GSA Green Building Advisory Committee Advice Letter: Recommendations for Advancing GHG Reductions in Existing Federal Buildings

November 9, 2022

Kevin Kampschroer
Chief Sustainability Officer and Federal Director,
Office of Federal High-Performance Green Buildings
U.S. General Services Administration (GSA)

RE: Policy Recommendations for Federal Building Decarbonization

Dear Mr. Kampschroer:

This letter summarizes the recommendations of the Green Building Advisory Committee (the Committee), based on the work of its Federal Building Decarbonization Task Group (FBDTG). This Task Group was formed to explore opportunities and challenges for reducing greenhouse gas emissions - in alignment with national climate goals and action plans - using renewable energy, energy efficiency, electrification, and smart building technologies at federal facilities. Having identified the potential savings to be significant, the FBDTG produced relevant and readily adoptable recommendations that can help GSA accelerate net zero emission retrofits of existing federal facilities.

The scope of the Task Group included individual buildings and campuses, considering the impacts of supporting infrastructure, including central energy plants, distributed energy resources, and EV charging. Building decarbonization includes whole life cycle emissions such as operational emissions, refrigerant emissions, and embodied carbon of materials (an issue previously addressed by the Committee). The Task Group believed it could add the most value by devoting its primary attention to the decarbonization of building operations. Building decarbonization improvements can provide additional benefits such as enhanced human health, water conservation, improved grid reliability and support equitable and resilient communities.

At the end of its initial phase in April 2022, the FBDTG drafted the Advice Letter: Federal Building Decarbonization: Preliminary Recommendations, which gained approval from the full Committee. The Committee at that time recommended continuing the work of the Task Group with a primary focus on accelerating net zero emissions building retrofits, initially across the GSA building portfolio, through sub-teams dedicated to building prioritization and project implementation and aligning the work of the Task Group sub-teams with the activities of GSA, the U.S. Department of Energy (DOE) and other teams currently supporting federal building decarbonization goals and activities.

The Advice Letter included additional recommendations on how federal agencies can most effectively optimize the decarbonization of their building portfolios, as well as Appendices outlining key principles, barriers and opportunities and a proposed Retrofit Playbook approach.

The Committee authorized the FBDTG to continue its work and delve deeper into strategies and tactics agencies should consider in approaching building portfolio decarbonization. This Advice

Letter summarizes the second phase of the Task Group's findings and recommendations.

The full Committee accepted this Advice Letter of the FBDTG at its Fall 2022 meeting on November 9, 2022, following review, discussion and comment.

Background

The White House and Congress have set a series of aggressive goals for federal building decarbonization. Executive Order 14057 mandates that the federal building portfolio achieve net-zero greenhouse gas (GHG) emissions by 2045, including a 50% reduction by 2032. This Executive Order will contribute to the broader goal of reducing federal GHGs by 65% in Scopes 1 and 2 from Federal operations by 2030 from 2008 levels.

The Climate Smart Buildings Initiative sets a goal of leveraging over $8 billion in private sector investment through performance contracts for building retrofits; this follows the Energy Act of 2020 mandate for agencies to complete at least 50% of all identified lifecycle cost effective energy and water savings measures through performance contracts. Most recently, the Inflation Reduction Act provided over $3 billion in funding to GSA for various purposes related to greenhouse gas reduction, clean energy, sustainable buildings, and clean materials purchasing.

These goals also coincide with White House initiatives to advance environmental justice and equity, including the Justice 40 intiative to direct that 40 percent of the overall benefits of Federal environmental investments flow to disadvantaged communities.

Findings

The United States federal government has an opportunity to lead by example in sending a clear, consistent signal to the market, creating meaningful reductions in existing federal building portfolios.

The decarbonization of existing buildings is GSA's greatest challenge, particularly over the next 3-5 years. With roughly 80 percent of the predicted building stock for 2050 already in existence today, there is a huge need—and opportunity—to retrofit existing assets. While larger facilities can more easily justify and obtain the additional resources required to execute an integrated design approach to optimize results for whole-building retrofits, smaller facilities need standardized strategies for implementing decarbonization projects.

