Introduction to Building Decarbonization

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Acknowledgements

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Also, thanks to all the volunteers of the Task Force for Building Decarbonization who collectively have identified hundreds of resources and documents on decarbonization

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Course Outline

- Introduction
- Building Energy and Carbon
- Basic Building Decarbonization Terminology
- Carbon in Buildings
- Building Decarbonization
- ASHRAE Resources for Decarbonization

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Building Growth
2060: 230 billion m²
Constructing an entire New York City every month
Source: Architecture 2030. 2022.

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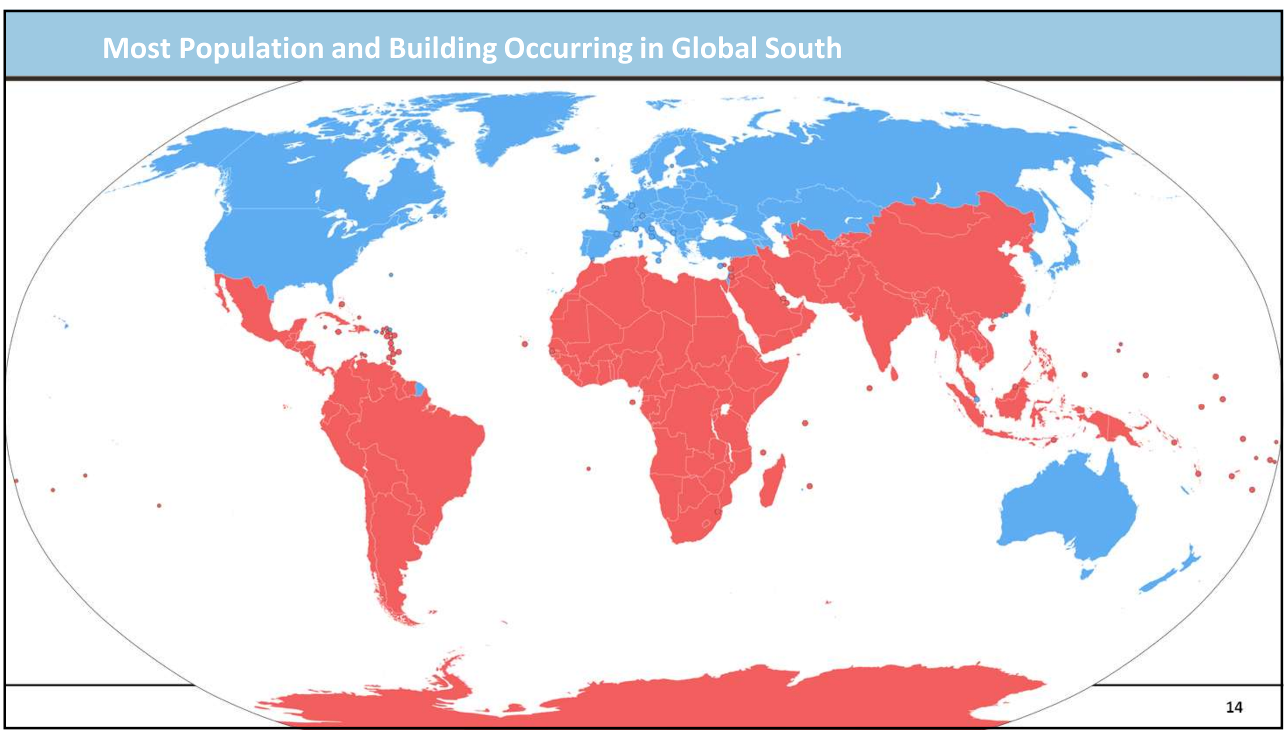
Most Population and Building Occurring in Global South
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Climate is Rapidly Changing

2015 UN Paris Agreement
2°C to 1.5°C

2018 UN IPCC Recommendation
1.5°C

In 2015, the Paris Agreement was adopted to limit the global temperature rise maximum at 2°C with a strong recommendation to retain it at 1.5°C

Source: IPCC 2018

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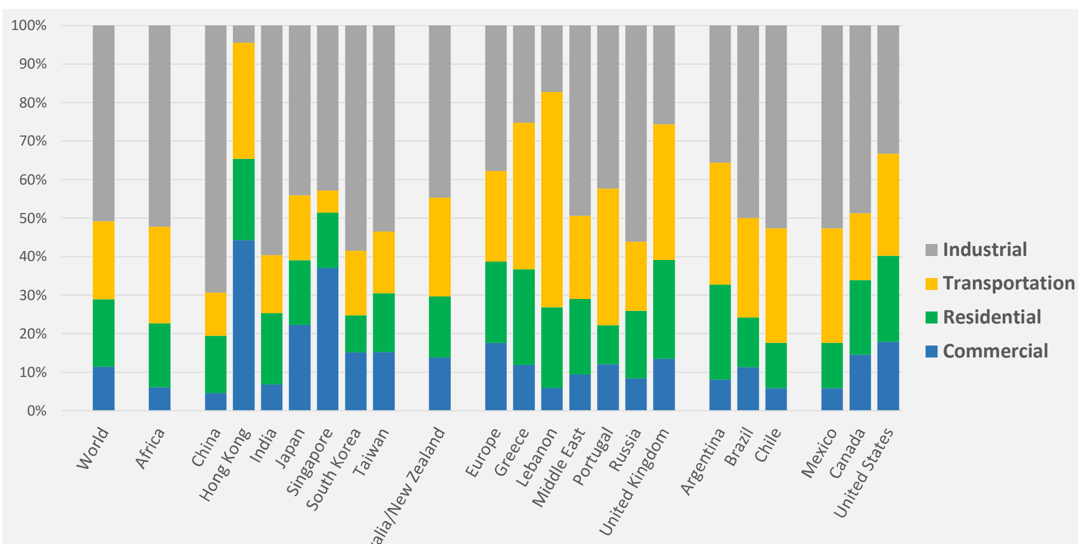
Building energy use worldwide



USEIA 2021a, BOE 2019, DBEIS 2020, EMA 2019, EMSD 2019, IEA 2020a

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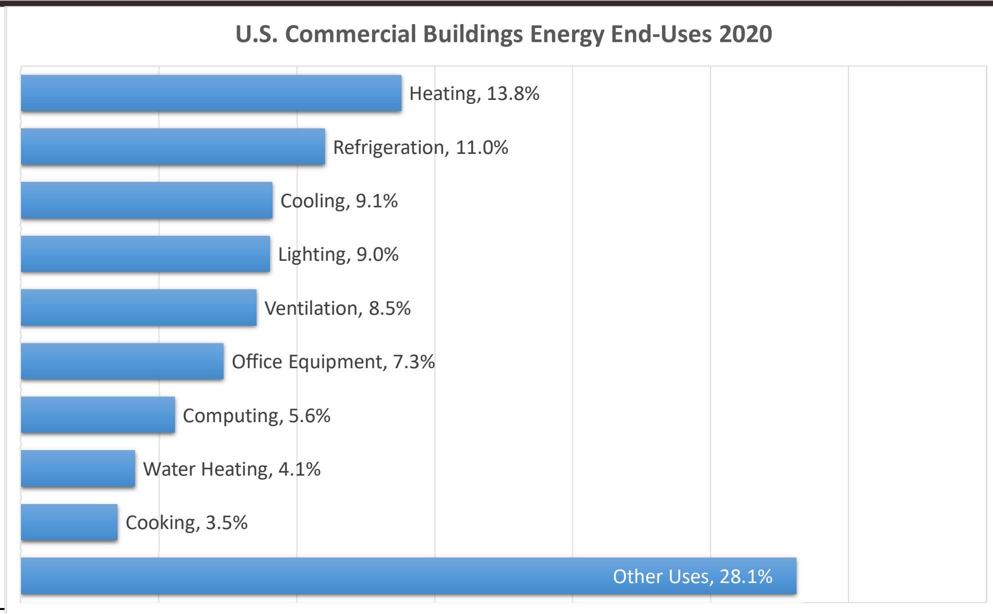
U.S. Buildings Energy Use



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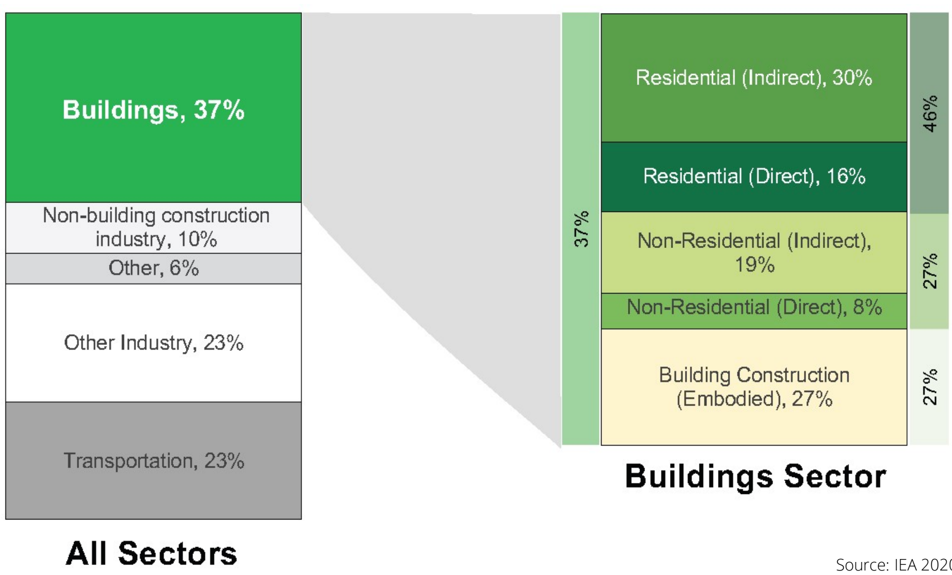
Energy-Related CO_2 Emissions in 2020



Source: IEA 2020a

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Why Is Carbon Important?

