Energy Exchange[SM]

ADVANCING FEDERAL INFRASTRUCTURE THROUGH INNOVATION

CINCINNATI, OHIO
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Net Zero Buildings: Cost-Effective and Sustainable for Retrofits and New Construction

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Federal Carbon Reduction Policy

Federal policies include:

- Executive Order 14057: Catalyzing America's Clean Energy Economy Through Federal Sustainability
  - Sec. 205. Achieving Net-Zero Emissions Buildings, Campuses, and Installations. (a) Each agency shall achieve net-zero emissions across its portfolio of buildings, campuses, and installations by 2045 and reduce greenhouse gas emissions by 50 percent from buildings, campuses, and installations by 2032 from 2008 levels, prioritizing improvement of energy efficiency and the elimination of onsite fossil fuel use.
  - 65% reduction in scope 1 and 2 emissions by 2030
  - 100% carbon pollution-free electricity (CFE) by 2030, including 50% on a 24/7 basis
  - Implementing instructions from Council on Environmental Quality.

4.4 Net-Zero Emissions Buildings, Campuses, and Installations

- Space Consolidation – consider lower occupancy, underused facilities, consolidation
- Prioritize efficiency and electrification
- New construction entering design phase in 2022 greater than 25,000 ft^2 MUST BE net-zero emissions

Definition: designed and operated so scope 1 and scope 2 greenhouse gas emissions from all facility energy use equal zero on an annual basis, when connected to on-site renewable energy or a regional grid that provides 100% CFE on a net annual basis.

4.4 Net-Zero Emissions Buildings, Campuses, and Installations – Performance Targets

Outcome-based Targets

1. Reducing Building Portfolio Emissions
2. Increasing Energy Efficiency
3. Increasing Water Efficiency

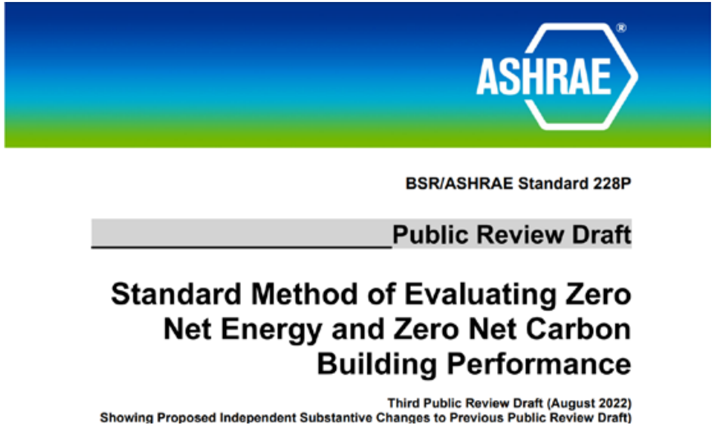
Strategy-based Targets

4. Electrifying Buildings through the Federal Building Performance Standard
5. Implementing Deep Energy Retrofits
6. Leveraging Performance Contracting

1. Emissions Reduction Priority strategies: Agencies should prioritize energy efficiency and the elimination of scope 1 emissions from on-site fossil fuel use through building electrification.
2. Efficiency Priority strategies: To achieve energy goals and reduce building emissions, agencies should prioritize improving the performance of high energy use intensity (EUI) facilities (Smart Labs Toolkit).
3. Building Performance Standards: The forthcoming Council on Environmental Quality Fiscal Year 2022 Federal Building Performance Standards will outline requirements for meeting the FY 2030 target.

ASHRAE 228P Standard Method of Evaluating Zero Net Energy and Zero Net Carbon Building Performance

- Can be used to determine whether a site has achieved “Zero Net Energy” or “Zero Net Carbon” on an operational basis
- Calculations are based on a source energy/captured energy efficiency approach and allowances are made for some off-site credit.


