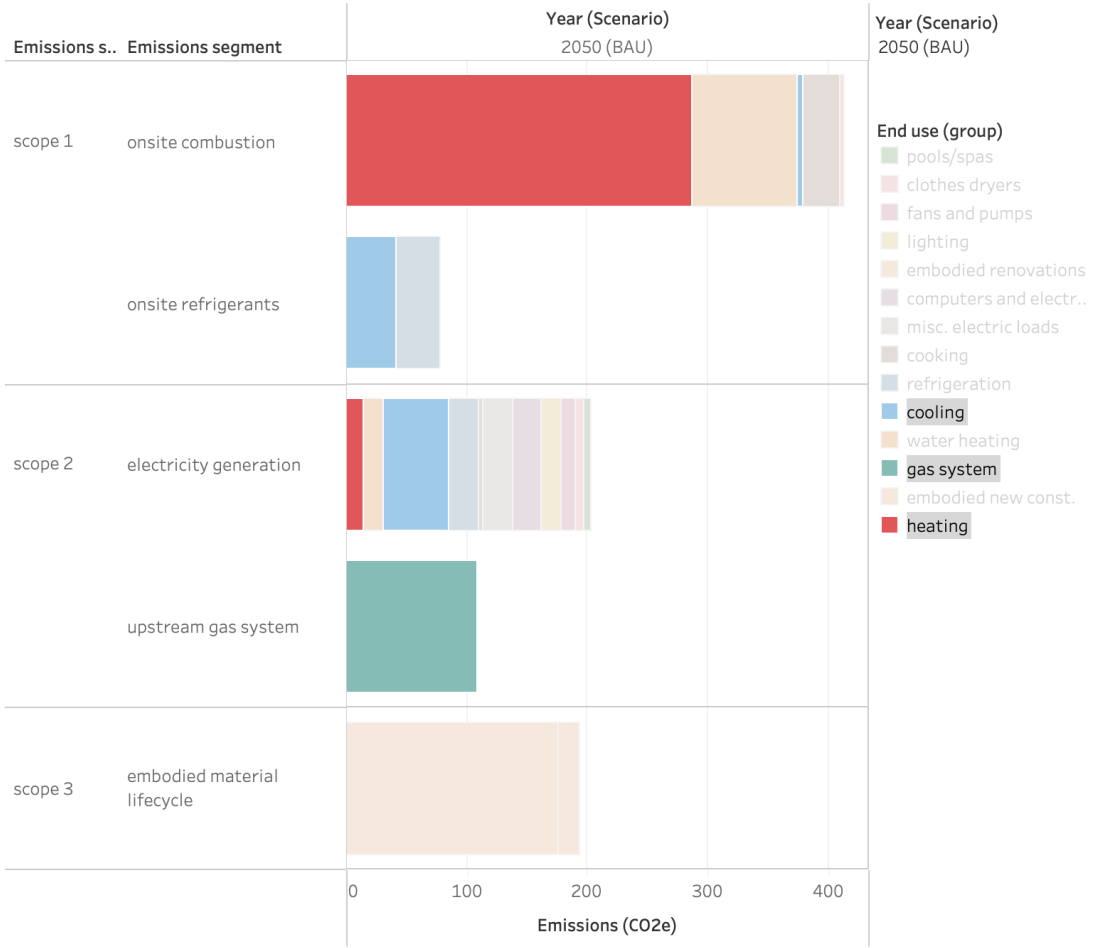
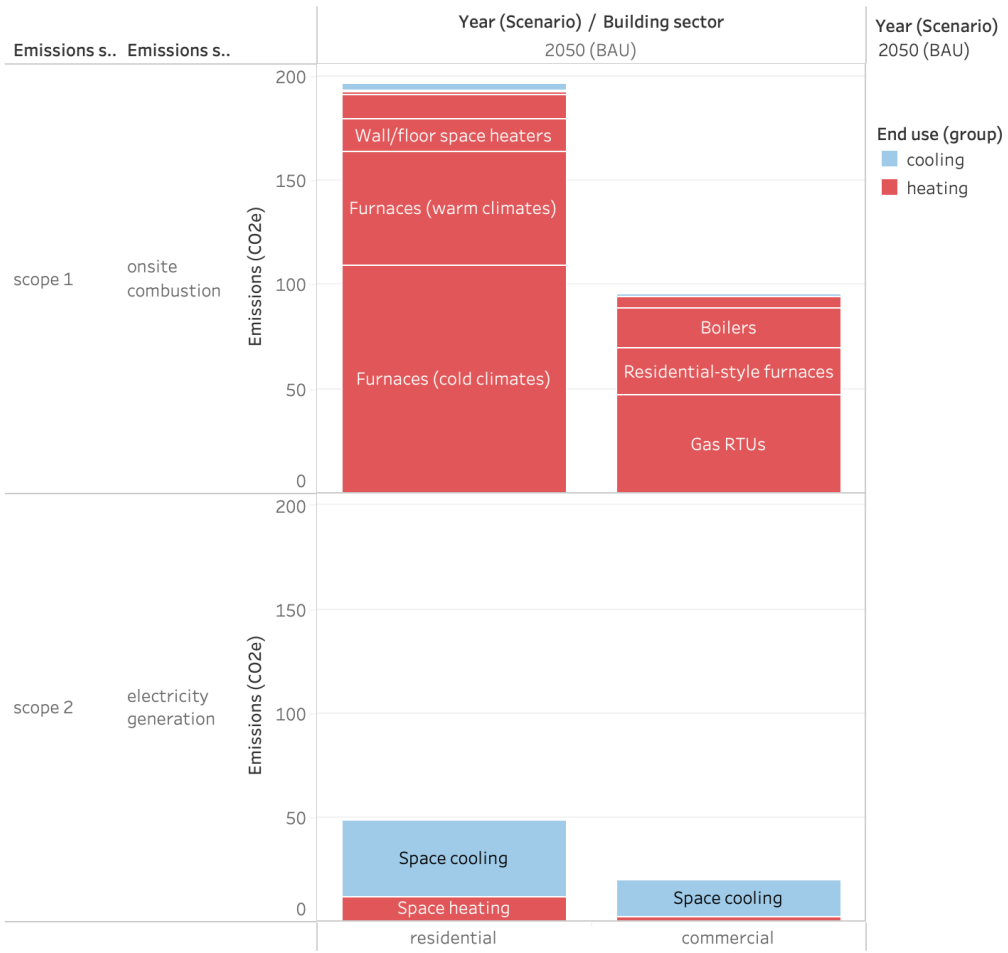