- Global human-caused emissions must reach net zero by approximately midcentury to limit climate change to substantially less than 2C (IPCC 2018)
- Climate stabilization requires full decarbonization of our energy systems and zero net greenhouse-gas emissions by around 2070 (World Economic Forum 2015)
- Many nations, states, cities, and companies have committed to replacing our current energy system by midcentury with a system that would emit zero net human-caused greenhouse gases (GHGs): CDP, USCA, NAS (2021), WEF (2015)

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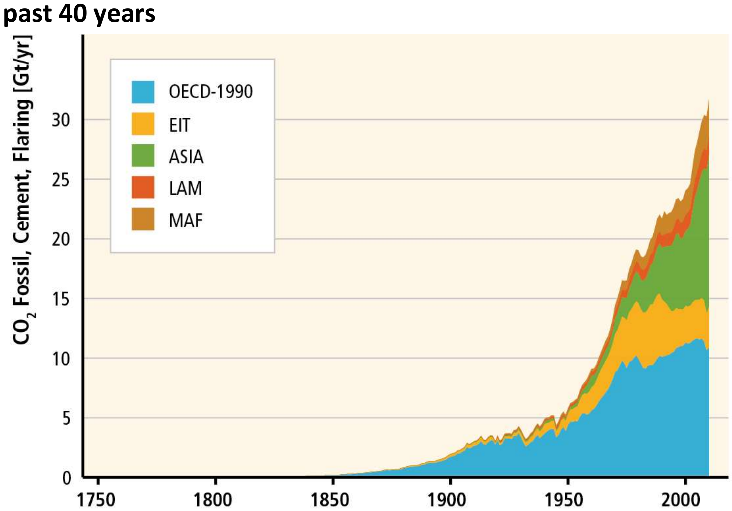
Where are GHGs Being Produced?

Half of the cumulative man-made carbon emissions since 1750 have occurred in the past 40 years



Source: IPCC 2014

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Why Decarbonize Buildings?

- Climate change is likely the most formidable environmental challenge every faced by society
- Buildings already represent 37% of global energy-related carbon emissions and the global building stock is expected to double by 2060
- With 40+ year lifetime, buildings can lock in high emissions for decades
- UNEP estimates that direct carbon emissions from building operations must be cut by ~50% and indirect emissions from power generation must drop by about 60% by 2030 → emissions must drop by 6%/year over this decade (equal to building sector temporary reduction in carbon during the COVID pandemic)

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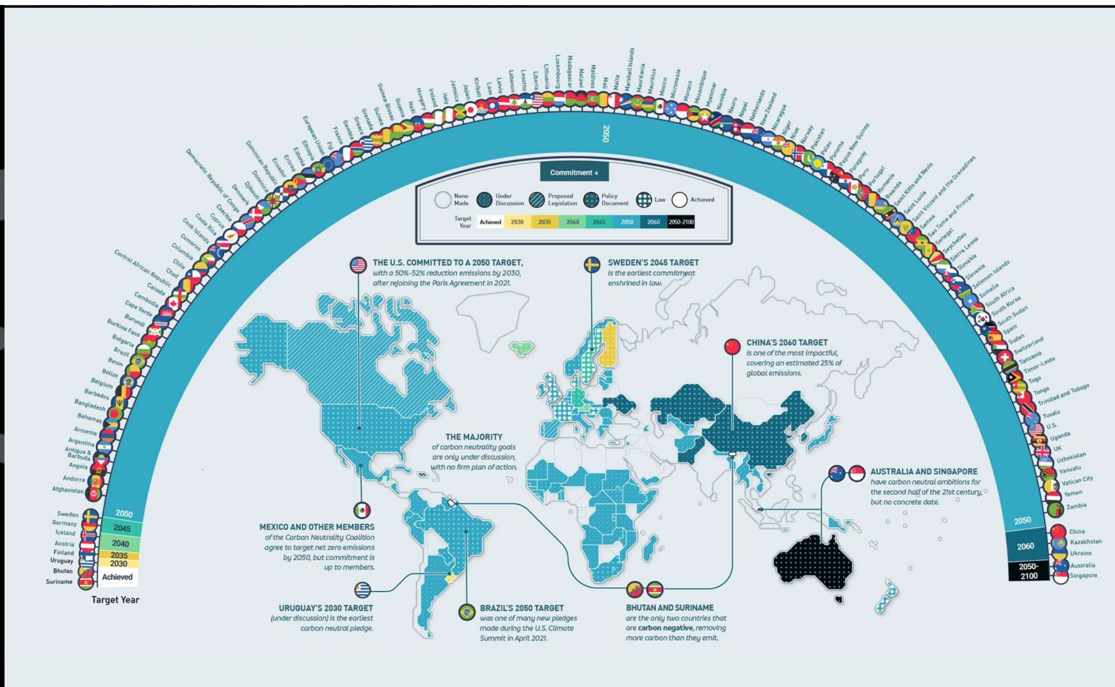
Carbon Commitments by Country



Sources: Energy and Climate Intelligence Unit, Net Zero Tracker (2022)

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Basic Decarbonization Terminology

Basic Terms: Carbon Dioxide (CO_2), Global Warming Potential, and Greenhouse Gas

Term	Definition
Carbon dioxide (CO_2)	A naturally occurring gas, CO_2 is also a by-product of burning fossil fuels (such as oil, gas and coal), of burning biomass, of land-use changes (LUC) and of industrial processes (e.g., cement production). It is the principal anthropogenic greenhouse gas (GHG) that affects the Earth's radiative balance. It is the reference gas against which other GHGs are measured and therefore has a global warming potential (GWP) of 1.
Global Warming Potential (GWP)	An index for estimating the relative global warming contribution of atmospheric emissions of a particular greenhouse gas compared to emissions of an equal mass of carbon dioxide (CO_2).
Greenhouse Gases (GHG)	Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself and by clouds--causing the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary GHGs in the Earth's atmosphere. Entirely human-made GHGs include halocarbons and other chlorine- and bromine-containing substances (Montreal Protocol). Kyoto Protocol covers CO_2, N_2O and CH_4 as well as sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). IPCC 2018

Basic Terms: Carbon Dioxide Equivalent (CO_2-e) Emissions

Term	Definition
Carbon dioxide equivalent (CO_2-e) emissions	The amount of carbon dioxide (CO_2) emission that would cause the same integrated radiative forcing or temperature change, over a given time horizon, as an emitted amount of a greenhouse gas (GHG) or a mixture of GHGs. Typically, the CO_2-equivalent emission is obtained by multiplying the emission of a GHG by its global warming potential (GWP) for a 100-year time horizon. For a mix of GHGs it is obtained by summing the CO_2-equivalent emissions of each gas.

Carbon emissions

IPCC 2018

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Basic Terms: Carbon, Emissions, and Electrification

Term	Definition
Operational Carbon	CO_2e emissions associated with energy and water used to operate the building/site or in the operation of infrastructure over its lifetime.
Embodied Carbon	CO_2e emissions associated with materials and construction processes throughout the whole life cycle of a building.
Direct Emissions	GHG emissions primarily from on-site combustion of fossil fuels
Indirect Emissions	GHG emissions primarily from electricity generated off-site to power buildings, includes district energy supplied
Electrification	Replacing direct fossil fuel use with electricity to reduce overall emissions and lower air pollutants.

IPCC 2018

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Basic Terms: LCA, EPD, CCUS, Site Carbon Sequestration, and BPS

Term	Definition
Life Cycle Assessment (LCA)	Methodology for assessing potential environmental of a product, service, or building throughout its life cycle.
Environmental Product Declaration (EPD)	Independently verified and registered document that presents transparent and comparable information about the life-cycle environmental impact of products, enabling comparisons among products.
Carbon capture, utilization, and storage (CCUS)	Capturing carbon emission from sources such as coal-fired power plants and either reuse or store the carbon so that it does not enter the atmosphere.
Site Carbon Sequestration	Long-term process of capturing and storing carbon emissions in solid and dissolved forms at the site to prevent it from entering the atmosphere. Carbon sequestration can be biological (plants) and geological.
Building Performance Standards (BPS)	Government policy (national, state or local) that requires building owners to actively improve their building's performance over time to meet performance targets. Targets can include energy and/or emissions targets requiring improved energy efficiency, reduced climate impacts, and renewable energy.

IPCC 2018

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Carbon in Buildings

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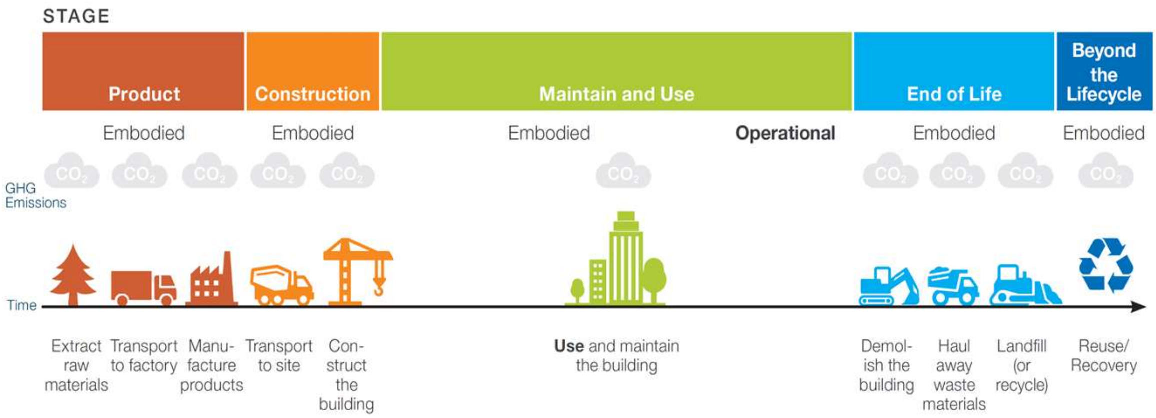
Carbon Life Cycle of a Building



Adapted from BS EN 15978:2011

Source New Buildings Institute. Lifecycle GHG Impacts in Building Codes, Figure 1 adapted from EN 15978
https://gettingtozeroforum.org/wp-content/uploads/sites/2/2022/01/NBI_Lifecycle-GHG-Impacts-in-Codes_Jan2022.pdf

