# Key Building Decarbonization Principles

GSA GBAC
Building Decarbonization Task Group

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# Context: Relevant Targets and Executive Orders

| | Most important and relevant | Source/Link |
|---|---|---|
| GSA | "GSA will lead by example" …<br>• "…Federal Building Decarbonization Task Group…."<br>• "…GSA goals of … the elimination of fossil fuel use in newly constructed facilities and facilities undergoing major modernization and achieving net zero emissions by 2030." | GSA Press Release May 17, 2021 |
| | "Today, the U.S. General Services Administration (GSA) announced its commitment to 100 percent renewable electricity sources for the federal real estate portfolio by 2025…" | GSA Press release, April 22, 2021 |
| All Federal Buildings | "Through a coordinated whole-of-government approach, the Federal Government shall use its scale and procurement power to achieve:<br>(i) 100 percent carbon pollution-free electricity on a net annual basis by 2030, including 50 percent 24/7 carbon pollution free electricity…<br>(iii) a net-zero emissions building portfolio by 2045, including a 50 percent emissions reduction by 2032;"<br>(iv)a 65 percent reduction in scope 1 and 2 greenhouse gas emissions, as defined by the Federal Greenhouse Gas Accounting and Reporting Guidance, from Federal operations by 2030 from 2008 levels;<br>(v) net-zero emissions from Federal procurement, including a Buy Clean policy to promote use of construction materials with lower embodied emissions | Executive Order 14057, December 8, 2021 |

# Purpose Statement

- **To reduce the impacts of climate change and hold to 1.5C increase, we must decarbonize our buildings.**
- **By implementing visionary decarbonization efforts, GSA will lead by example.**
- **These principles are intended to shape federal decarbonization activities, prioritizing the next 5 years.**
- **These principles build on the GSA commitment of** 100% renewable electricity sources for the federal real estate portfolio by 2025.
- **These principles could be used to inform:**
  - GSA's P100 Federal Building Standards decarbonization updates
  - Project selection and funding rubrics for GSA and others
  - Decarbonization strategies and planning efforts
- **These principles apply to new and existing buildings, across all federal agencies (including DOD) and across all use types**

# Definitions

## There are 2 considerations to building decarbonization – Operational and Embodied.

***Operational carbon*** *pertains to carbon emissions from operations, including electricity and gas use, and refrigerants)*

***Embodied carbon*** *pertains to the carbon emissions from the manufacturing, transportation, installation, maintenance, and disposal of building materials.*

***Most of our focus is on operational carbon in existing buildings, since the federal building portfolio is almost entirely existing buildings and new construction is limited.***

## What is a Carbon-Neutral Building?

*"A carbon neutral building is one where the design, construction, and operations do not contribute to emissions of greenhouse gases that cause climate change." NYSERDA Carbon Neutral Buildings Roadmap*

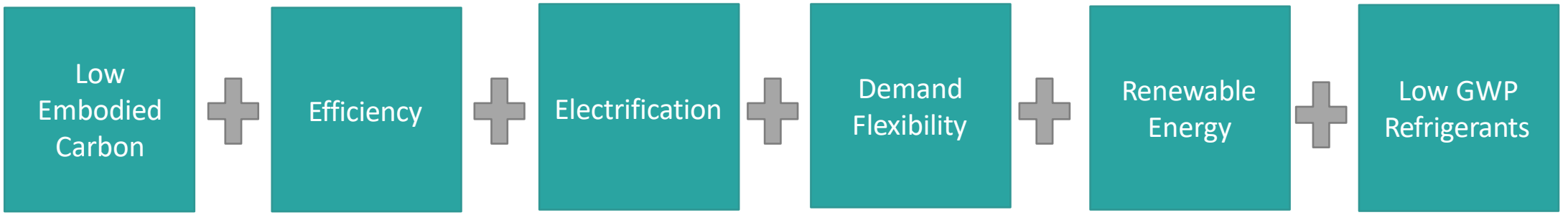
## What is a Zero Carbon-Ready Building?