ASHRAE

BSR/ASHRAE Standard 228P

Public Review Draft

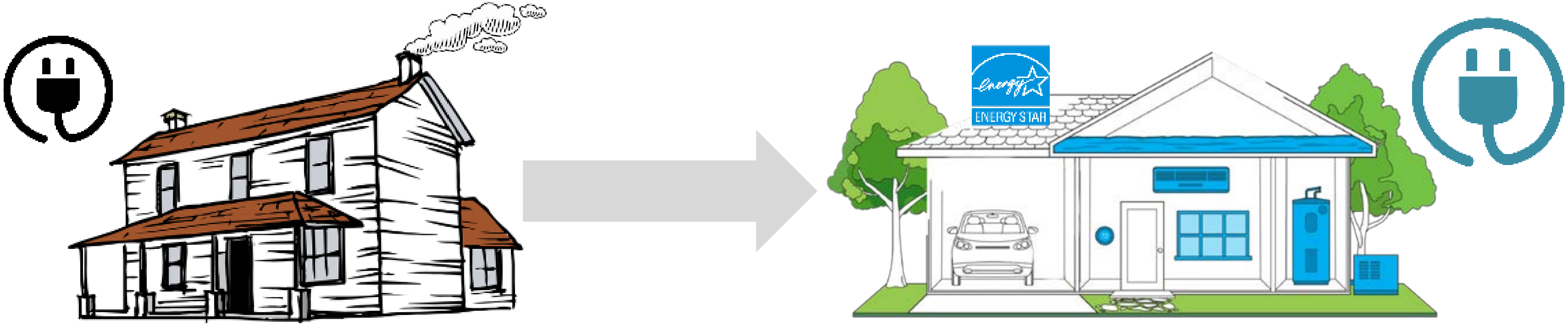
Standard Method of Evaluating Zero Net Energy and Zero Net Carbon Building Performance

Third Public Review Draft (August 2022)
Showing Proposed Independent Substantive Changes to Previous Public Review Draft)

Decarbonization Strategies

Strategy is unique to each site

- Primarily a function of on-site fossil fuel use (scope 1)
- Influenced by serving utility's current and future generation mix (scope 2)



Baseline Load → Optimized Load

Step One: Deep energy efficiency and load reduction

- Lighting, chillers, and load reduction
- When replacing inefficient fossil fuel-based equipment, begin with load reduction, then electrification and demand flexibility
- Avoid new long-lived fossil fuel burning equipment (e.g., boiler) when possible

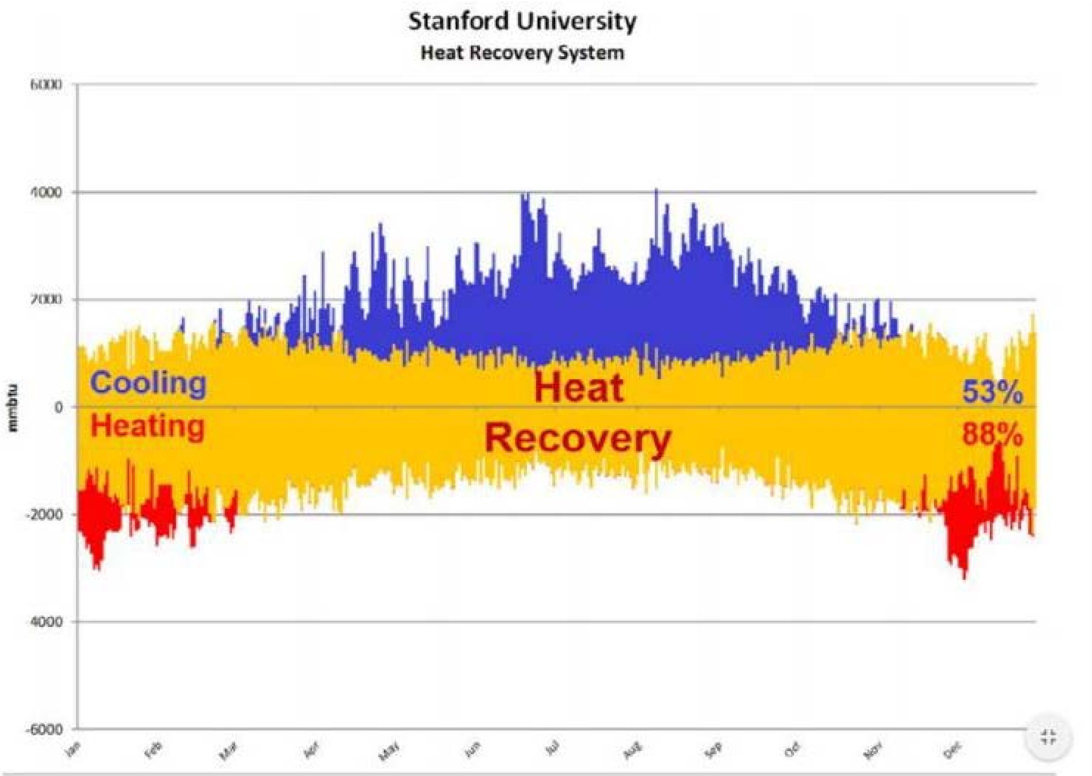
Step Two: Electrification (electric vehicles, heat pumps)