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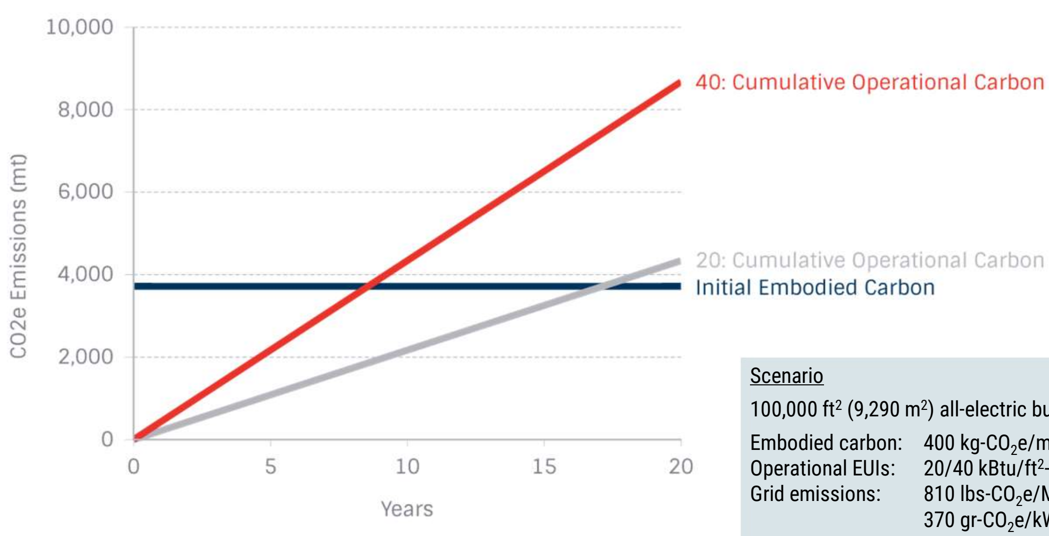
Comparing embodied and operational carbon



Scenario

100,000 ft² (9,290 m²) all-electric building

Embodied carbon:	400 kg-CO_2e/m²
Operational EUIs:	20/40 kBtu/ft²-yr
Grid emissions:	810 lbs-CO_2e/MWh
	370 gr-CO_2e/kWh

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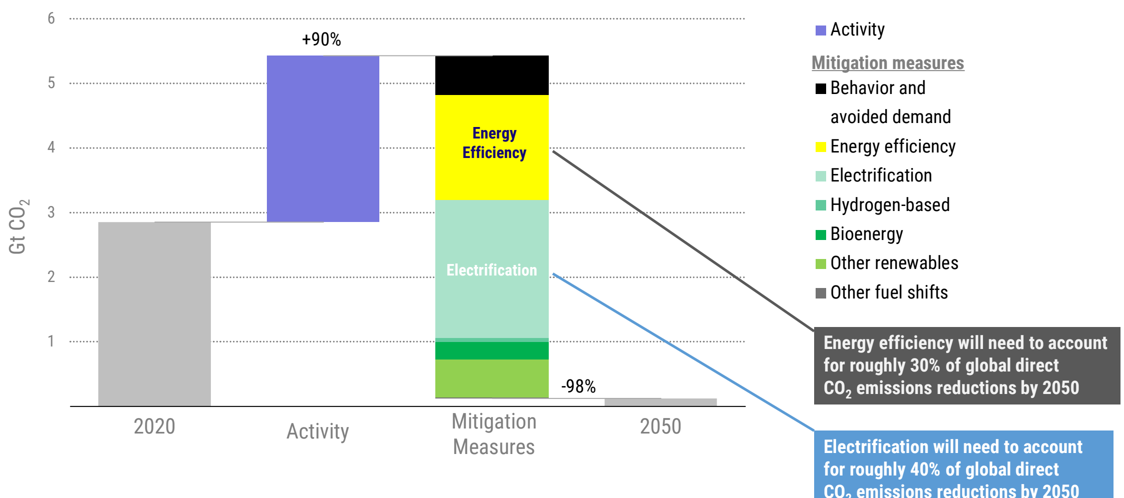
Building Decarbonization

What is Building Decarbonization?

- Reducing or eliminating man-made carbon emissions relating to buildings
  → Goal is to eliminate man-made carbon emissions entirely

- Decarbonization pillars
  - Reduce carbon emissions in materials and systems
  - Energy efficiency
  - Switching to cleaner energy sources
  - Shifting to electricity produced with low-carbon energy sources

Global direct CO_2 emissions reductions by mitigation measure in buildings in the 2050 NZE



Source: International Energy Agency (2021), Net Zero by 2050, IEA, Paris

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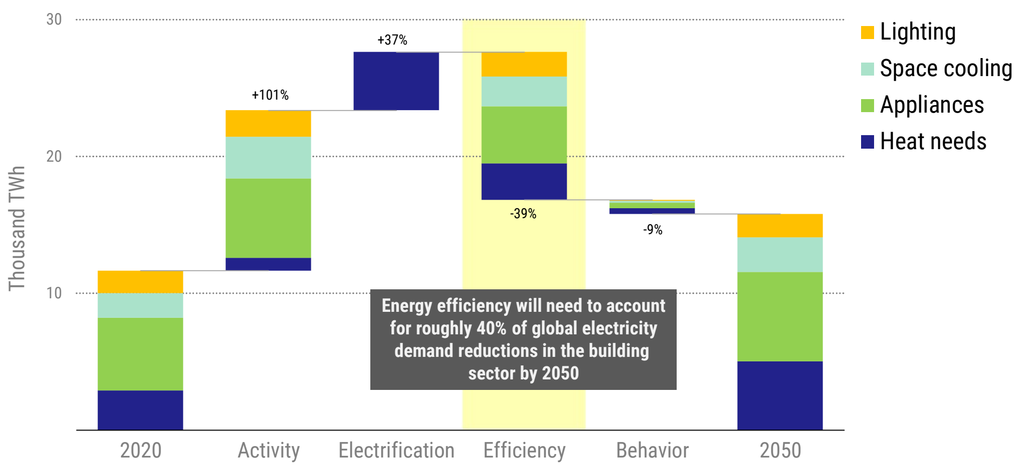
Global change in electricity demand by end-use in the buildings sector



Source: International Energy Agency (2021), Net Zero by 2050, IEA, Paris

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Building Decarbonization Principles

- **Reuse existing** buildings, structures, and materials whenever possible
- **Optimize building orientation and geometry** to reduce energy use and maximize solar potential
- **Prioritize passive efficiency** to reduce energy use before implementing **active efficiency measures**
- Optimize waste energy use
- **Minimize embodied carbon** in new **construction materials and construction**
- **Electrify space and water heating and cooking** where feasible
- **Use low GWP refrigerants** while maintaining energy efficiency
- Optimize **on-site renewable energy** resources
- **Purchase off-site renewable energy**
- **Real time carbon usage/removal**
- **Purchase carbon offsets** for any remaining emissions

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Building Decarbonization Issues

- One-size does not fit all
  - Residential – commercial - industrial
  - New vs retrofit (60-80% of buildings in 2050 are already built depending on the country)
  - Spectrum of existing generation fuel mix
  - Developed vs underdeveloped countries

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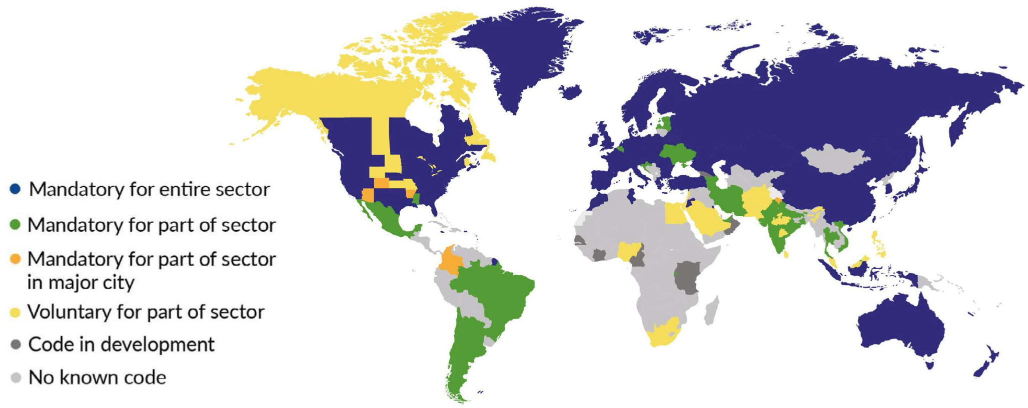
Building Decarbonization Issues

Standards and Codes – Scope is not uniform



Source: Adapted from GABC/IEA/UNEP 2020

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Building Decarbonization Issues

- Metrics
  - Energy use or carbon (embodied and operational)
  - Carbon metrics – average, hourly, historical, forward looking, cost?
  - Offsets – allowed in CIBSE, USEPA, WRI, and ASHRAE 228-2023
  - Benchmarks – common measurement scale
    - Inclusion of plug loads or just thermal
  - Embodied carbon / LCA – availability of data and geographically differences

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Building Decarbonization Issues

- Refrigerant Leakage

Application	Annual Leakage Rate
Domestic Refrigeration	0.1 – 0.5%
Stand-Alone Commercial Applications	1 – 10%
Medium and Large Commercial Refrigeration	10 – 30%
Transport Refrigeration	15 – 50%
Industrial Refrigeration including Food Processing and Cold Storage	7 – 25%
Chillers	2 – 15%
Residential and Commercial A/C, including Heat Pumps	1 – 5%
Mobile Air Conditioners	10 – 20%

IPCC 2000

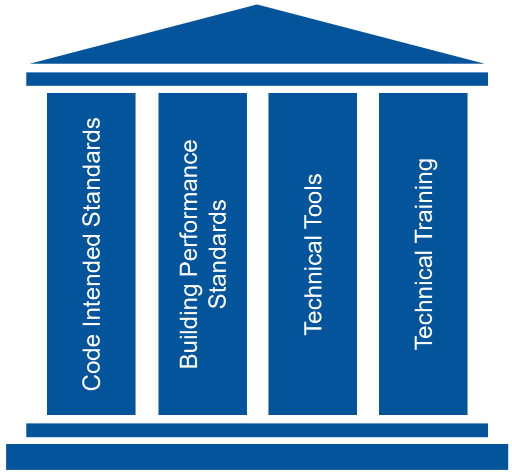
Building Decarbonization Issues

- Timing of Energy Use – generation source and emissions are time dependent
- Energy storage –thermal and electrical
- Cold climates and heat pump heating and SWH
- Controls & communication –internal and with the grid (more than load controllers)
- Maintenance and operation complexities
- Commissioning and retro-commissioning