*A Zero-Carbon Ready building is a building that has implemented energy efficiency and has a plan to implement full electrification, demand flexibility and add renewable generation at key trigger events (e.g. equipment replacement or roof replacement) – Refer to RMI/ULI's Zero Over Time concept paper*

# The Recipe for Net Zero Emissions Buildings

Low Embodied Carbon

Zero Operational Carbon




= **carbon free, healthy, resilient buildings**

Contextual and Infrastructure Factors

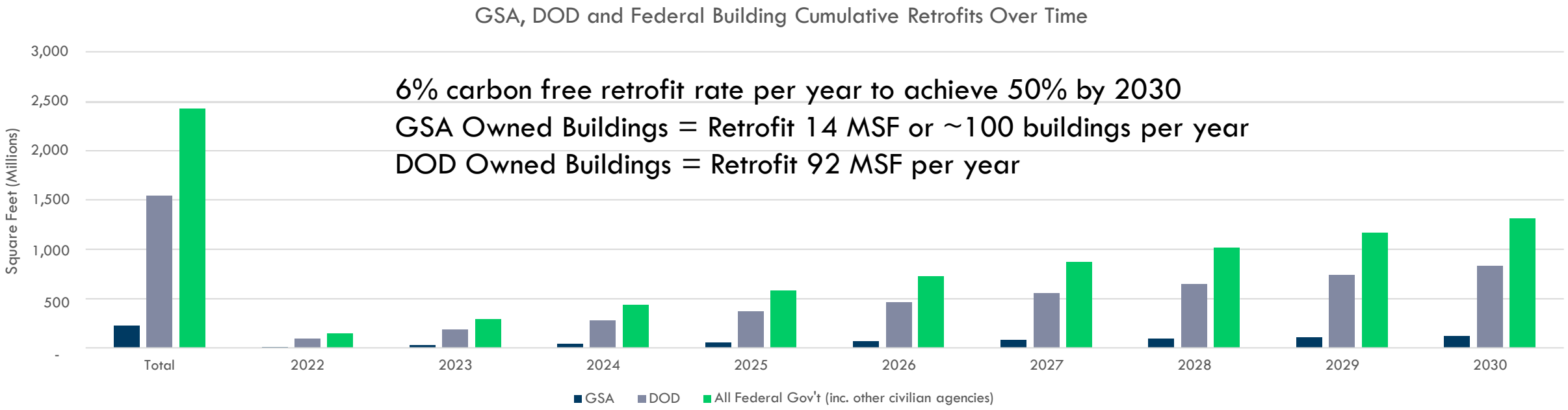
# Federal Building Decarbonization Principles

To decarbonize our federal buildings and cut GHG emissions in half by 2030 to meet Biden administration targets and limit warming to 1.5 C, we must…

1. Accelerate the rate of net zero emissions building retrofits.
2. To optimize for cost and impact, plan comprehensively to include efficiency, electrification, demand flexibility and solar/storage. Loading order matters, and varies with location and existing conditions.
3. Maximize the use of onsite renewable generation.
4. Include embodied, refrigerant and EV charging emissions.
5. Support resilience, health and comfort.
6. Support system wide optimization to avoid unintended consequences.
7. Support equal opportunity job creation and training underpinned by equitable procurement practices.

# 1. Accelerate the rate of net zero emissions building retrofits

Retrofit 6% of the federal portfolio each year between 2022 and 2030 to operational net zero emissions and operational net zero emissions-ready standards to reach 50% reduction by 2030.

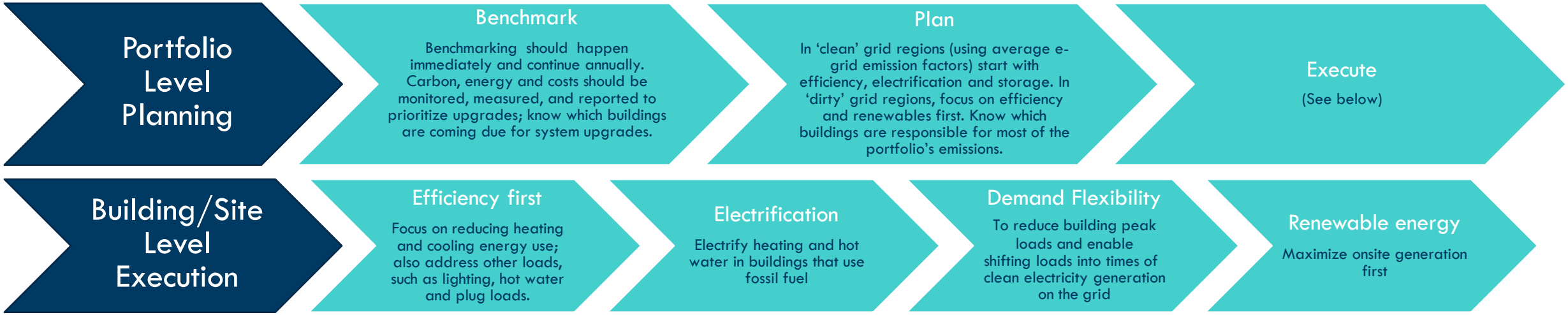



* Includes all buildings (even small ones). Does not include 'leased' or 'otherwise' buildings. Does not include 'structures' or land.