With over 1,600 federally-owned buildings in the GSA portfolio, there is a need for a tool to quickly screen and prioritize buildings for decarbonization. Portfolio prioritization can be achieved by considering current building efficiency levels, electric grid emissions intensity and electricity/fossil fuel ratio with timing also based on the need for near-term major equipment or envelope replacement. The Task Group developed a proof-of-concept spreadsheet tool, which determines recommended decarbonization improvements across a building portfolio (e.g., energy efficiency, electrification, on-site renewable energy), prioritized based on the investment cost per metric ton of emissions reduction. A review by the DOE's Building Technologies Office (BTO) suggested that the Standard Energy Efficiency Data (SEED) Platform would be the preferred platform to host the proposed building prioritization tool functionality.

For smaller buildings with packaged equipment, technical experts are rarely available to support initial project development. In this case, data collected from basic building audits can be used to determine standard decarbonization retrofit packages and estimate approximate project costs and impacts. The Task Group developed a draft preliminary specification for GSA to propose extending DOE's Building Energy Audit Template tool to automatically generate standard retrofit packages, including retro-commissioning, energy efficiency improvements, electrification, demand management, low-GWP refrigerants, and low-carbon energy supply. With the recommended new features, Audit Template tool could define decarbonization plans with improvements phased over time to coincide with major equipment replacement or other critical events.

For evaluating equity and environmental justice impacts associated with building decarbonization, the Task Group reviewed the Beta version of the Climate and Economic Justice Screening Tool[1]. The tool identifies disadvantaged communities by census location, using open-source, consistent data sources. This and similar tools should be reviewed as part of future work on federal building decarbonization.

Recommendations

Key recommendations to reduce operational energy and carbon in existing buildings:

1. GSA and other federal agencies should utilize the proposed **building prioritization methodology, based on the proof-of-concept spreadsheet tool,** to screen all significant and long-term owned assets for decarbonization opportunities.
    a. GSA should request that DOE support the integration of the building prioritization tool into the DOE SEED platform.
    b. GSA should incorporate the use of the building prioritization as a means of complying with EO 14057 Implementing Instructions and the Inflation Reduction Act.
2. GSA and other federal agencies should utilize the proposed **building decarbonization project implementation methodology** for existing buildings.
    a. GSA should request that DOE support the further development of the existing DOE Building Energy Audit Template tool to provide building decarbonization implementation recommendations for existing buildings as outlined herein.
    b. The tool should utilize building asset data, energy audit data, and other building information to identify a building decarbonization plan with decarbonization measures, organized into packages, and phased over time to achieve operational net zero emissions goals.
3. GSA should expand data collection on smaller (non-covered) facilities and perform EPA Portfolio Manager analysis so they can be analyzed using the building prioritization and project implementation process.

Next Steps

The Committee further recommends that the Task Group extend its work into 2023 with a focus on building and campus electrification. A procurement policy with supporting guidance has the potential to drive the replacement of fossil-fuel heating equipment with electric alternatives (e.g., heat pumps) at scale, especially in widely distributed small buildings with packaged HVAC equipment. After a preliminary assessment of potential improvement measures earlier this year, the Committee suggests a more detailed study of opportunities to decarbonize district energy and combined heat and power plants which are significant emitters in the federal building portfolio. There is also an opportunity to update existing energy analysis tools (e.g., DOE's Building Efficiency Targeting Tool for Energy Retrofits (BETTER) tool) to incorporate building

[1] Based on the Executive Order 14008 *Tackling the Climate Crisis at Home and Abroad.*

electrification and decarbonization measures.

Thank you for your careful consideration of this package, and for the opportunity to recommend these important actions to GSA. On behalf of the Green Building Advisory Committee, we respectfully submit these recommendations for your consideration.