Global Building Sector Net Zero Emissions by 2050

Energy Efficiency
30% reduction in direct energy
40% reduction in indirect energy

Electrification
Transition from fossil fuels in buildings to zero carbon electricity



Grid Friendly
Storage and sequences for grid responsiveness

Zero Carbon Energy
Renewable energy and nuclear generation

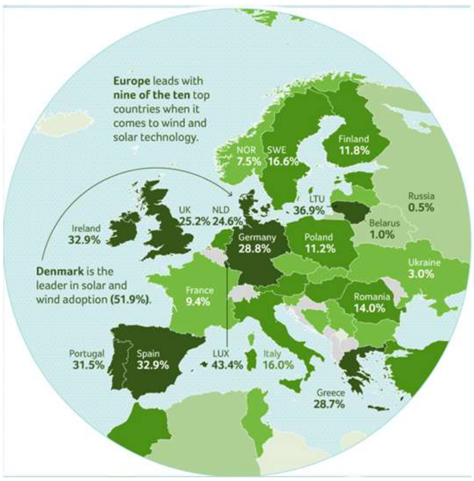
Source: IEA 2021a

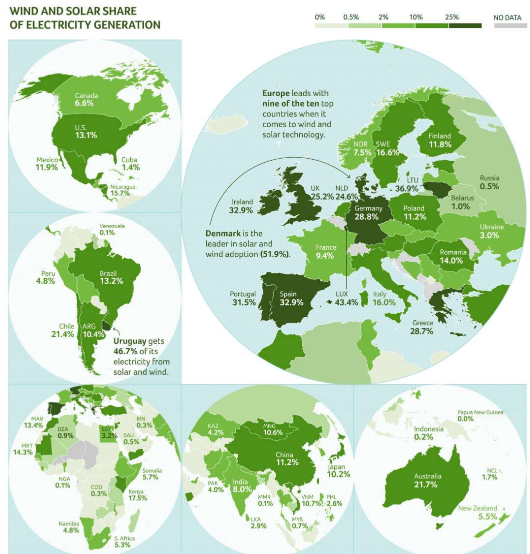
Building Performance Standard Example – Boston, MA

Building use	Emissions standard ($kgCO_2e/SF/yr.$)					
	2025 - 2029	2030-2034	2035-2039	2040-2044	2045-2049	2050-
Assembly	7.8	4.6	3.3	2.1	1.1	0
College/ University	10.2	5.3	3.8	2.5	1.2	0
Education	3.9	2.4	1.8	1.2	0.6	0
Food Sales & Service	17.4	10.9	8.0	5.4	2.7	0
Healthcare	15.4	10.0	7.4	4.9	2.4	0
Lodging	5.8	3.7	2.7	1.8	0.9	0
Manufacturing/ Industrial	23.9	15.3	10.9	6.7	3.2	0
Multifamily housing	4.1	2.4	1.8	1.1	0.6	0
Office	5.3	3.2	2.4	1.6	0.8	0
Retail	7.1	3.4	2.4	1.5	0.7	0
Services	7.5	4.5	3.3	2.2	1.1	0
Storage	5.4	2.8	1.8	1.0	0.4	0
Technology/Science	19.2	11.1	7.8	5.1	2.5	0

Source: City of Boston 2021

Grid Solar and Wind Power by Country





https://elements.visualcapitalist.com/mapped-solar-and-wind-power-by-country/

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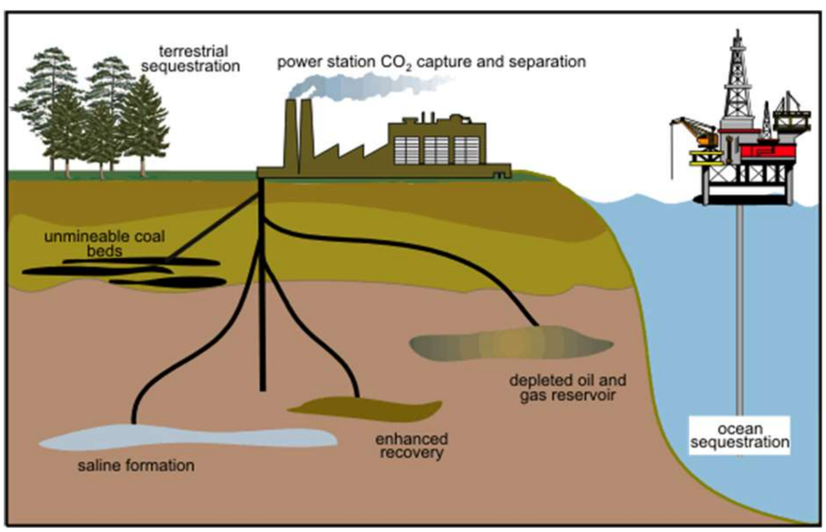
Carbon Emissions Offsets -- Sequestration

Using natural processes and manmade means of storing carbon away from the atmosphere:

- **Oceanic**
- **Terrestrial**
- **Geologic**



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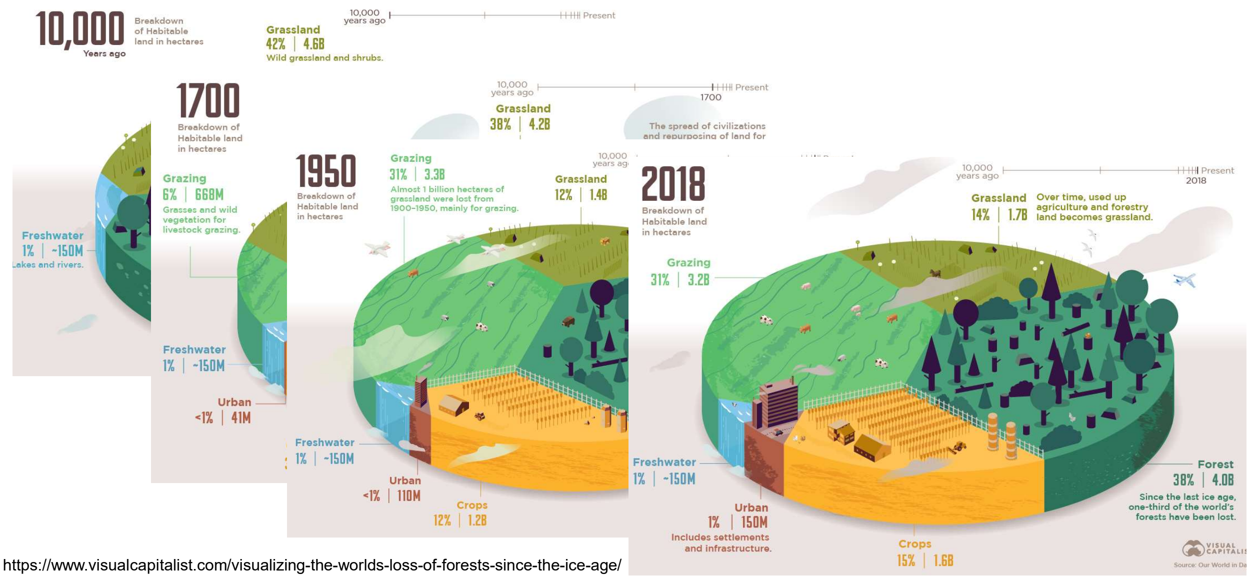
Global Loss of Forests



https://www.visualcapitalist.com/visualizing-the-worlds-loss-of-forests-since-the-ice-age/

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Current Carbon Sequestration Methods and Technologies

- **Storage**: CO_2 Fuels
- **Capture**:
  - Forestry
  - CO_2 Chemicals
- **Capture and Storage**:
  - Carbon Storage and Enhanced Oil Recovery
  - Bioenergy with Carbon Capture and Storage
  - Enhanced Weathering Technology
  - Soil Carbon Sequestration
  - Concrete Building Material
  - HVAC Systems Capture
  - Microalgae
  - Biochar

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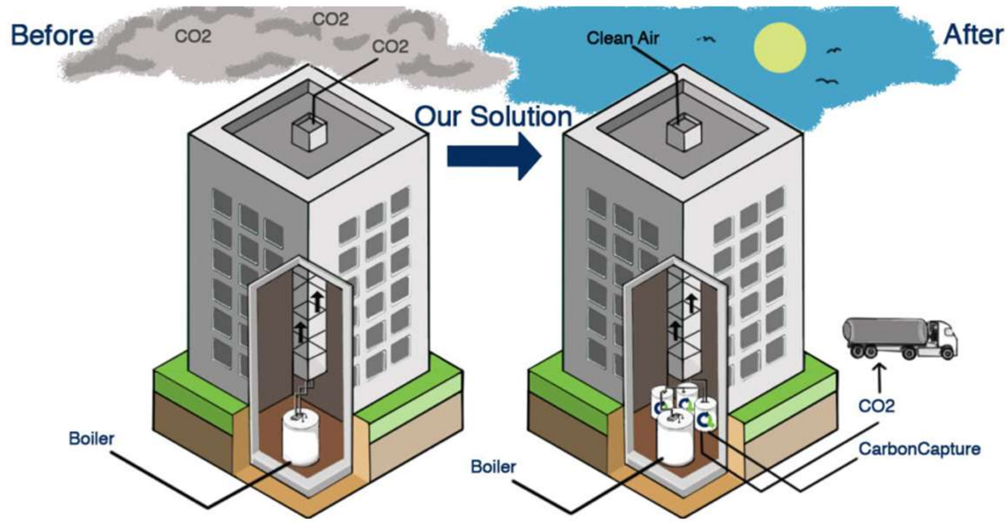
Example Carbon Capture Process



Source: Carbon Quest 2022

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Whole Building Life Cycle Analysis