- Reduces emissions in most locations
- Largest reductions where current/future utility carbon emissions are relatively low

Step Three: On-site carbon free energy generation/storage

- Largest emissions reduction where current/future utility carbon emissions are relatively high

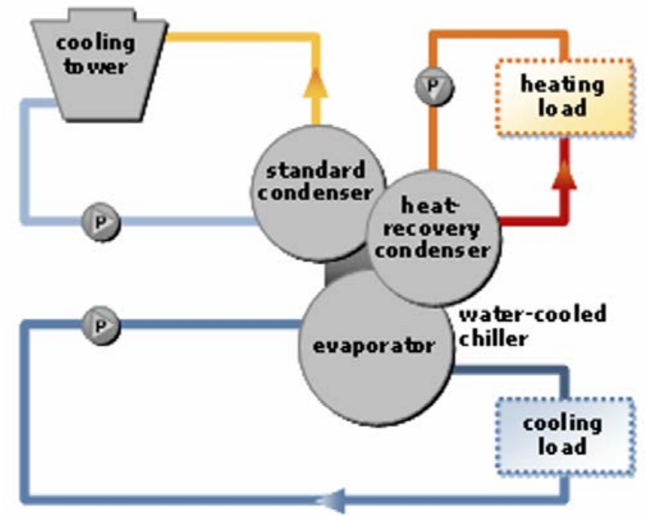
Heat Recovery Chillers – Simultaneous Heating and Cooling



SESI Website
SESI Brochure

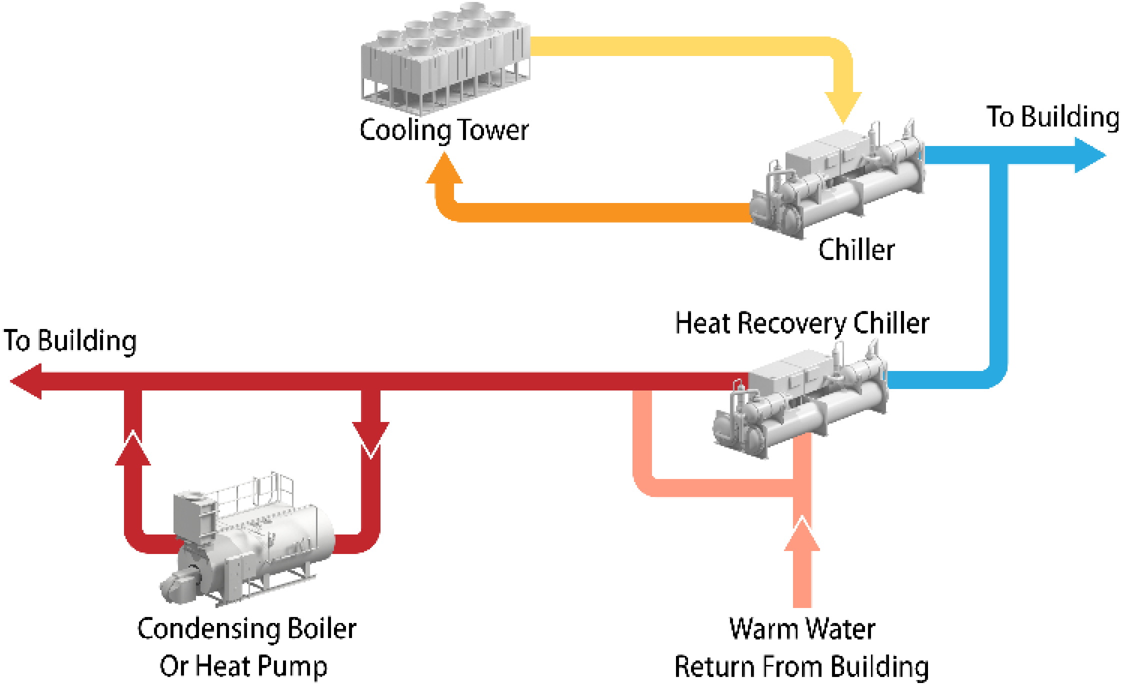
Since 2015, the Stanford Energy System Innovations (SESI) Project has achieved a 68% greenhouse gas reduction and 18% water reduction, meeting 88% of campus heating load with heat pumps at lower life cycle cost than alternatives.