Sincerely,

Fernando Arias, Acting Co-Chair
Green Building Advisory Committee

Ralph DiNola, Acting Co-Chair
Green Building Advisory Committee

Clay Nesler, Co-Chair
Federal Building Decarbonization Task Group

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Federal Building Decarbonization Task Group

Appendices

A. Presentations and Briefings

B. Building Decarbonization Prioritization Methodology and Proof-Of-Concept Prototype Screening Tool

C. Building Decarbonization Implementation Tool Concept Specification

Task Group Participants

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Appendix A: Presentations and Briefings

Presentations to the Green Building Advisory Committee Federal Building Decarbonization Task Group, Phase II

- Hannah Kramer, Lawrence Berkeley National Lab (LBNL): DOE Better Buildings Program's Better Climate Challenge and Low Carbon Pilot
- Harry Bergmann, DOE Building Technologies Office (BTO) and Supriya Goel, Pacific Northwest National Lab (PNNL): DOE Audit Template Tool
- Chris Tremper, DOE Federal Energy Management Program (FEMP): EISA 432 Compliance Tracking System (CTS) Database
- Paul Mathew, LBNL: DOE BTO Integrated Systems Packages Project
- Michael Bloom, GSA OFHPGB: GSA Public Buildings Service (PBS) Total Workplace Scorecard
- Laurie Kerr, US Green Building Council (USGBC): Deep Energy Retrofit Plan Analysis (DERPA) tool)
- Tim Unruh, National Association of Energy Service Companies (NAESCO): Promoting ESPCs/UESCs for Building Decarbonization
- Bruce Hedman, DOE Advanced Manufacturing Office (AMO): Combined Heat and Power (CHP) and Decarbonization
- Max St-Denis, Public Service and Procurement Canada (PSPC): National Portfolio Decarbonization – Driving The Green Building Agenda in Canada
- Ken Sandler, GSA OFHPGB: Executive Order 14057 Implementing Instructions
- Sheila Hayter, National Renewable Energy Lab (NREL) and Kathleen Judd, PNNL: Net Zero Labs Pilot Initiative

Organizations Briefed on Interim Findings of Task Group

- GSA PBS
    - Offices of Facilities Management, Design & Construction and Portfolio
- DOE FEMP
- DOE BTO
- Council on Environmental Quality, Office of Federal Sustainability

Appendix B: Building Decarbonization Prioritization Methodology and Proof-Of-Concept Prototype Screening Tool

Objective

The proposed building decarbonization prioritization methodology was developed to address short-term challenges for GSA and other federal agencies to develop building decarbonization plans at a building and portfolio level. These challenges include the following:

- Quickly prioritizing existing federal buildings for decarbonization
- Identifying appropriate decarbonization measures
- Estimating potential energy and greenhouse gas reductions
- Estimating required investments and payback
- Developing preliminary plans using minimal existing data

In response to these challenges, the Task Group defined a suggested prioritization methodology and developed a proof-of-concept, prototype spreadsheet tool to implement the methodology on a sample set of federal buildings.

Building Prioritization Methodology

The prioritization methodology begins with an initial screen of buildings of the same type (e.g., office buildings) to determine the targeted decarbonization measures. These targeted measures, along with the building's current energy usage and cost information, are then used to estimate energy, GHG and cost savings at a building level as well as the required investment.

The potential buildings projects are then evaluated based on workplace criteria, such as plans for disposal or workplace renovation and evaluated based on its proximity to a disadvantaged community. The GSA Total Workplace Scorecard is a potential source of data on workplace requirements including air quality, thermal comfort, and lighting. The Beta version of the Climate and Economic Justice Screening Tool can be used to identify environmental justice communities. Finally, near-term plans for major equipment or building renovations are considered in prioritizing buildings for decarbonization improvements.

The following diagram shows a high-level overview of the building decarbonization prioritization methodology.