- What is Whole Building Life Cycle Analysis?
  - Science-based methodology for quantifying lifetime environmental impacts
  - Most effective tool available to measure the life-cycle carbon emissions of any construction project
  - Often a mandatory part of planning regulations in many countries and green building certifications
- LCA looks at key environmental and resource use indicators over a building's life
  - GWP, Acidification, Eutrophication, Ozone Depletion, Photochemical Ozone Creation, and Abiotic Depletion for Fossil Resources

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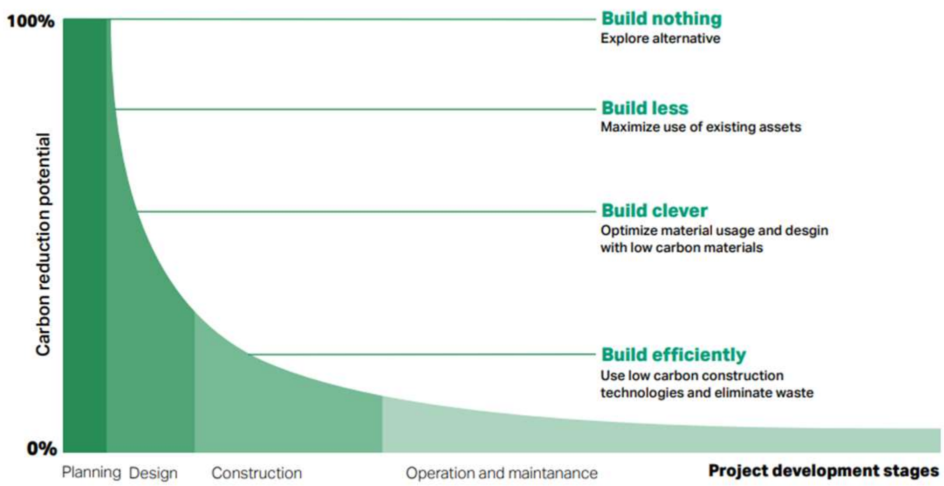
Why do LCA?

Opportunity to reduce embodied carbon declines as the project moves through design, construction and into operation



Source: WBCSD 2021

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Green Building Certifications Require LCA

LEED v4.1

Whole Building Life Cycle Assessment: Up to 3 points for performing LCA and reducing carbon of structure and enclosure by 10%

ILFI Zero Carbon Certification

Reduce embodied carbon of primary foundation, structure, and enclosure by 10% -- max 500 $kgCO^2e/m^2$

BREEAM

Assess embodied carbon of building elements or of whole building through LCA.

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What LCA Tools are Available?

Databases

- Inventory of Carbon and Energy (ICE) http://www.circularecology.com/embodied-energy-and-carbon-footprint-database.html#.XVWHdo7VnIw (UK focused)
- Quartz http://quartzproject.org/ (typical impacts of 100 generic products)

Early Phase Embodied Carbon Estimating Tools

- Carbon Designer https://www.oneclicklca.com/carbon-designer/ (early design phase add-on to One Click LCA)
- Construction Carbon Calculator http://buildcarbonneutral.org/ (few building details needed but a bit old)
- EcoCalculator https://calculatelca.com/software/ecocalculator/ (entry level LCA tool)

Source: Building Green 2019, USGBC 2022

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Whole Building Life-Cycle Assessment Tools

- Athena Impact Estimator
  http://www.athenasmi.org/our-software-data/impact-estimator/ (easy access to advanced life-cycle inventory data)
- One Click LCA
  https://www.oneclicklca.com/ (early to late LCA analysis, increasing detail throughout design)
- Tally
  https://choosetally.com/ (BIM plug-in for very detailed LCA analysis, embodied carbon not considered)
- EC3 (Embodied Carbon Construction Calculator)
  https://www.buildingtransparency.org/ (open access, free database of construction EPDs with building impact calculator)

Source: Building Green 2019, USGSA 2022

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Environmental Product Declarations (EPD)

- Independently verified and registered document that presents transparent and comparable information about the life-cycle environmental impact of products, enabling comparisons among products.
- Accurate data on embodied carbon and environmental impact of materials and systems
- Developed in accordance with ISO 14025 (ISO 2006) and other standards
- EPD data is collated into various database products
- EPD data i**s critical for performing accurate LCA**
- **Most MEP equipment sold in the US** do not have EPD data

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What Does it Take to Do a Building LCA?

Step 1. Define the goal and scope (often based on client or regulatory requirements)

Hardest part

Step 2. Collect inventory (materials, energy and water use, site operations)

Step 3. Environmental impact assessment

Step 4. Interpret results, optioneering and reporting

Source: ISO 14040

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Building Equipment

- **Fossil fuel powered equipment**
  - Furnaces, boilers, heating equipment, SWH
- **Alternatives to reduce carbon**
  - Lower GWP refrigerants
  - Green fuels (hydrogen)
  - Renewable gas (methane recovery)
  - Bio-fuels (cooking oil)
- **Heat pumps**

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Lower GWP Refrigerants

	R-410A	R-134A	R-32	R-513A	HFO R1 234yf	HFO-1234ze(E)	R514A	R744*
Global Warming Potential	2088	1300	675	547	4	< 1	1	1
ASHRAE Standard 34 Refrigerant Safety Classification	A1	A1	A2L	A1	A2L	A2L	B1	A1

*CO_2

Source: ASHRAE 2019

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Heat Pumps

Thermodynamic heating/refrigerating system to transfer heat. The condenser and evaporator may change roles to transfer heat in either direction. By receiving the flow of air or other fluid, a heat pump is used to cool or heat. Heat pumps may be the air source with heat transfer between the indoor air stream to outdoor air or water source with heat transfer between the indoor air stream and a hydronic source (ground loop, evaporative cooler, cooling tower, or domestic water). (ASHRAE)

Heat pump sources and sinks include:

- Air
- Water
- Ground-coupled
- Solar Energy
- Industrial

Product scale – everything from residential appliances to large heat recovery and HP chillers, and industrial HPs

Source: ASHRAE Terminology 2022a

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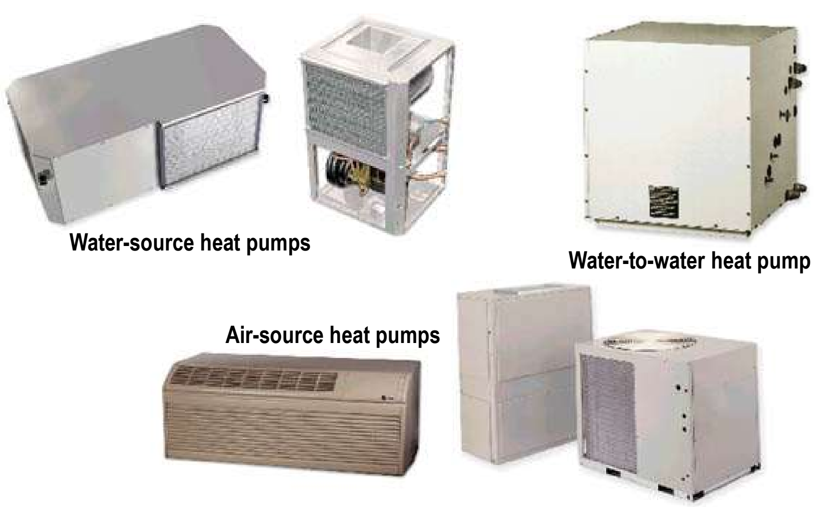
Heat Pump Examples



Source: Courtesy of Trane

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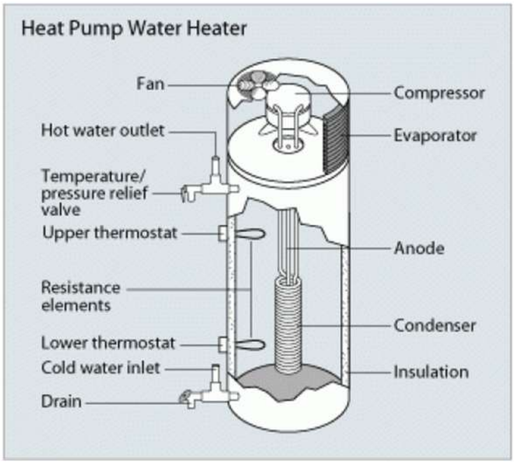
Heat pump appliances

Heat Pump Water Heater



Source: USDOE/USEPA 2022

Heat Pump Dryer

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2020 ASHRAE Handbook – HVAC Systems & Equipment

Table 1 Heat Pump Sources and Sinks

		Suitability		Availability		Cost		Temperature		Common Practice	
Medium	Examples	Heat Source	Heat Sink	Location Relative to Need	Coincidence with Need	Installed	Operation and Maintenance	Level	Variation	Use	Limitations
AIR											
Outdoor	Ambient air	Good, but efficiency and capacity in heating mode decrease with decreasing outdoor air temperature	Good, but efficiency and capacity in cooling mode decrease with increasing outdoor air temperature	Universal	Continuous	Low	Moderate	Variable	Generally extreme	Most common, many standard products	Defrosting and supplemental heat usually required
Exhaust	Building ventilation	Excellent	Fair	Excellent if planned for in building design	Excellent	Low to moderate	Low unless exhaust is laden with dirt or grease	Excellent	Very low	Excellent as energy-conservation measure	Insufficient for typical loads
WATER											
Well*	Ground-water well may also provide potable water source	Excellent	Excellent	Poor to excellent; practical depth varies by location	Continuous	Low if existing well used or shallow wells suitable; can be high otherwise	Low, but periodic maintenance required	Generally excellent; varies by location	Extremely stable	Common	Water disposal and required permits may limit; may require double-wall exchangers; may foul or scale
Surface	Lakes, rivers, oceans	Excellent for large water bodies or high flow rates	Excellent for large water bodies or high flow rates	Limited; depends on proximity	Usually continuous	Depends on proximity and water quality	Depends on proximity and water quality	Usually satisfactory	Depends on source	Available, particularly for fresh water	Often regulated or prohibited; may clog, foul, or scale
Tap (city)	Municipal water supply	Excellent	Excellent	Excellent	Continuous	Low	Low energy cost, but water use and disposal may be costly	Excellent	Usually very low	Use is decreasing because of regulations	Use or disposal may be regulated or prohibited; may corrode or scale
Condens-ing	Cooling towers, re-frigeration systems	Excellent	Poor to good	Varies	Varies with cooling loads	Usually low	Moderate	Favorable as heat source	Depends on source	Available	Suitable only if heating need is coincident with heat rejection
Closed loops	Building water-loop heat pump systems	Good; loop may need supplemental heat	Favorable; may need loop heat rejection	Excellent if designed as such	As needed	Low	Low to moderate	As designed	As designed	Very common	Most suitable for medium or large buildings
Waste	Raw or treated sewage, gray water	Fair to excellent	Fair; varies with source	Varies	Varies; may be adequate	Depends on proximity; high for raw sewage	Varies; may be high for raw sewage	Excellent	Usually low	Uncommon; practical only in large systems	Usually regulated; may clog, foul, scale, or corrode