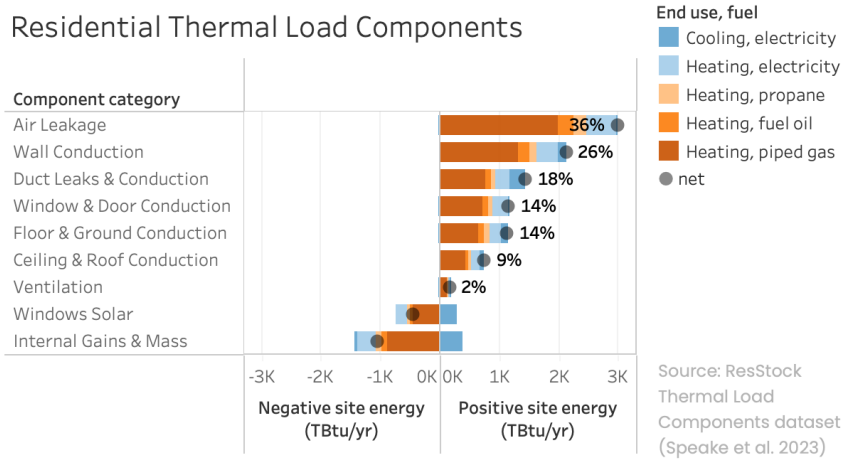