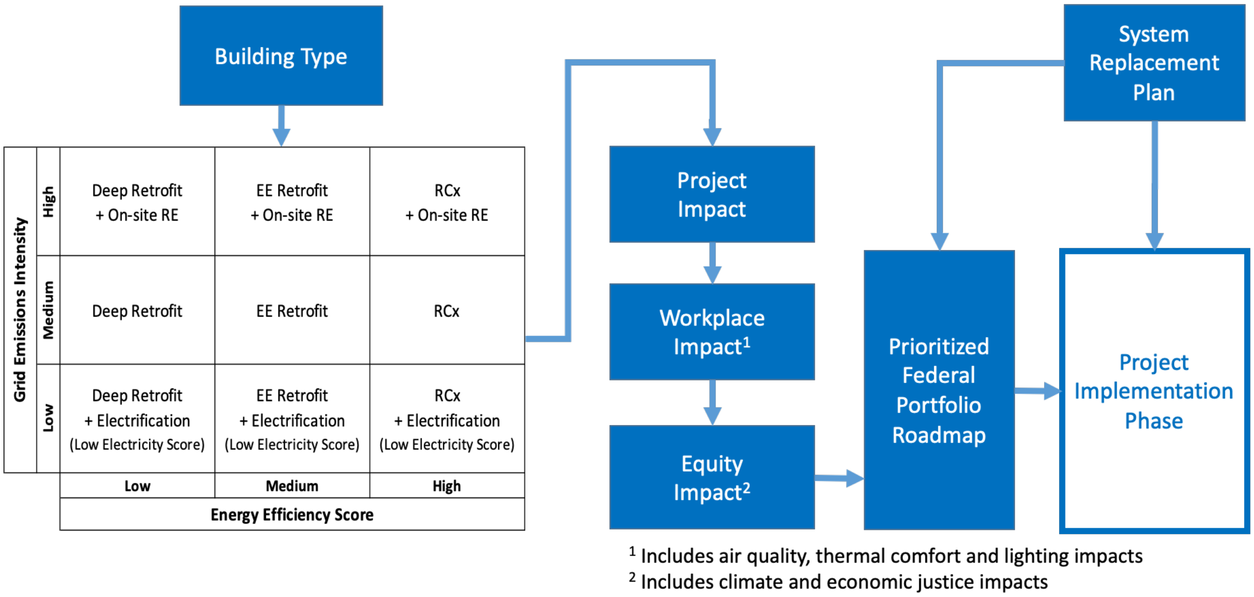

Figure 1 – Building Decarbonization Prioritization Methodology

Building Prioritization Screen

The initial screen is based on three factors: energy efficiency; grid emissions intensity; and electricity score.

> Energy Efficiency - The ENERGY STAR Score from ENERGY STAR Portfolio Manager is used as the energy efficiency indicator when available. This indicator provides a percentile ranking of building energy performance normalized for building type, building size, building occupancy, plug-loads, and climate zone. If this data is not available, then the percentile ranking of building site energy use intensity may be used.
>
> Grid Emissions Intensity – The data used for this factor is the most recent eGRID Scope 2 emissions factor (MT CO2e/kWh) from the appropriate subregion.
>
> Electricity Score – The electricity score is the ratio of electricity use (BTUs) to the building total energy use from all sources (electricity, gas, oil, district heat and chilled water.

Building Decarbonization Measures

The next step of the prioritization process is to use the three screening factors to determine which general decarbonization measures should be targeted for each building. These measures include retro-commissioning, energy efficiency retrofits, deep energy retrofits, electrification, and on-site renewable energy. Estimated energy savings ranges are included in the description below

> Retro-commissioning – Low-cost/no-cost measures resulting from re-tuning and repair of building systems and equipment, typically resulting in 10-15% energy savings[2].
>
> Energy Efficiency Retrofits – Replacement and upgrading of HVAC equipment, lighting, and controls, typically resulting in 20-30+% energy savings[3].

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[2] https://www.epa.gov/sites/default/files/2016-03/documents/table_rules_of_thumb.pdf
[3] https://www.gsa.gov/cdnstatic/Deep_Energy_Retrofits_Using_ESPC_508_small.pdf

Deep Retrofits – Repair, replacement, and enhancement of the building envelope (e.g., roof, walls, windows) combined with the integrated retrofit of HVAC, lighting, controls, and the introduction of plug-load management, low GWP refrigerants, energy storage, and active demand management, typical resulting in 40-50+% energy savings[2].

Electrification – Complete or partial replacement of fossil fuel heating (space heating, service hot water, and cooking) with electric alternatives (e.g., heat pumps, heat recovery chillers), typically resulting in 50-100% reduction in fossil fuel energy use.

On-site Renewables – Addition of solar PV, battery electric storage and other distributed energy resources (e.g., EV charging, renewable CHP) with energy savings dependent on building space and site (e.g., carpark roof, grounds) availability and orientation.