Heat Recovery Chillers, Combined with Conventional Chillers/Boilers



[Introduction of Heat Recovery Chiller Control and Water System Design]

Heat Recovery coefficient of performance 6–8 @113°F (hot water), 41°F (chilled water)



Zero Energy Buildings (ZEB) 2.0

- **ZEB 1.0: annual production = annual energy use**
  Key Metric: EUI (annual kBtu/ft^2)
  Challenges: Efficient envelope, lighting, and heating, ventilation, and air conditioning (HVAC), sizing rooftop solar photovoltaic (PV)
- **ZEB 2.0: 100% renewables, 100% of the time**
  Key Metric: Load Coverage Factor (LCF), % of load covered by renewables each hour
  Challenges: Electrification, hourly grid emissions and renewable data and communication, flexible loads, dispatchable energy storage.

The Future of Zero Energy Buildings: Produce, Respond, Regenerate

Preprint

Paul A. Torcellini, Sammy Houssainy, Shanti D. Pless, William Livingood, and Ben Polly

National Renewable Energy Laboratory

The LCF metric provides a different viewpoint of achieved success in ZEB 2.0 buildings.
Source: NREL's ACEEE 2020 paper on ZEB 2.0

New Buildings (ZEB 2.0)

- Design for the grid in 20 years
- Establish \$/MtCO2e to use for capital projects and design decisions
  - *Evaluate \$/MtCO2e on an hourly basis*
- Include in Engineer/Architect Requests for Proposal (RFPs):
  - EUI/net EUI target *plus*:
  - Load coverage factor target
  - All electric
  - Peak HVAC loads allowance (~Passive House standards)
  - Resiliency and/or storage requirement
  - List and detail flexible loads and allowable deviations
  - Require conceptual design energy analysis, including sensitivities.

Cambium Data Set

NREL's Cambium data set can be used to better understand hourly emission reductions from CFE projects and purchases:

- What type of generation is offset?
- How quickly is your grid expected to decarbonize?
- What is the total estimated emission reduction from your project?
- How do grid emissions vary throughout the day?

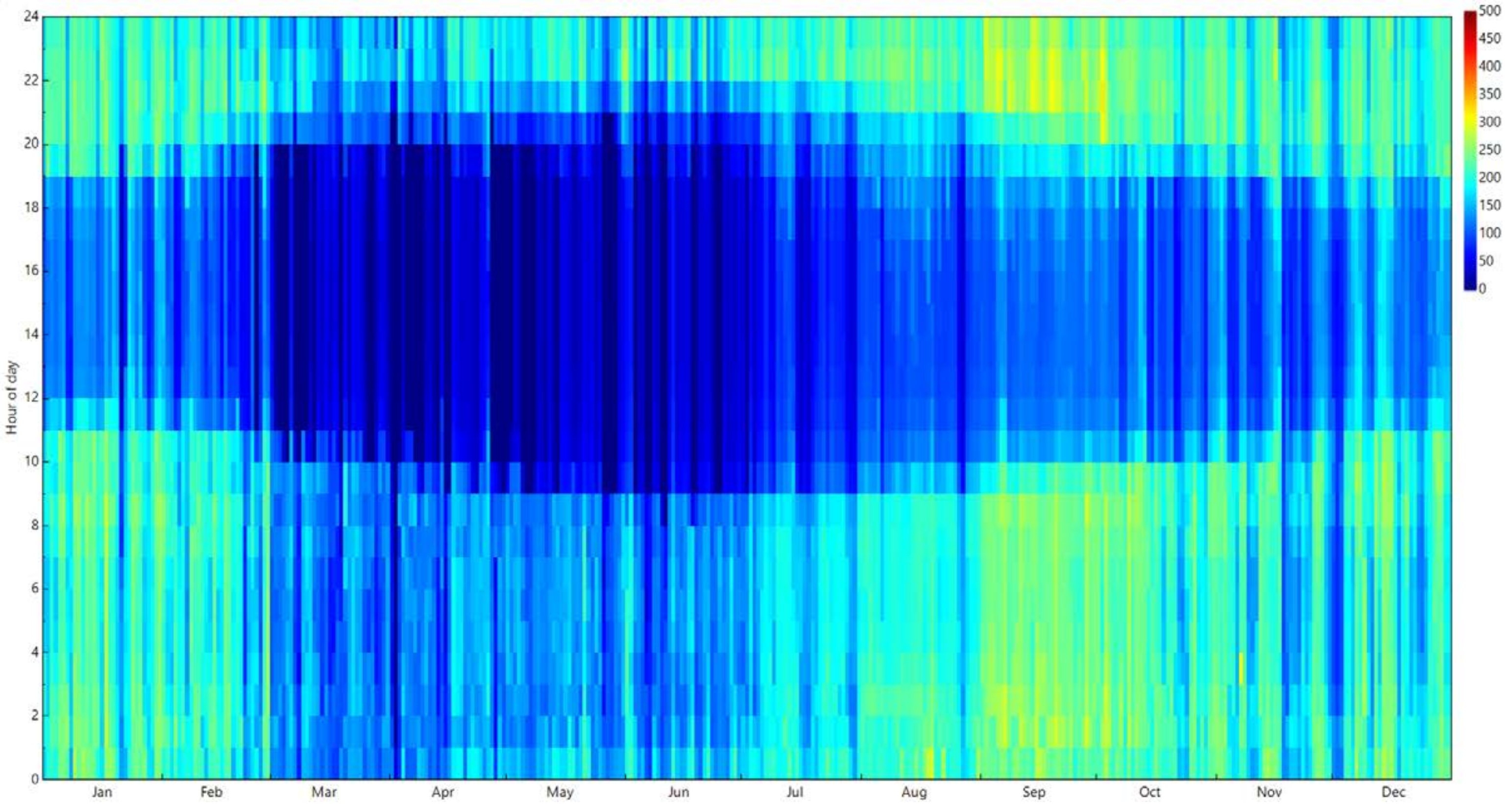
User Inputs	
Emission	CO2
Emission stage	Combustion
Start year	2023
Evaluation period (years)	20
Discount rate (real)	0.03
Scenario	Mid-case
Global Warming Potentials	100-year (AR5)
Location	End-use
2050 Fraction	0.00