*Source: FY 2019 Federal Real Property Profile

# 2. To optimize for cost and impact, plan comprehensively to include efficiency, electrification, demand flexibility and solar/storage

**Key Process Steps:**




**Key Considerations:**

1. Loading order matters and varies with location and existing conditions.
2. Improvements should include both capital and operational expenses and savings (and should be lifecycle cost effective, per P100) and include the social cost of carbon in accounting for the costs and benefits of projects.
3. Zero carbon retrofits should coincide with upgrade cycles where possible - each building should have a decarbonization roadmap including vulnerabilities and solutions to align around deferred maintenance and end of equipment life. (e.g. Facilities Conditions Assessments)

# 3. Maximize onsite renewable generation before considering Renewable Energy Certificates

## 1. Maximize onsite renewable production (and storage).

This includes installing solar on or adjacent to the building or load. It is important since it lowers the demand for electricity at the source, potentially reducing infrastructure for transmission and distribution and associated line losses. Coupling solar with storage enhances the value proposition and solar utilization. Further, if connected to microgrids, they can provide resilience benefits during grid outages. Retain RECs for onsite solar.

a. Next, consider green power purchasing through your utility.

   Utility scale green power programs, or community solar, are usually generated within the same grid region as the building.

b. Lastly, consider renewable energy procurement and Bundled Renewable Energy Certificates (RECs).

   Renewable energy procurement, including 24x7 hourly matching strategies which align use with renewable production, play an important and growing role in decarbonizing power systems. However, costs increase significantly for higher levels of load matching and near-term emissions reductions depend on the regional grid mix and how storage resources are operated. * If purchasing renewable energy through a Power Purchase Agreement, retain RECs.

*Source: RMI, 2021 Clean Power by the Hour

# 4. Consider embodied, refrigerant and EV charging emissions

1. **Embodied carbon:** Invest in creating a knowledge base.
   a. **Establish baselines:** Assess the embodied carbon of new construction, existing buildings, and renovations in the major types of federal buildings.
   b. **Do pilot projects:** Invest in pilot projects that reduce the embodied carbon of new construction and renovations. Publish results and promote best practices learned.
   c. **Create policies:** Aim to reduce embodied carbon in new construction and renovations by a minimum of 40% below baselines as per the federal building stock or Carbon Leadership Forum data as appropriate, reducing that threshold over time. Extend the lifespan of existing buildings to reduce the need for new buildings. (Note White House Buy Clean Task Force now working on these issues.)
1. **Refrigerants:** Reduce refrigerant need, use low GWP refrigerants, reduce refrigerant charge, mitigate leakage, and enhance recovery. *
3. **Transportation:** Ensure GSA buildings can support EV charging and ensure charging is managed to contribute to efficient building & grid management.
4. **Water:** Minimize water use in buildings to reduce treatment and pumping related emissions.

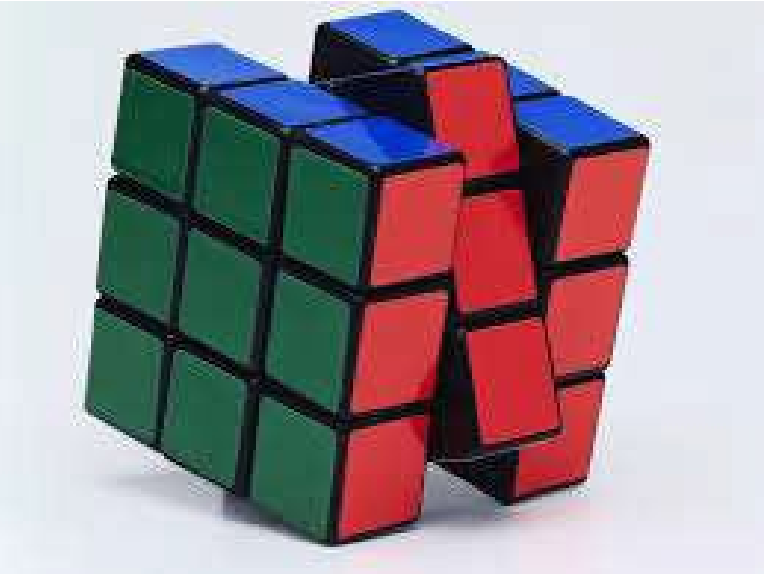

* Source: Integral Group, 2020: Refrigerants + Environmental Impacts Best Practices Guide

# 5. Support resilience, health and comfort

1. Consider incorporating resilience strategies in all buildings at the time of retrofits. Especially by designing to withstand increasing and more extreme weather events, which are the new norm, per IPCC 6th Assessment Report.
2. Evaluate Thermal comfort based on an expanded suite of parameters (beyond just air temperature, but also to include mean radiant temperature, humidity, air velocity, etc.)
3. Ensure 1-2 days of passive survivability (limited mission fulfilment functionality with no active energy input to maintain comfort criteria, per P100. For residences and critical facilities, aim to provide a minimum of two days survivability if the grid goes down.