The relative level of building energy efficiency determines the first three decarbonization measures:

- High energy efficiency score: Retro-commissioning
- Medium energy efficiency score: Energy Efficiency Retrofit
- Low energy efficiency score: Deep Retrofit

The grid emissions factor determines the last two decarbonization measures:

- High grid emissions factor: On-site Renewable Energy
- Low grid emissions factor: Electrification[4]

Building Data Requirements

Basic location, energy use and GHG emissions data is needed to perform the building prioritization preliminary screening and analysis. The required data includes the following:

- Building Type
- Building Location
- Building Size (GSF)
- Building Climate Zone
- ENERGY STAR Score from EPA Portfolio Manager (if available)
- eGRID Factor - Scope 2 Emissions (MT CO2e/kWh)
- Scope 1 GHG emissions (MT CO2e)
- Scope 2 GHG emissions (MT CO2e)
- Electricity, Gas, Oil, Steam, Chilled Water Annual Consumption (mmbtus)
- Electricity, Gas, Oil, Steam, Chilled Water Annual Cost ($)

[4] Note that in addition to a low grid emissions factor, electrification should be prioritized for buildings with low electricity scores and significant fossil fuel usage. Also, electrification will be most economical if the ratio of electricity to fossil fuel cost per BTU is low.

Prototype Building Decarbonization Screening Tool

The prototype Building Decarbonization Screening (BDS) Tool is a functional, proof-of-concept spreadsheet implementation of the building screening and analysis process used in the building prioritization methodology. The proposed screening tool includes a “building data” worksheet, a “user input” worksheet, a “data analysis” worksheet, a “dashboard” worksheet with output data and other worksheets showing various charts of data analysis output.

The *Building Data Worksheet* includes the data required to perform building screening and analysis. It is organized by building site in a table which is populated with data from agency sources. To help evaluate the prioritization methodology and prototype BDS tool, GSA’s Public Buildings Service (PBS) provided anonymized data from 25 office buildings, ranging in size from 60K to 1.5M GSF covering all five Commercial Buildings Energy Consumption Survey (CBECS) climate zones. Members of the Task Group used these data to conduct sample analyses to test the prototype tool, the results of which are illustrated in sample screenshots below.

The following shows an example of the *Building Data Worksheet*.

Building Site	FY 21 Energy Intensity (BTU/GSF)	Energy Star Score	CY22 eGRID Factor Scope 2 GHG (MT CO2e/kWh)	FY21 Scope 1 GHG (MTCO2e)	FY21 Scope 2 GHG (MTCO2e)	Electricity (mmbtus) FY 2021	Electricity (cost) FY 2021	Steam (mmbtus) FY 2021	Steam (cost) FY 2021	Gas (mmbtus) FY 2021	Gas (cost) FY 2021	Oil (mmbtus) FY 2021	Oil (cost) FY 2021	Chilled Water (mmbtus) FY 2021	Chilled Water (cost) FY 2021	CBECS Climate Zone
CT	31,192	86	0.000242	179.3	191.3	2911.8	$ 144,844			2262.5	$ 32,261	797.3	$ 13,790			2
MA	29,275	89	0.000242	250.1	1330.9	20261.6	$ 1,031,913			4710.4	$ 55,855					1
NJ	95,475	80	0.000297	155.3	321.5	3462.9	$ 122,470			2910.9	$ 23,392	9.2	$ 225			2
NY	93,854	93	0.000289	0.0	1282.0	10061.7	$ 502,410	5484.0	$ 196,204							3
MD	60,404	81	0.000297	0.9	2970.2	15797.5	$ 418,361	11036.0	$ 314,188			12.5	$ 202	17005.8	$ 532,399	3
PA	45,814	86	0.000449	0.0	4515.0	21884.9	$ 542,301	14128.0	$ 402,604		$ 238					2
FL	35,937	71	0.000380	0.0	1086.7	9457.1	$ 211,569				$ 438					5
GA	40,305	88	0.000392	34.8	375.5	2899.8	$ 81,629			655.1	$ 5,360					4
KY	44,825	84	0.000381	289.7	1982.4	15602.4	$ 402,626			5455.1	$ 39,311					3
IL	37,970	84	0.000449	0.0	4489.7	31443.4	$ 872,058									2
MI	59,519	94	0.000526	0.0	1269.0	3615.9	$ 162,394	3984.0	$ 81,074							2
OH	55,094	79	0.000449	1826.3	6663.3	46666.3	$ 1,005,694			34392.8	$ 148,849					2
MO-1	39,017	70	0.000677	34.1	9257.4	43636.8	$ 912,108			642.7	$ 4,659					3
MO-2	49,514	86	0.000436	0.0	7672.8	36436.2	$ 1,161,735	24943.0	$ 537,189	0.0						2
OK	31,380	85	0.000425	103.7	403.5	3014.2	$ 74,852			1953.0	$ 9,750					4
TX-1	39,722	88	0.000373	551.2	2330.1	20084.5	$ 460,251			10380.4	$ 66,893					5
TX-2	28,656	41	0.000373	0.6	1893.3	16319.7	$ 327,210			10.4	$ 333					5
MT	52,478	36	0.000274	182.2	156.5	1634.6	$ 54,913			3431.4	$ 26,790					1
UT	50,317	83	0.000274	399.2	1167.5	12193.6	$ 281,365			7517.0	$ 48,440					2
CA-1	42,562	91	0.000234	559.5	272.8	4506.2	$ 275,521			10537.3	$ 108,942					4
CA-2	46,116	86	0.000234	228.5	1305.3	21563.0	$ 902,795			4303.2	$ 38,331					4
AK	58,561	89	0.000243	313.6	1198.3	16350.8	$ 335,204					4227.0	$ 57,938			1
WA	43,008	81	0.000274	0.0	2456.3	25501.6	$ 901,377	11707.0	$ 380,778							1
DC-1	43,907	85	0.000297	0.5	2649.5	20864.1	$ 861,502	7242.0	$ 281,713	9.1	$ 413					3
DC-2	54,356	83	0.000297	0.0	4200.9	27124.4	$ 872,700	17102.0	$ 665,268							3