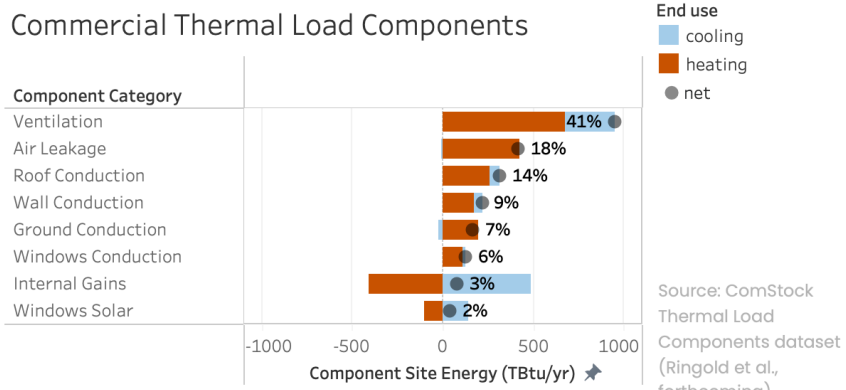
Heating and cooling emissions by equipment



Heating and cooling site energy by thermal load component

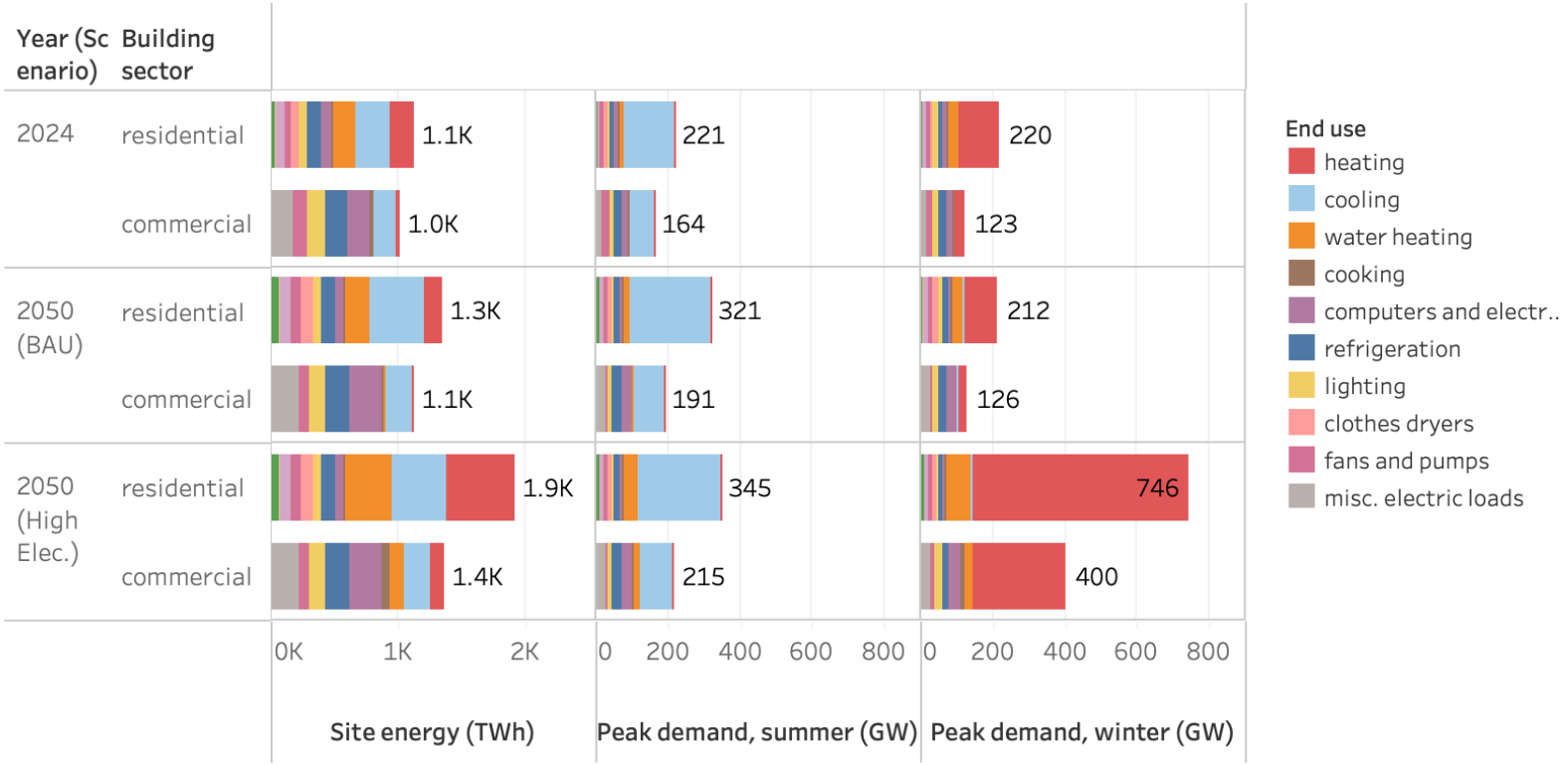


Source: ResStock Thermal Load Components dataset (Speake et al. 2023)



Source: ComStock Thermal Load Components dataset (Ringold et al., forthcoming)

Not Just About Emissions: **Site Energy and Peak Demand Segmentation** by Year and Scenario



Where do these data come from?

- **Scenarios:**
  - Current snapshot
  - 2024-2050, Business-as-Usual (BAU): Scout baseline (EIA AEO 2023)
  - 2024-2050, High Electrification: Scout Inefficient Electrification case
- **Metrics:**
  - **Thermal load components (2024):** ResStock/ComStock Component Loads datasets
  - **GHG emissions (2024, 2050)**
    - Fossil/electric equipment: Scout demand +Cambium 2022 Mid Case grid
    - Fugitive emissions (refrigerants/gas system): Scout/EPA
    - Embodied emissions: See National Buildings Decarbonization Blueprint for details
  - **Site energy use (2024, 2050):** Scout
  - **Seasonal peak (2024, 2050):**
    - Scout annual demand disaggregated via hourly ResStock/ComStock End Use Load Profiles
    - BAU overall peak hour definitions based on Scout defaults
    - High electrification scenario assumes generic 9AM January winter peak

Key caveats and limitations

- Validation of 2024 data with EIA & FERC data is ongoing (via Buildings Standard Scenarios)
- High uncertainty in estimates:
  - gas system emissions
  - embodied emissions
  - speed of grid decarbonization
  - speed of building electrification
- Aggregate U.S. winter peak under High Electrification scenario assumed to be 9 am on Jan. 1 in all regions
- Continuing to investigate interpretation of NEMS data (e.g., “unspecified” error term)

Download the Blueprint:

bit.ly/buildingsdecarb

Thank you

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