# 6. Support system-wide optimization to avoid unintended consequences

1. Decarbonization should avoid creating a bigger problem for the grid, subsequently increasing costs for all building owners and occupants. Solutions should account for the regional energy mix.
2. Interventions should be planned proactively, creating a roadmap to a zero-carbon portfolio – don't do something that will prevent or negate future options.
3. Validate and align building/site decarbonization plans or roadmap based on utility plans.



# 7. Support equal opportunity job creation and training underpinned by equitable procurement practices

1. New building selection should be encouraged in locations where it will bring benefits to the local community, including supporting public transportation.
2. Design, retrofit, procurement, implementation, etc. should support diversity, equity and inclusion.

# SUMMARY OF BARRIERS & SOLUTIONS TO DECARBONIZATION FOR EXISTING & NEW BUILDINGS

GSA Advisory Committee –Decarbonization Task Group

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# Embodied and Operating Carbon:
## Building Life Cycle

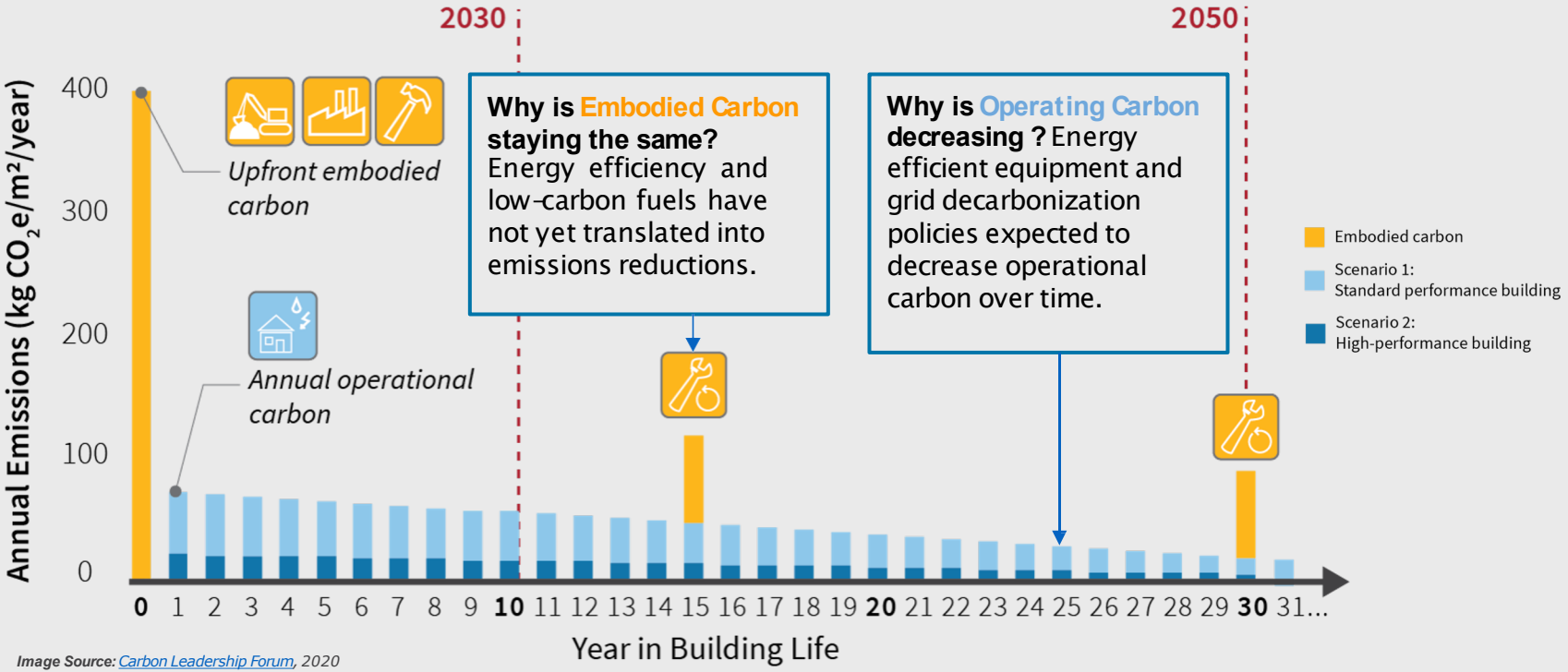


*Image Source: Carbon Leadership Forum, 2020*

# Summary:
# Capital Access & Investments

- **Barrier:** It may be hard to justify appropriations for low economic returns, despite a strong carbon reduction.
- **Solution:** Taking a "portfolio-wide approach" will enable GSA's high value projects to support those with weaker returns.