Figure 2 – Sample *Building Data Worksheet*

The *User Input Worksheet* allows users to select building sites for analysis, override recommended decarbonization measures in the analysis, adjust criteria for screening buildings, specify parameters for impact analysis, and specify parameters for financial analysis including the use of a social cost of carbon adjustment in payback and net present value analysis. Default values and an explanation of each parameter is included in the spreadsheet.

The following shows an example of the *User Input Worksheet* data template.

Analysis Inputs		User Value	Default Value	Parameter Description
Screening Parameters	Use Energy Star Score for Analysis	Yes	Yes	"Yes" uses the Energy Star Score to prioriotize energy efficiency measures; "No" uses the percentile rank of Energy Use Intensity values.
	RCx	100	100	The maximum Energy Star Score (or EUI percentile) for Retrocommissioning
		90	90	The minimum Energy Star Score (or EUI percentile) for Retrocommissioning
	EE Retrofit	90	90	The maximum Energy Star Score (or EUI percentile) for EE Retrofits
		75	75	The minimum Energy Star Score (or EUI percentile) for EE Retrofits
	Deep Retrofit	75	75	The maximum Energy Star Score (or EUI percentile) for Deep Retrofits
		0	0	The minimum Energy Star Score (or EUI percentile) for Deep Retrofits
	Heating Electrification	0.0004	0.0004	Maximum value of grid emissions factor for Electrification
		80%	80%	Maximum value of the Electricity Score (electrical/total energy) for Electrification
		100	100	Minimum fossil fuel energy use for Electrification
		10	10	Maximum electricity/fossil fuel cost ratio (per BTU) for Electrification
	On-site Renewables	0.0004	0.0004	Minimum value of grid emissions factor for On-site Renewables
Energy Savings (Scope 1)	RCx Only	10%	10%	Reduction in fossil fuel energy use
	EE Retrofit	20%	20%	Reduction in fossil fuel energy use
	Deep Retrofit	40%	40%	Reduction in fossil fuel energy use
	Heating Electrification	100%	100%	Reduction in fossil fuel energy use due to Electrification (fuel switching)
	On-site Renewables	0%	0%	Reduction in fossil fuel energy use
Energy Savings (Scope 1)	RCx Only	10%	10%	Reduction in electrical energy use
	EE Retrofit	20%	20%	Reduction in electrical energy use
	Deep Retrofit	40%	40%	Reduction in electrical energy use
	Heating Electrification	100%	100%	Reduction in fossil fuel energy use due to Electrification (fuel switching)
		30%	30%	Increase in electrical energy use due to Electrification (fuel switching)
	On-site Renewables	10%	10%	Reduction in electrical energy use
Payback Periods	RCx Only	0.5	0.5	Minimum payback period (years), adjusted using electricity cost
		1	1	Maximum payback period (years), adjusted using electricity cost
	EE Retrofit	6	6	Minimum payback period (years), adjusted using electricity cost
		12	12	Maximum payback period (years), adjusted using electricity cost
	Deep Retrofit	15	15	Minimum payback period (years), adjusted using electricity cost
		20	20	Maximum payback period (years), adjusted using electricity cost
	Heating Electrification	10	10	Minimum payback period (years), adjusted using electricity cost
		30	30	Maximum payback period (years), adjusted using electricity cost
		1	1	Part-load factor (cost factor = fossil fuel reduction factor ^PLF)
	On-site Renewables	10	10	Minimum payback period (years), adjusted using electricity cost
		20	20	Maximum payback period (years), adjusted using electricity cost
Investment	Measure Lifetime	20	20	Measure lifetime (years)
	NPV Term (years)	20	20	Net Present Value term (years)
	NPV discount rate (%)	3.00%	3.00%	Net Present Value discount rate (%)
	Social Cost of Carbon ($)	$0	$0	Cost of carbon avoided ($51 per MT is the current OMB guidance)