Levelized Long-run Marginal Emission Rates (Annual)			
Units: kg of CO2 per MWh at the point of end-use			
AL	AR	AZ	CA
405.3	332.7	244.3	123.3

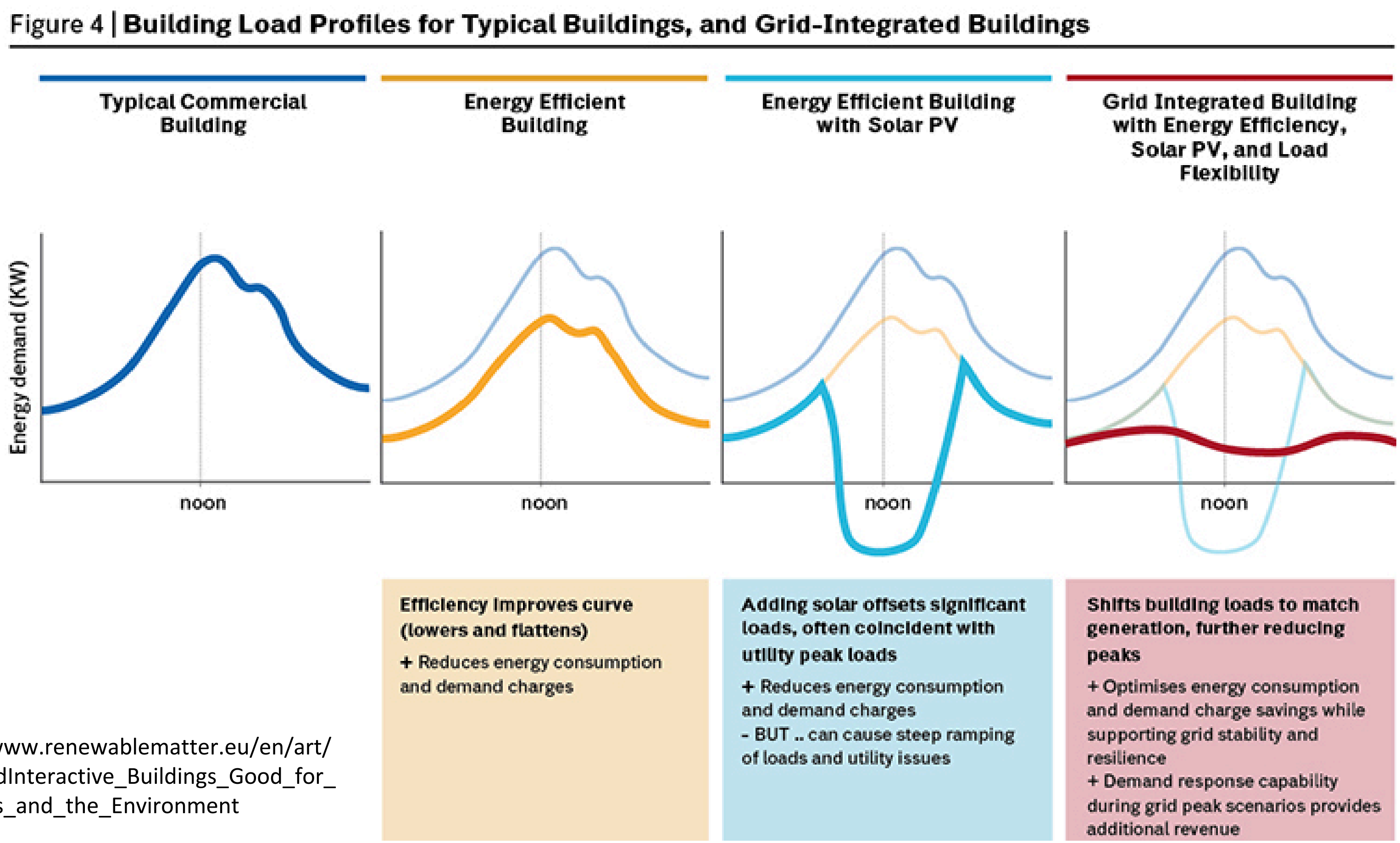
Workbook Outputs				
Levelized Long-run Marginal Emission Rates (Time-of-day)				
Units: kg of CO2 per MWh at the point of end-use				
Hour	AL	AR	AZ	CA
1	487.6	374.1	271.0	151.0
2	489.1	372.8	276.9	157.2
3	487.4	372.5	280.0	161.3
4	486.7	371.3	280.6	158.4
5	484.8	372.7	279.7	155.7
6	445.3	359.6	274.3	135.9
7	381.0	326.9	250.2	115.9
8	325.8	293.9	230.9	102.6
9	301.9	277.2	216.8	97.7
10	296.0	274.8	212.1	98.3
11	294.1	275.1	211.4	98.2
12	295.0	275.4	210.8	99.0
13	296.2	275.6	210.0	99.6
14	301.5	277.7	210.8	100.0
15	313.3	280.2	211.4	101.5
16	349.7	288.7	214.9	106.8
17	412.2	316.1	232.9	121.0
18	464.3	360.2	250.3	128.6
19	487.0	389.9	260.8	132.6
20	478.8	391.5	265.4	130.4
21	475.2	384.0	262.1	128.6
22	488.3	380.7	260.8	135.1
23	494.2	380.2	262.9	137.4
24	489.8	376.3	265.1	145.6