- **Barrier:** Banks are underwriting carbon neutral assets the same as conventional designs.
- **Solution:** GSA should advise its private sector landlords to utilize the Appraisal Institutes "Green Addendum" and "Green Registry" to enable them to increase loan dollars to pay for low-carbon improvements.

- **Barrier:** There is currently no income or value stream associated with embodied carbon, as a result appraisers are not giving value to sustainable & low-carbon improvements.
- **Solution:** A Green Bank, similar to an SBA loan guarantee, and Green Bonds could be utilized by GSA's private sector landlords to help satisfy "First Costs" more cost effectively.

- **Barrier:** There are no baseline metrics to value and budget for the social cost of carbon.
- **Solution:** Quantify embodied carbon and assign a score or grade to a building's embodied footprint.

# Summary:
# Workforce & Building Technologies

- **Barrier:** A shortage of skilled industry professionals that understand how to design, build, and operate lower-carbon existing buildings.
- **Solution:** Establish in-person and virtual trainings to industry professionals in how to design, build, and operate lower-carbon existing buildings.

- **Barrier:** A shortage of non-structural materials for renovations with product-specific EPDs that facilitate carbon accounting for the project.
- **Solution:** Adopt recommendations from the "GBAC Policy Recommendations for Procurement of Low Embodied Energy and Carbon Materials by Federal Agencies"

- **Barrier:** GSA PM staff resistant to adopting lower-carbon materials and management processes.
- **Solution:** Engage senior GSA leadership to establish pilot projects that will persuade broader adoption of key concepts.

- **Barrier:** Subcontractor operating emissions during construction and renovations not easily captured.
- **Solution:** Require subcontractors to track and report operational emissions during construction and renovations, with a target to reduce emissions during their contract work.

# Summary:

## Climate Zones & Building Performance Design

- **Barrier:** Variation in a building's shape and climate zone, affect the ability to reduce the EUI.
- **Solution:** Use an integrated design approach sensitive to shape and climate zones to minimize EUI. Encourage on-site renewables to further reduce EUI. Publish successful case studies.

- **Barrier:** Lack of local utility-scale renewables/storage in many locations, make carbon emissions reduction challenging. Utility rate differences effect paybacks for on-site renewables/storage.
- **Solution:** Encourage ISO's to invest in renewables and storage. Where grid carbon content is above average, utilize on-site renewables with provisions for energy storage. Where grid carbon content is below average, increase focus on energy storage. Provide incentives for renewables and storage.

- **Barrier:** Current building codes often restrict FAR and heights, making on-site renewable installations difficult. They rarely require new or renovations of existing buildings to be all electric and rarely address embodied carbon.
- **Solution:** Encourage the use of local "stretch codes" to test decarbonization strategies. Convene building code officials to discuss how to integrate embodied carbon into building codes.

- **Barrier:** Embodied carbon represents a significant amount of carbon emissions related to buildings which is rarely considered in standards and during design.
- **Solution:** Educate GSA staff on embodied carbon and adaptive building reuse, while using low carbon materials, and designing buildings that last long and can serve multiple uses.

## Capital Access & Investments:
ROI, NPV, First Cost/Operating Cost

| Barriers | | Solutions | |
|---|---|---|---|
| Embodied | Operating | Embodied | Operating |
| • Some financial decisions are being made based on ROI, vs. impact on asset value.<br>• A reduction in energy is easier to value than a reduction in carbon.<br>• Materials with low embodied carbon may be more costly w/o increasing ROI.<br>• Investment decisions are sometimes made on a Short-Term basis.<br>• There is currently no income/value stream associated with embodied carbon.<br>• Lack of demand from customers for low-carbon products. | • Financing options are not efficient.<br>• Regional differences in first cost; cost of power and REC's along with building differences, may take the NPV below the first cost.<br>• Storage is relatively expensive & not commonly installed.<br>• Despite a potentially high ROI, meaningful up-front capital will be required. | • Assigning a "Carbon Score" to each building.<br>• Companies are beginning to ask vendors for its ESG compliance, including carbon footprint, and considering this as part of vendor selection. This trend may create value for embodied carbon.<br>• ESG investors are starting to recognize low-carbon buildings as a lower risk investment, with higher returns than conventional buildings. | • A holistic design mentality can make many solutions cost-neutral.<br>• The cost of many products and technologies are projected to come down. GSA demand will help accelerate this.<br>• Projects with stronger valuations will help support the weaker ones when looked at as a portfolio.<br>• Due to higher returns at lower risk (see embodied), lending community gives value to sustainable improvements and lends toward first cost. |