Recommended Measures		Alternative Measures					
Site	Include In Analysis	Include Alternative	RCx Only	EE Retrofit	Deep Retrofit	Heating Electrification	On-site Renewables
CT	X	X	X				
MA	X	X		X			
NJ	X	X			X		
NY	X	X	X			X	
MD	X	X	X				X
PA	X						
FL	X						
GA	X						
KY	X						
IL	X						
MI	X						
OH	X						
MO-1	X						
MO-2	X						
OK	X						
TX-1	X						
TX-2	X						
MT	X						
UT	X						
CA-1	X						
CA-2	X						
AK	X						
WA	X						
DC-1	X						
DC-2	X						

Figure 3 – Sample *User Input Worksheet*

The *Dashboard Worksheet* shows the results of the analysis in tabular form. Portfolio level aggregate analysis is shown, based on user selections, as well as individual building level analysis.

The following is an example *Dashboard Worksheet* for the 25 GSA office buildings.

Portfolio Level Data		
Total Current	Number of Buildings	25
	Gross Square Feet	13,979,914
	Total Annual Energy Use (mmBTU)	640,144
	Total Annual Emissions (MT CO2e)	66,551
	Total Annual Energy Cost ($)	$16,993,629
Financial	Investment ($)	$51,435,466
	Payback Period (years)	13.2
	NPV ($)	$6,711,923
	Investment/GSF ($)	$3.68
	Investment/MT Emissions ($)	$125
Performance	Annual Cost Savings ($)	$3,908,418
	Annual Cost Savings (%)	23.0%
	Annual Energy Reduction (BTUs)	179,304
	Annual Energy Reduction (%)	28.0%
	Annual GHG Reduction (MT CO2e)	20,546
	Annual GHG Reduction (%)	30.9%