Excerpts from Cambium Long-run Marginal Emission Rates Workbook
Results available for all continental U.S. states and/or grid regions

Northern CA, 2030 Average Hourly Emissions from Cambium (kg of CO2/MWh)



Grid Interactive Efficient Buildings (GEB)



Source: http://www.renewablematter.eu/en/art/997/GridInteractive_Buildings_Good_for_Business_and_the_Environment

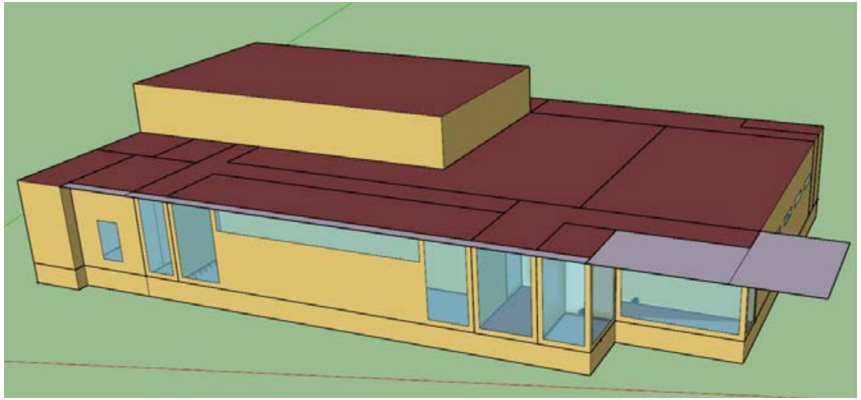
Net Zero Buildings Summary

- Design all new buildings to be net zero carbon (Executive Order 14057)
- Efficiency first, exceed energy code requirements, climate-sensitive design
- Electrify buildings, use on site renewable energy (typically PV), CFE
- Design GEB – **when** energy use is as important as how much energy is used
- Use waste heat sources (e.g., data centers, sewer heat recovery) to heat buildings
- If hot water heating systems are used design for low-temperature hot water (130°F or lower)
- Use heat pumps and heat recovery chillers