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2020 ASHRAE Handbook – HVAC Systems & Equipment

Table 1 Heat Pump Sources and Sinks

		Suitability		Availability		Cost		Temperature		Common Practice	
Medium	Examples	Heat Source	Heat Sink	Location Relative to Need	Coincidence with Need	Installed	Operation and Maintenance	Level	Variation	Use	Limitations
					GROUND[a]						
Ground-coupled	Buried or submerged fluid loops	Good if ground is moist; other-wise poor	Fair to good if ground is moist; other-wise poor	Depends on soil suitability	Continuous	High to moderate	Low	Usually good	Low, particularly for vertical systems	Rapidly increasing	High initial costs for ground loop
Direct-expan-sion	Refrig-erant circulated in ground coil	Varies with soil conditions	Varies with soil conditions	Varies with soil conditions	Continuous	High	High	Varies by design	Generally low	Extremely limited	Leak repair very expensive; requires large refrigerant quantities
					SOLAR ENERGY						
Direct or heated water	Solar collectors and panels	Fair	Poor; usually un-acceptable	Universal	Highly intermittent; night use requires storage	Extremely high	Moderate to high	Varies	Extreme	Very limited	Supplemental source or storage required
					INDUSTRIAL PROCESS						
Process heat or exhaust	Distillation, molding, refining, washing, drying	Fair to excellent	Varies; often impractical	Varies	Varies	Varies	Generally low	Varies	Varies	Varies	May be costly unless heat need is near rejected source

[a] Groundwater-source heat pumps are also considered ground-source heat pump systems.

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Grid Transition to Renewables and Clean Fuels

- **Renewables** – for buildings, essentially utility-scale solar and wind)
- **Storage** – electric batteries, compressed air energy systems, pumped hydroelectric storage, flywheels, molten salt energy storage
- **Clean fuels** – renewable hydrogen, hydrogen-infused natural gas, bio-gases (landfill and agricultural methane)

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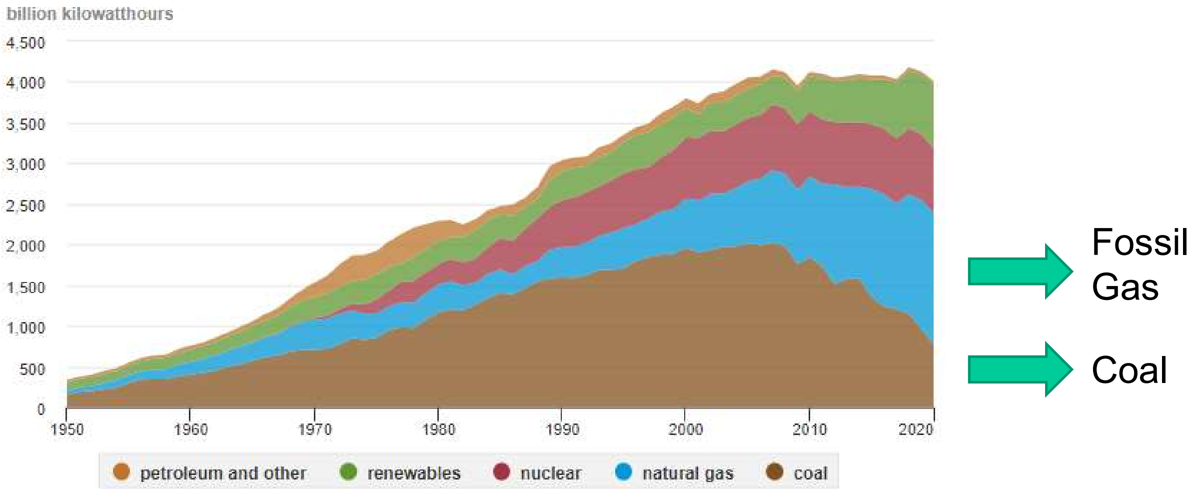
U. S. Electricity Generation by Major Energy Source, 1950-2020



Source: US EIA 2021b

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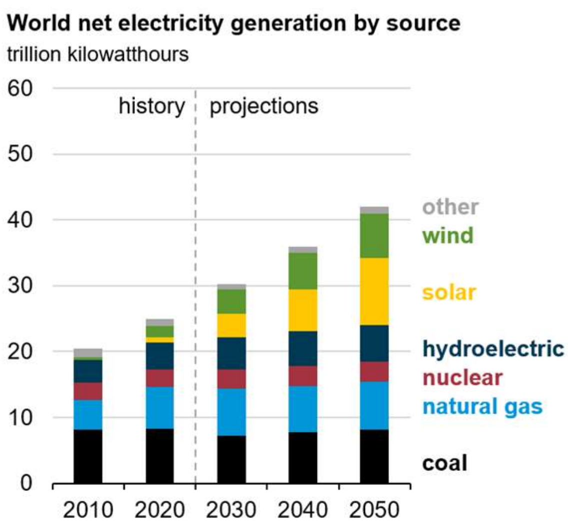
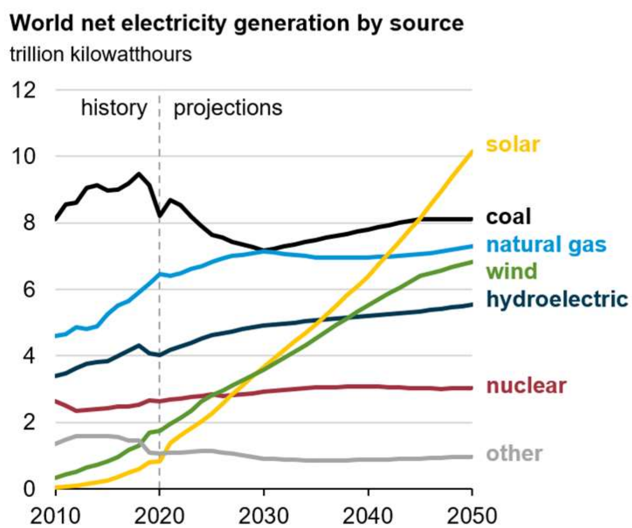
World Electricity Generation by Source 2010-2050





Source: US EIA 2021a

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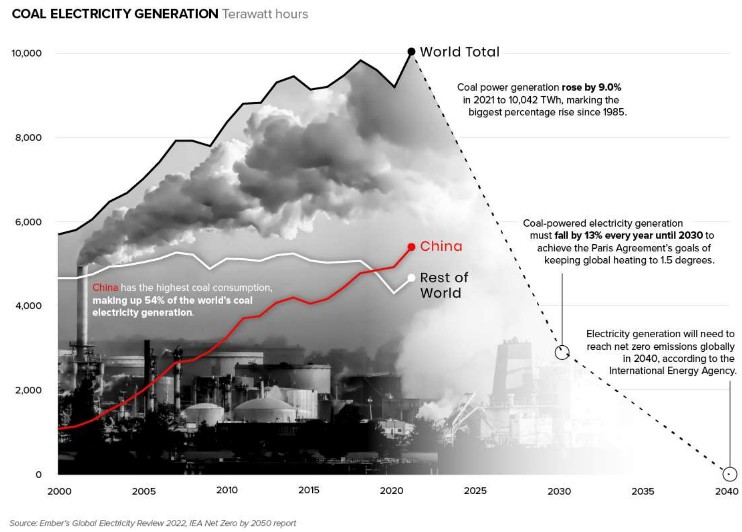
Phasing Out Coal for Electricity Generation

Over 40 nations have agreed to phase out coal in the coming years.

However, in 2021 coal-powered/fueled electricity generation reached all-time highs.



https://elements.visualcapitalist.com/how-far-are-we-from-phasing-out-coal/

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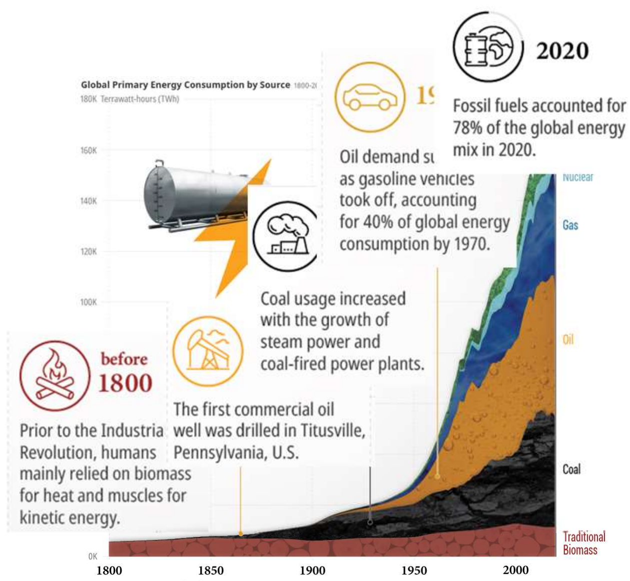
We have transitioned from other energy sources many times

Economic and technological advances over the last 200 years have transformed how we produce and consume energy. Here's the global mix of energy source since 1800.