## Capital Access & Investments:
Bonds, Green Bank, Appropriations/Policy

| Barriers | | Solutions | |
|---|---|---|---|
| Embodied | Operating | Embodied | Operating |
| • Lack of clear risk indicators (cost of Carbon?)<br>• Banks are currently underwriting ZNE / carbon<br>• Neutral assets the same as conventional design.<br>• Appraisers are not giving value to sustainable improvements<br>• Will funding be appropriated if an economic return is hard to justify, despite a strong carbon reduction? | • Source of repayment (energy savings) will vary from project to project.<br>• Lenders are not recognizing the value to its collateral that ZNE, more resilient carbon-neutral buildings provide.<br>• What criteria will need to be met to be awarded funding? ROI thresholds; carbon reduction; over what time-frame, etc.? | • Green Bonds would help satisfy "First Costs" at a more reasonable ROI.<br>• Source of repayment would need to be tied to Operating Savings in lieu of carbon tax savings.<br>• A Green Bank, like an SBA loan guarantee, could be utilized by the private sector that acts as landlord to GSA<br>• The mentality of a triple bottom line outcome<br>• (Planet) must be part of the value proposition.<br>• The private sector is already beginning to do this. | • The Appraisal Institute's "Green Registry" and "Green Addendum" will help lenders get more "First Cost" dollars out.<br>• Low-cost Green Bonds will help enable acceptable ROI's in areas with inexpensive power (which is often "dirty / high carbon power") furthering the impact.<br>• A carbon neutral building is more resilient while stabilizing (reducing) tenant operating costs, leading to stronger (more valuable) collateral for the banks to lend against.<br>• Take a long-term approach, and if the GSA looks at its portfolio, the higher return projects will justify the tougher (lower ROI) projects when averaged out. |

## Workforce & Building Technologies:
Skill Set Availability

| Barriers | | Solutions | |
|---|---|---|---|
| Embodied | Operating | Embodied | Operating |
| • Lack of skilled labor relative to procurement, delivery, execution of low-carbon materials.<br>• Demand may create a shortage of skilled labor where it currently exists.<br>• Skilled, permitted technicians in short supply | • Inertia (GSA project managers resist change to new technologies)<br>• Demand may create local shortages of skilled labor<br>• Lack of skilled labor relative to design, implementation, operation and maintenance of energy & storage systems along with BAS, etc. | • Create educational resources for local labor.<br>• Certified training and placement workforce programs to add 2.5x capacity into the economy. | • Leadership from the top will be needed to help change PM's habits and mindset.<br>• Certified training and placement workforce programs to add 150% capacity into the economy.<br>• **Establish** internal GSA procurement advisory team to assist Government PM staff guidance on implementing P100 requirements in alignment with decarbonization strategies. |

## Workforce & Building Technologies:
Materials Supply Chain

| Barriers | | Solutions | |
|---|---|---|---|
| Embodied | Operating | Embodied | Operating |
| • Locations where local materials are not readily available<br>• Make information on where equipment/materials are sourced from available | N/A | • Require subcontractors to use vehicle "telematics" technologies, synched to maps/programs to show lowest carbon transportation routes and mode (truck, rail etc.). (ie, Google is doing to GPS routing.<br>• Develop software tools to estimated carbon in delivery.<br>• Adopt recommendations from the "GBAC Policy Recommendations for Procurement of Low Embodied Energy and Carbon Materials by Federal Agencies," including use of materials with EPDs and verifiable Global Warming Potential (GWP) analysis. | N/A |

## Workforce & Building Technologies:
## Carbon Management and Technology

| Barriers | | Solutions | |
|---|---|---|---|
| Embodied | Operating | Embodied | Operating |
| N/A | • Subcontractor operating emissions during construction and renovations not easily captured.<br>• Need to introduce carbon reduction calculations into building controls packages.<br>• Need for integration of BMS, lighting, PV and battery system controls to be integrated.<br>• Need to incorporate best practice EV charging strategies into building design.<br>• Availability of appropriate building management systems and cost (primarily smaller-medium sized projects).<br>• Technology +Data Security can present unfamiliar technologies that can potentially increase hacking risks.<br>• BMS technologies proprietary and not-interoperable across all GSA facilities. | N/A | • Require subcontractors to track and report operational emissions during construction and renovations, with a target to reduce emissions during their contract work.<br>• Grid connected energy management controls to maximize time-of-use and peak load flexibility.<br>• Software to track carbon content of local grids to inform fuel mix procurement.<br>• Electric Vehicles and bi-directional EV charging equipment.<br>• Open-source software may accelerate tech upgrades.<br>• Technology +Data Security training and coaching, along with better data security software and procedures.<br>• Isolate the range of BMS technologies that include interoperability or push data across API. |