- All these requirements (e.g., net zero, electrification, Smart Labs) should be included in 1391/budget justification applications; procurement/acquisition strategy (include in RFP and design/construction services with performance incentives program)

New Construction Example: NREL RAIL Lab

- Performance-based (30% below ASHRAE 90.1 1019) design build
- Smart Labs Principals
  - Ventilation rated based on ventilation risk assessment
  - Occupancy sensor for lower unoccupied ventilation rate
  - Exhaust air energy recovery with indirect evaporative cooling
  - Direct evaporative cooling
  - Exhaust wind tunnel dispersion model, exhaust discharge velocity reset
  - Fume hood face velocity lowest that provides containment (ASHRAE 110 testing)
- Heating designed for 130°F water
- Long axis of building east-west with well-shaded south and east glass, daylighting and occupancy lighting controls
- Construction complete end of 2022.



Reuse Example: GSA Denver Fed Center Bldg 48

Sustainability

Goals
Net Zero Energy design, Net Zero Carbon design, LEEDv4 Gold, SITES Silver, GPC (Guiding Principles)

Renewables
PV system on Roof & and Denver Federal Campus

Green Vehicle Charging Stations

SITES
Native garden area, pollinator gardens

Advanced Metering
Post-Occupancy reporting capabilities through the SkySpark system

Construction Waste Diversion
Averaging 85%+ waste diversion on site thus far

Operational Strategies
Low mercury lighting policy, green cleaning plan, employee health and/or equity programs

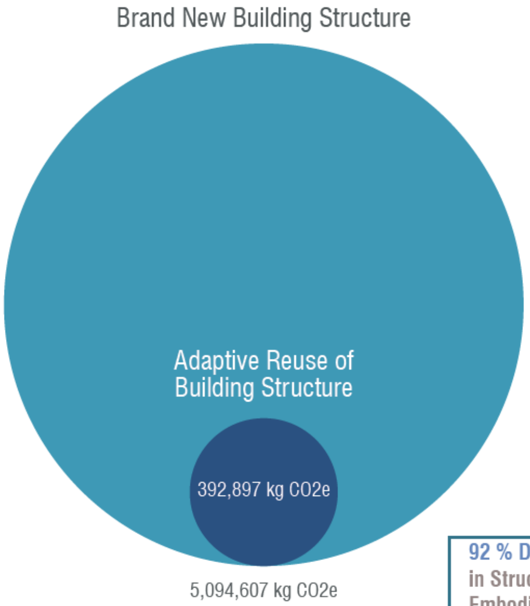
Energy Savings
'High efficiency' MEP components (est. 54% energy cost reduction)

Water Savings
Low-flow flush fixtures planned to be used (est. 40% portable water reduction)

Materials
Sustainably sourced materials, 90% building re-use, from a structural and envelope perspective