https://elements.visualcapitalist.com/the-history-of-energy-transitions/



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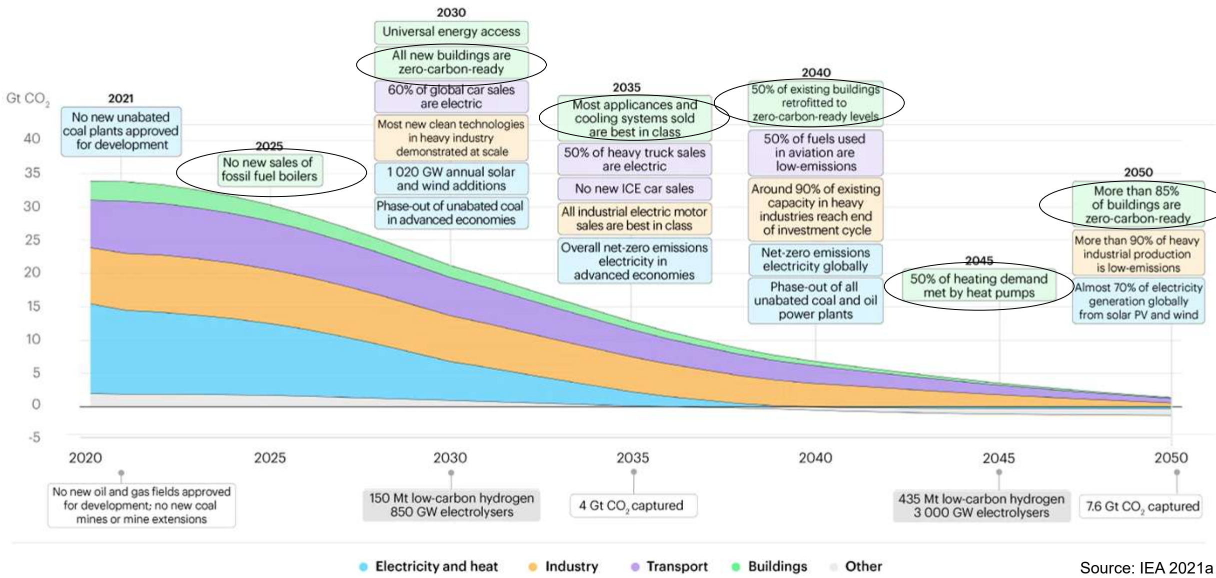
IEA Roadmap to Net Zero Carbon



Source: IEA 2021a

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ASHRAE Building Decarbonization Resources

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Why is ASHRAE involved?

- ASHRAE is the standards authority for energy performance, usage, and efficiency in buildings
- Many ASHRAE standards already include or are considering carbon metrics
- ASHRAE has best practices guides, guidelines, benchmarking, training and education
- ASHRAE has an international presence – with members in over 130 countries

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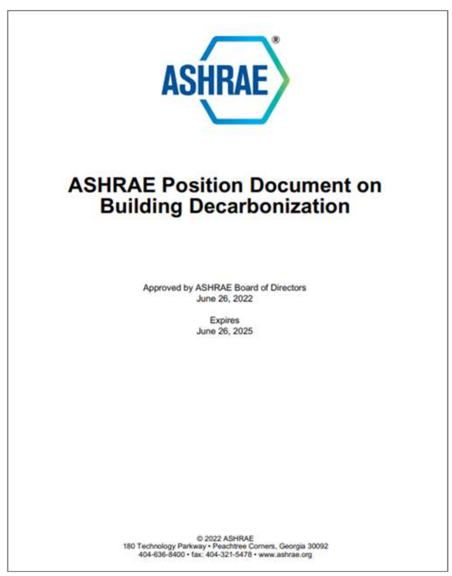
ASHRAE Building Decarbonization Position Document

ASHRAE Position Document on Building Decarbonization

- Position Document Committee started June 2021 and submitted a draft in March 2022
- Final Position Document approved by Technology Council and the ASHRAE Board in June 2022



ASHRAE

ASHRAE Position Document on Building Decarbonization

Approved by ASHRAE Board of Directors
June 26, 2022

Expires
June 26, 2025

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ASHRAE Building Decarbonization Position Document

- Eliminating greenhouse gas (GHG) emissions from the built environment is essential to address climate change.
- By 2030, the global built environment must halve its 2015 GHG emissions, whereby
  - all new buildings must be net-zero GHG emissions in operation,
  - widespread energy efficiency retrofit of existing assets must be well underway, and
  - embodied carbon of new construction must be reduced by at least 40 percent.
- By 2050, at the latest, all new and existing assets must be net zero emissions across the whole life cycle.
- ASHRAE is committed to continued efforts relating to building decarbonization in the following areas:
  - Research and standards development
  - Design and equipment applications
  - Technical guidance and training
  - Regulatory guidelines and measures
  - Educational resources and outreach

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Related ASHRAE standards and design guides

Standards

- **Refrigerant classification and safety which include low global warming potential refrigerants**
  - 34-2019, 15-2019
- **Energy standards for new buildings, residential buildings, and data centers**
  - 90.1-2022, 90.2-2018, 90.4-2022
- **Energy Efficiency in Existing Buildings**
  - 100-2018
- **Standard Methods of Determining, Expressing, and Comparing Building Energy Performance and Greenhouse Gas Emissions**
  - 105-2021
- **Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment and Systems**
  - 147-2019
- **Standard for the Design of High-Performance Green Buildings and Health Care Facilities**
  - 189.1-2020, 189.3-2021
- **Standard Method of Evaluating Zero Net Energy and Zero Net Carbon Building Performance**
  - 228-2023
- **Passive Building Design**
  - 227-proposed
- **Evaluating Greenhouse Gas (GHG) and Carbon Emissions in Building Design, Construction and Operation**
  - 240-proposed

Design Guides

- **Zero Energy building Guides for K-12 Schools, Offices, and Multifamily Residential**

Source: ASHRAE www.ashrae.org

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ASHRAE Standards with Efficiency, Carbon and Refrigerant Emissions, and Renewables

90.1-2022 published

Standard/Code	Topic: Energy Efficiency	Operational GHG Emissions	Embodied GHG Emissions	Refrigerant Emissions	Renewables
ANSI/ASHRAE Standard 34-2019, *Designation and Safety Classification of Refrigerants*				✔	
ANSI/ASHRAE/IES Standard 90.1-2019, *Energy Standard for Buildings Except Low-Rise Residential Buildings*	✔	(✓)			✔
ANSI/ASHRAE/IES Standard 90.2-2018, *Energy-Efficient Design of Low-Rise Residential Buildings*	✔	(✓)			✔
ANSI/ASHRAE Standard 90.4-2019, *Energy Standard for Data Centers*	✔				
ANSI/ASHRAE/IES Standard 100-2018, *Energy Efficiency in Existing Buildings*	✔				
ANSI/ASHRAE Standard 105-2021, *Standard Methods of Determining, Expressing, and Comparing Building Energy Performance and Greenhouse Gas Emissions*	✔	✓			✔
ANSI/ASHRAE Standard 147-2019, *Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment and Systems*				✔	
International Green Construction Code® and **ANSI/ASHRAE/ICC/USGBC/IES Standard 189.1-2020,** *Standard for the Design of High-Performance Green Buildings*	✔	✔	✔		✔

✔ Included in Standard
✓ Carbon calculation methodology included in Standard
(✓) Under consideration
☑ Included in proposed Standard
☐✓ Carbon calculation methodology included in proposed Standard

Note: Energy efficiency directly contributes to operational carbon emission reductions

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ASHRAE Standards with Efficiency, Carbon and Refrigerant Emissions, and Renewables

Standard/Code	Topic: Energy Efficiency	Operational GHG Emissions	Embodied GHG Emissions	Refrigerant Emissions	Renewables
ANSI/ASHRAE/ASHE Standard 189.3-2021, *Design, Construction, and Operation of Sustainable High-Performance Health Care Facilities*	✔	✔	✔	✓	✔
Proposed ASHRAE Standard 227P, *Passive Building Design Standard*	☑			☑	
Proposed ASHRAE Standard 228P, *Standard Method of Evaluating Zero Net Energy and Zero Net Carbon Building Performance*		☐✓		☐✓	☐✓
Proposed ASHRAE Standard 240P, *Evaluating Greenhouse Gas (GHG) and Carbon Emissions in Building Design, Construction and Operation*	☑	☑	☑	☑	☑

Now published

✔ Included in Standard
✓ Carbon calculation methodology included in Standard
(✓) Under consideration
☑ Included in proposed Standard
☐✓ Carbon calculation methodology included in proposed Standard

Note: Energy efficiency directly contributes to operational carbon emission reductions

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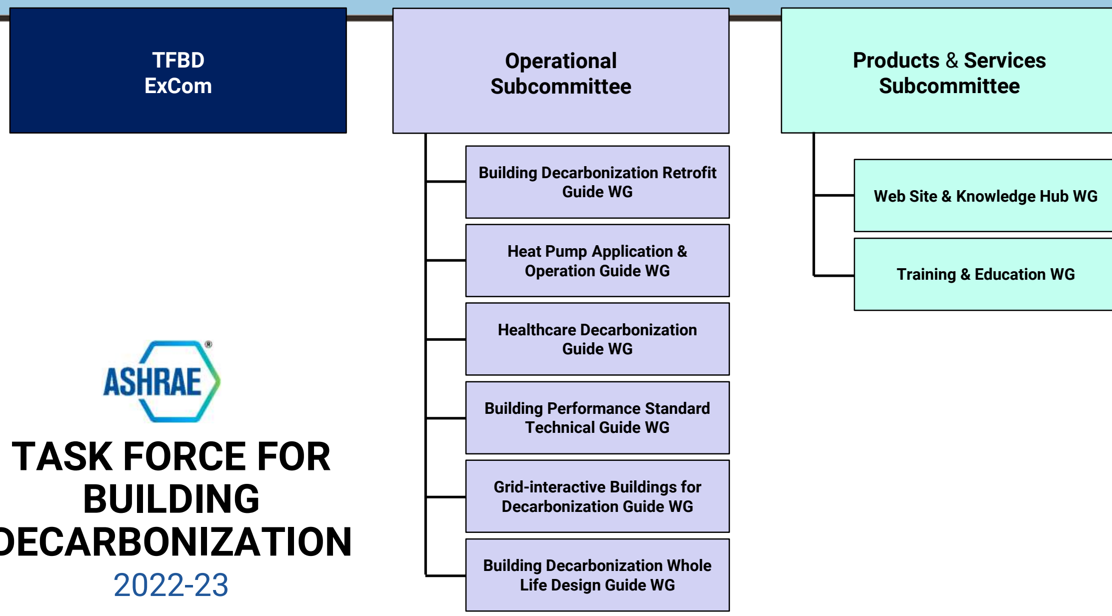