## Climate Zones & Building Performance Design:
Geometry, Size, Material and Equipment

| Barriers | | Solutions | |
|---|---|---|---|
| Embodied | Operating | Embodied | Operating |
| • Embodied carbon in new buildings represent about 13 years of operational carbon<br>• Building materials, especially envelope/curtain wall assemblies, shipped long distances add CO2 in transport<br>• Replacement of worn equipment increases embodied carbon<br>• Loss of economies of scale for smaller projects | • Huge variations in buildings:<br>○ New vs. existing<br>○ Large vs. small<br>○ Different orientations and geometries<br>• Poor envelope design and material selection decreases building energy performance.<br>• Gas equipment often costs less to purchase and operate than electric equipment.<br>• First cost of high performance energy related systems is higher. | • Educate GSA staff on embodied carbon. Reuse existing building when possible, design buildings for flexible use, use low carbon materials such as low carbon concrete mixes, recycled steel, and mass timber, consider open ceilings and floor plans to minimize building materials<br>• Source building materials locally when feasible<br>• Consider design to provide better flexibility for use changes, durability, deconstruction and end of life use of materials<br>• Consider group purchases for small projects | • Utilize an integrative design process and experienced teams to optimize efficiency. Publish successful case studies of various buildings types and locations.<br>• Require high performance envelopes and detailed energy models.<br>• Require all electric buildings.<br>• Incorporate life cycle assessment and carbon impacts into budget and financial decisions. |

## Climate Zones & Building Performance Design:
Location

| Barriers | | Solutions | |
|---|---|---|---|
| Embodied | Operating | Embodied | Operating |
| • Lack of industry awareness of the benefits of local sourcing<br>• Local grids may not be adequate for all electric transportation. | • Various climate zones have challenging weather and temperatures conditions<br>• Locations where temperature, noise and air quality discourage natural ventilation<br>• Building locations with poor solar access<br>• Intermittent renewable energy resources | • Work with design professionals to communicate the benefits of local sourcing. Encourage local manufacturers to provide information for local designs. Procure locally-based envelope/curtain wall assemblies.<br>• Add incentives based on "bio-based fuel" or EV delivery. | • Utilize an integrated design process and teams experienced with high performance design to optimize for local climate<br>• Use DOAS, HRV's, and economizer cycles with high quality filters to introduce outdoor air.<br>• Consider ground mount solar and portfolio wide approaches.<br>• Use energy storage to reduce grid demand when renewables are unavailable<br>• Minimize EUI and mandate generation of carbon free energy at grid level, incentivise renewables, resilience / microgrids |

## Climate Zones & Building Performance Design:
Energy Markets, Codes and Standards

| Barriers | | Solutions | |
|---|---|---|---|
| Embodied | Operating | Embodied | Operating |
| • Dirty grids with low cost energy supply power for manufacturing increasing embodied carbon.<br>• Fossil fuel based transportation of materials increases embodied carbon in building materials.<br>• Few if any codes regarding embodied energy. | • Codes do not address embodied carbon and items such as FAR; height limitations make installation of solar difficult.<br>• Availability of low-cost questionable REC's.<br>• Lack of available utility scale renewable energy or energy storage<br>• Developers resist using new technologies that could reduce carbon emissions<br>• Local grids provide low cost electricity with carbon content above the national average<br>• Local grids with carbon content below the national average make onsite renewables less effective for reducing carbon emissions | • Federal support to more rapidly decarbonize electrical grids and move manufacturing to 100% electrical.<br>• Federal support shipping to 100% electrical.<br>• Train code officials on issues regarding Develop codes regarding calculating and minimizing the embodied carbon of materials used in buildings and calculating and minimizing the embodied carbon used in delivering materials to sites. | • Encourage the use of "stretch codes" to find new methods to reduce carbon emissions.<br>• Develop more rigorous vetting of REC's and benefits.<br>• Use "time of use" and "demand" charges to encourage on-site installed solar and storage<br>• Provide case studies of successful carbon reduction strategies.<br>• Encourage ISO's to increase use of renewables. Use on-site energy efficiency and renewables to minimize carbon emissions.<br>• Consider use of energy storage systems and bi-direction EV charging to minimize carbon emissions, add to the P100. |

# Federal Building Decarbonization

## Retrofit Playbook Objectives

- Provide practical guidance for GSA and practitioners to advance federal government building decarbonization goals
- Leverage the work of the key principles and barriers/solutions sub-teams
- Use the 80/20 principle to develop playbooks aligned with critical events in large numbers of existing federal facilities