Reuse Example: GSA Denver Fed Center Bldg 48

Embodied Carbon of Structural Design



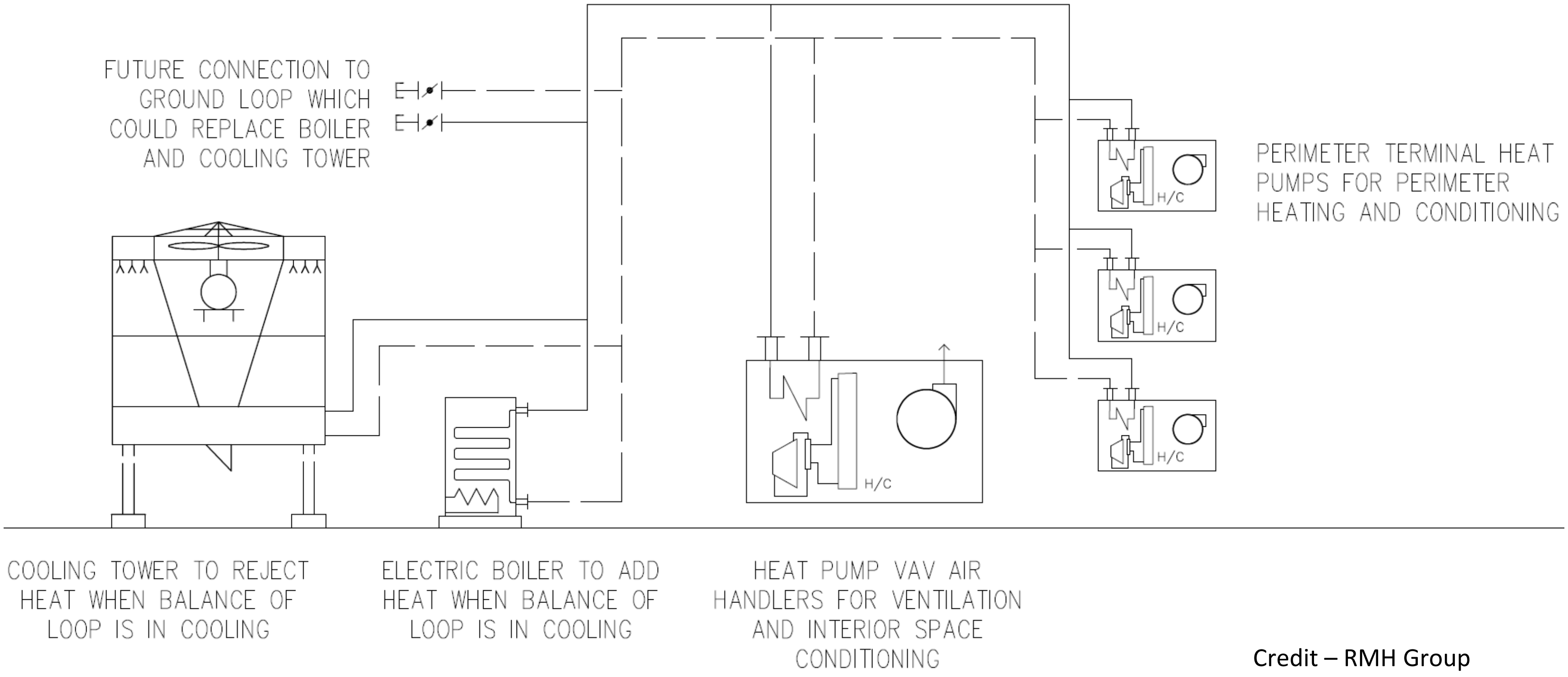
92 % Decrease in Structural Embodied Carbon

The carbon savings from Building 48's structural reuse are equivalent to:

- 1+million gas-powered passenger vehicles driven for 1 year
- 914,000 homes' electricity use for 1 year
- 32,000 acres of U.S. forests saved from conversion to cropland

The waste savings from Building 48's structural reuse is~151,375 cubic feet of construction waste saved. This would fill approximately 9 average U.S. single family homes, or one-third of the White House.

Reuse Example: GSA Denver Fed Center Bldg 48 Ground Source Heat Pump Ready



Credit – RMH Group

Questions?

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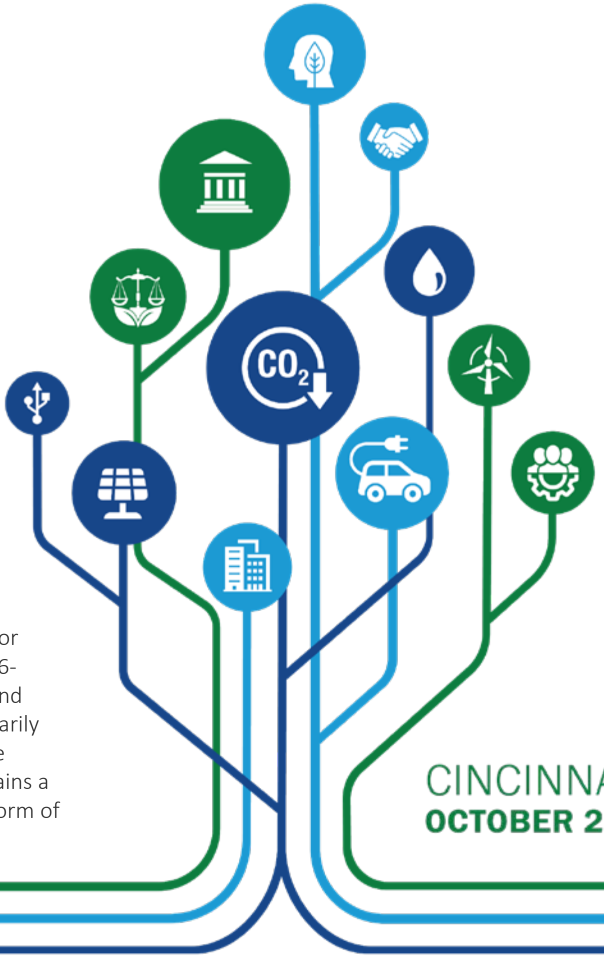

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