TASK FORCE FOR BUILDING DECARBONIZATION
2022-23

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2022-23 Task Force for Building Decarbonization Objectives

- Provide a comprehensive plan for integrating building decarbonization activities into the ASHRAE structure
- This plan would include recommendations for any changes required to the ASHRAE structure and streamlining current processes for speed and efficiency
- Coordinate Task Force work with ASHRAE councils, committees and task forces to align goals and eliminate bottlenecks –seek TC liaisons on all operational WGs
- Coordinate with and assist the Planning Committee to incorporate ASHRAE's building decarbonization goals into the Society strategic plan
- Report to the Board of Directors on progress and goals quarterly, including at the Winter and Annual meetings

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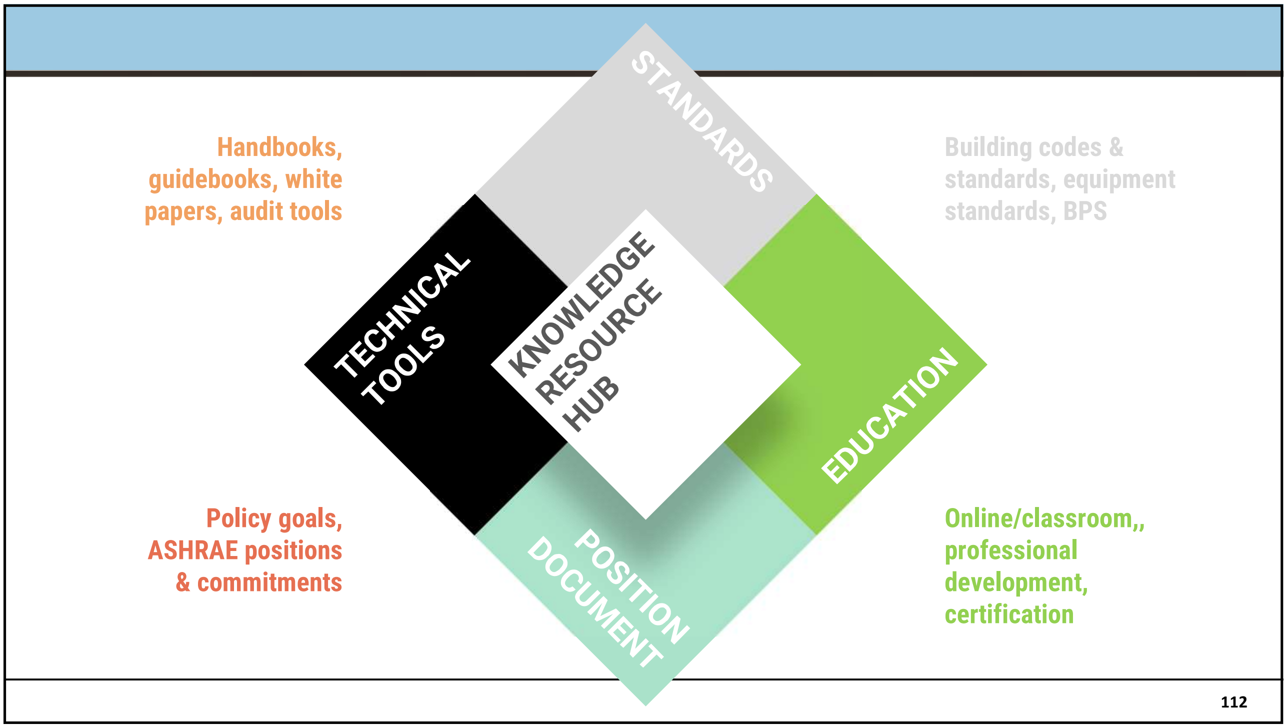

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Conclusions

- Buildings contribute 37% of global carbon emissions that contribute to climate change
- New buildings can lock in high emissions for decades
- Building decarbonization means energy efficiency, cleaner energy sources and moving to electricity from low-carbon sources
- As operational energy and carbon emissions are reduced, embodied carbon becomes increasingly important
- ASHRAE’s extensive resources support membership ’s Task Force for Building Decarbonization focuses efforts to engage with other organizations, provide information to policy makers, and recommending best practices for HVAC&R industry to decarbonize
- The TFBD Research / Knowledge Hub is identifying and archiving information, literature, and research for the Task Force and ASHRAE members

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Thank you!

Questions?

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ASHRAE Decarbonization Resources

ASHRAE Task Force for Building Decarbonization
https://www.ashrae.org/about/ashrae-task-force-for-building-decarbonization

ASHRAE Position Documents

- **ASHRAE and CIBSE – Resiliency in the Built Environment**
  https://www.ashrae.org/file%20library/about/position%20documents/ashrae_cibse_resiliencyinthebuiltenvironment_2019.pdf
- **Climate Change**
  https://www.ashrae.org/file%20library/about/position%20documents/ashrae-position-document-on-climate-change---2021.pdf
- **Energy Efficiency in Buildings**
  https://www.ashrae.org/file%20library/about/position%20documents/pd_energyefficiencyinbuildings_2020.pdf
- **Refrigerants and their Responsible Use**
  https://www.ashrae.org/file%20library/about/position%20documents/pd_refrigerants-and-their-responsible-use-pd-6.29.2020.pdf
- **Building Decarbonization**
  https://www.ashrae.org/file%20library/about/position%20documents/pd_buildingdecarbonization_2022.pdf

ASHRAE Decarbonization Resources

ASHRAE Public Policy Issue Briefs

- **Building Decarbonization**
  https://www.ashrae.org/file%20library/about/government%20affairs/public%20policy%20resources/briefs/ppib-on-building-decarbonization.pdf

- **Resiliency in the Built Environment**
  https://www.ashrae.org/file%20library/about/government%20affairs/public%20policy%20resources/briefs/resiliency-in-the-built-environment.pdf

- **Climate Change and the Built Environment**
  https://www.ashrae.org/file%20library/about/government%20affairs/public%20policy%20resources/briefs/climate-change-and-the-built-environment.pdf

- **Refrigerants and Their Responsible Use**
  https://www.ashrae.org/file%20library/about/government%20affairs/public%20policy%20resources/briefs/refrigerants-and-their-responsible-use.pdf

- **Utilizing Energy Metrics and Building Benchmarking to Improve Whole Building Energy Performance**
  https://www.ashrae.org/file%20library/about/government%20affairs/public%20policy%20resources/briefs/building-energy-benchmarking--assessments--and-performance-targets.pdf

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ASHRAE Decarbonization Resources

ASHRAE Standards

- **ANSI/ASHRAE Standard 15-2022 Safety Standard for Refrigerant Systems**
  https://www.techstreet.com/ashrae/standards/ashrae-15-2022-packaged-w-standard-34-2022?product_id=2504061
- **ANSI/ASHRAE Standard 34-2022 Designation and Safety Classification of Refrigerants**
  https://www.techstreet.com/ashrae/standards/ashrae-15-2022-packaged-w-standard-34-2022?product_id=2504061
- **ANSI/ASHRAE/IES 90.1-2022 Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings**
  https://www.ashrae.org/technical-resources/bookstore/standard-90-1
- **ANSI/ASHRAE Standard 90.2-2018 Energy Efficient Design of Low-Rise Residential Buildings**
  https://www.techstreet.com/ashrae/standards/ashrae-90-2-2018?product_id=2030773
- **ANSI/ASHRAE 90.4-2022 Energy Standard for Data Centers**
  https://www.techstreet.com/ashrae/standards/ashrae-90-4-2022?product_id=2524333
- **ANSI/ASHRAE Standard 105-2021 Expressing and Comparing Building Energy Performance and Greenhouse Gas Emissions**
  https://www.techstreet.com/ashrae/standards/ashrae-105-2021?product_id=2242191
- **ANSI/ASHRAE/ICC/USGBC/IES 189.1-2020 Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings**
  https://www.techstreet.com/ashrae/standards/ashrae-189-1-2020?product_id=2202993
- **ANSI/ASHRAE/ASHE Standard 189.3-2017 Design, Construction and Operation of Sustainable High Performance Health Care Facilities**
  https://www.techstreet.com/standards/ashrae-189-3-2017?product_id=1952161
- **ANSI/ASHRAE Standard 228-2023 Standard Method of Evaluating Zero Net Energy and Zero Net Carbon Building Performance**
  https://www.techstreet.com/ashrae/standards/ashrae-228-2023?product_id=2562375

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ASHRAE Decarbonization Resources

ASHRAE Standards Under Development

- **SPC 227P Passive Building Design Standard**
  https://www.ashrae.org/technical-resources/standards-and-guidelines/titles-purposes-and-scopes#spc227
- **SPC 240P Evaluating Greenhouse Gas (GHG) and Carbon Emissions in Building Design, Construction and Operation**
  https://www.ashrae.org/technical-resources/standards-and-guidelines/titles-purposes-and-scopes#spc240p

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Other Major Decarbonization Resources

American Institute of Architects	https://www.aia.org/
BRE BREEAM	https://bregroup.com/products/breeam/
Building Green	https://www.buildinggreen.com
CDP North America	https://www.cdp.net/en
Chartered Institute of Building Services Engineers	https://cibse.org/
Energy & Climate Intelligence Unit	https://eciu.net/netzerotracker
Global Alliance for Buildings and Construction	https://globalabc.org/
Institute for Market Transformation	https://www.imt.org/
International Energy Agency	https://www.iea.org/
International Living Future Institute	https://living-future.org/
Intergovernmental Panel on Climate Change (United Nations)	https://www.ipcc.ch/
National Academy of Sciences	http://nasonline.org/
National Institute of Building Sciences	https://www.nibs.org/
Net Zero Tracker	https://zerotracker.net/
New Buildings Institute	https://newbuildings.org/
US Climate Alliance	https://www.usclimatealliance.org/
US Green Building Council	https://www.usgbc.org/
We Are Still In	https://www.wearestillin.com/
World Business Council for Sustainable Development	https://www.wbcsd.org/
World Economic Forum	https://www.weforum.org/
World Green Building Council	https://www.worldgbc.org/

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