# Federal Building Decarbonization

## Retrofit Playbook Priorities

- Building types:
  - Small buildings with distributed HVAC (<50K ft²)
  - Large buildings with central plant (>50K ft²)
- Project scenarios:
  - Equipment replacement
  - Building envelope repair
- Project scope
  - Building Envelope
  - Energy Efficiency
  - Building Controls
  - Building Operations
  - Water Conservation
  - Electrification
  - On-site Renewables
  - Off-site Renewables
  - Demand Flexibility
  - Embodied Carbon
  - Refrigerants
  - Resilience, Health, Equity

# Federal Building Decarbonization

## Retrofit Playbook Content

- Project Development Checklist
  - Specific to building type and project driver
  - Based on the key building decarbonization principles and solutions
  - Considerations for grid emissions, climate zones, energy costs, health and resiliency
- Project Development Process and Tools
  - ESPC ENABLE process (FEMP)
  - Commercial Building Energy Saver Pro (LBNL)
  - Integrated Systems Packages (LBNL)
  - Controller Retuning (PNNL)
  - Healthy Buildings & Energy Support Tool (PNNL)
  - Reopt Lite Tool (NREL)
  - Water Project Screening Tool (FEMP)

# Federal Building Decarbonization

## Retrofit Checklist Example

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## HVAC Equipment Replacement for Small Buildings

1. Take advantage of **planned HVAC equipment replacements** to incorporate complementary building decarbonization/resiliency measures.
2. Evaluate current equipment load trend data and compare with current equipment capacity to identify **opportunities for downsizing** during replacement.
3. Identify **low-cost, no-cost and short payback energy efficiency measures**, and especially those impacting heating and cooling loads, to further reduce building energy use.
4. **Replace any packaged heating equipment using high efficiency heat pumps** - carbon reduction costs favor clean grids and high energy prices.
5. In very cold climate zones, **consider using hybrid heating equipment** (dual fuel rooftop units) to provide efficient and resilient operation.

# Federal Building Decarbonization

## Retrofit Checklist Example

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## HVAC Equipment Replacement for Small Buildings

6. Replace packaged space cooling equipment with **high efficiency, low GWP cooling equipment** including variable refrigerant flow (VRF) or packaged rooftop units.
7. Replace **fossil fuel water heating with heat pumps** or heat recovery chillers and heat pumps
8. Reduce **water consumption** to save electricity and heating energy requirements.
9. Install **solar photo-voltaic panels** on buildings and other on-site structures and grounds, carbon mitigation economics favors dirty electrical grids and high electricity costs.
10. Install **energy storage (electric and/or thermal)** to provide demand flexibility and increase resilience.

# Federal Building Decarbonization

## Retrofit Checklist Example

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## HVAC Equipment Replacement for Small Buildings

11. Install **EV charging stations** with the ability to provide smart charging and demand flexibility.
12. Install **automated building controls** with the ability to integrate distributed energy resources and EV charging and provide automated demand response and flexibility services.
13. Install **energy sub-metering, energy information management systems** and automated fault detection and diagnostic systems.
14. Maintain **comfortable and healthy indoor environments** through proper air filtration, ventilation and air treatment.
15. Increase **building resiliency** through a combination of passive measures (thermal insulation, day lighting, operable windows and water storage) and backup energy generation and energy storage.

# Federal Building Decarbonization

## Retrofit Checklist Example

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## HVAC Equipment Replacement for Small Buildings

16. Review facility condition indicators to identify any **deferred maintenance projects** which could be integrated into the current project.
17. Estimate energy savings and carbon reductions for all potential improvement measures to determine which deliver the **largest carbon reductions at the lowest cost**.
18. Use **lifecycle cost analysis** to determine the most cost-effective carbon reductions which meet financial return targets.
19. Target projects in **underserved communities, using local contractors, diverse suppliers and workers** participating in apprentice programs.
20. Maximize the use of **low-carbon building materials**, and especially the use of reused, remanufactured, recycled and locally-sourced materials.

# Federal Building Decarbonization

## Retrofit Checklist Example

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## Envelope Repair For All Buildings

1. Take advantage of **building envelope repair** to improve passive efficiency and incorporate complementary building decarbonization and resiliency measures.
2. Evaluate **passive survivability** through passive efficiency measures, targeting 48 hours without grid power for critical areas and functions.
3. Estimate **reduction in heating and cooling energy use** through implementation of passive building envelope measures.
4. Identify **additional low-cost, no-cost and short payback energy efficiency measures**, and especially those that reduce heating and cooling loads, to further reduce building energy use.
5. Evaluate current equipment load trend data and compare with current equipment capacity to identify **opportunities for equipment downsizing**.