Recommended Measures						Building Level Data													
Site	RCx Only	EE Retrofit	Deep Retrofit	Heating Electrification	On-site Renewables	Investment	NPV	Payback Period	Annual GHG Reduction	GHG Reduction (%)	Energy Use Reduction	Energy Reduction (%)	Energy Cost Reduction	Energy Cost Reduction (%)	Annual Energy Cost Savings	Investment Cost/Tonne	Gross Square Feet	Investment Cost/GSF
CT	X					$ 10,738	$ 273,266	0.6	37	10%	597	10%	19,090	10%	19,090	14	[illegible]	$ 0.06
MA		X				$ 1,360,145	$ 1,876,503	6.3	316	20%	4,994	20%	217,554	20%	217,554	215	[illegible]	$ 1.59
NJ			X			$ 961,837	$ (92,475)	16.5	191	40%	2,553	40%	58,436	40%	58,436	252	[illegible]	$ 14.39
NY	X			X		$ 37,865	$ 1,001,496	0.5	128	10%	1,555	10%	69,861	10%	69,861	15	[illegible]	$ 0.23
MD	X				X	$ 762,884	$ 1,741,756	4.5	594	20%	5,965	14%	168,351	13%	168,351	64	[illegible]	$ 1.05
PA		X			X	$ 2,865,092	$ 753,984	11.8	1,356	30%	9,391	26%	243,259	26%	243,259	106	[illegible]	$ 3.64
FL			X			$ 1,625,670	$ (364,018)	19.2	436	40%	3,783	40%	84,803	40%	84,803	187	[illegible]	$ 6.18
GA		X				$ 156,580	$ 102,255	9.0	82	20%	711	20%	17,398	20%	17,398	95	[illegible]	$ 1.78
KY		X		X		$ 1,726,619	$ (446,398)	20.1	594	26%	7,266	35%	86,051	19%	86,051	145	[illegible]	$ 3.68
IL		X			X	$ 2,958,370	$ 933,837	11.3	1,347	30%	9,433	30%	261,617	30%	261,617	110	[illegible]	$ 3.57
MI	X				X	$ 203,720	$ 400,100	5.0	254	20%	1,122	15%	40,586	17%	40,586	40	[illegible]	$ 1.60
OH		X			X	$ 4,483,398	$ 448,158	13.5	2,364	28%	20,878	26%	331,478	29%	331,478	95	########	$ 3.05
MO-1			X		X	$ 8,930,464	$ (2,117,806)	19.5	4,642	50%	22,075	50%	457,918	50%	457,918	96	########	$ 7.87
MO-2		X			X	$ 4,669,448	$ 2,114,061	10.2	2,302	30%	15,919	26%	455,958	27%	455,958	101	########	$ 3.77
OK		X			X	$ 294,016	$ 69,078	12.0	142	28%	1,295	26%	24,406	29%	24,406	104	[illegible]	$ 1.86
TX-1		X		X		$ 2,070,072	$ (554,753)	20.3	876	30%	11,906	39%	101,853	19%	101,853	118	[illegible]	$ 2.70
TX-2			X			$ 2,620,344	$ (671,139)	20.0	758	40%	6,532	40%	131,017	40%	131,017	173	[illegible]	$ 4.60
MT			X	X		$ 1,355,195	$ (938,554)	48.4	292	86%	3,468	68%	28,005	34%	28,005	232	[illegible]	$ 14.04
UT		X		X		$ 1,952,031	$ (1,013,498)	30.9	576	37%	8,152	41%	63,084	19%	63,084	169	[illegible]	$ 4.98
CA-1	X			X		$ 1,980,179	$ (2,537,515)	(52.9)	507	61%	8,143	54%	(37,462)	-10%	(37,462)	195	[illegible]	$ 5.60
CA-2		X				$ 1,365,386	$ 1,434,930	7.3	307	20%	5,173	20%	188,225	20%	188,225	223	[illegible]	$ 2.43
AK		X		X		$ 2,662,338	$ (1,112,387)	25.6	586	39%	6,483	32%	104,181	26%	104,181	227	[illegible]	$ 7.58
WA		X				$ 2,052,474	$ 1,762,572	8.0	491	20%	7,442	20%	256,431	20%	256,431	209	[illegible]	$ 2.37
DC-1		X				$ 1,715,442	$ 1,687,417	7.5	530	20%	5,623	20%	228,726	20%	228,726	162	[illegible]	$ 2.68
DC-2		X				$ 2,615,161	$ 1,961,055	8.5	840	20%	8,845	20%	307,594	20%	307,594	156	[illegible]	$ 3.21

Figure 4 – Sample *Dashboard Worksheet*

The *Emissions Waterfall Worksheet* includes a standard figure showing the Scope 1 (related to fossil fuel use) and Scope 2 (related to electricity use) emissions reductions, or increases, for each recommended decarbonization measure.

The following shows a sample *Emissions Waterfall Chart* for the 25 GSA office buildings.

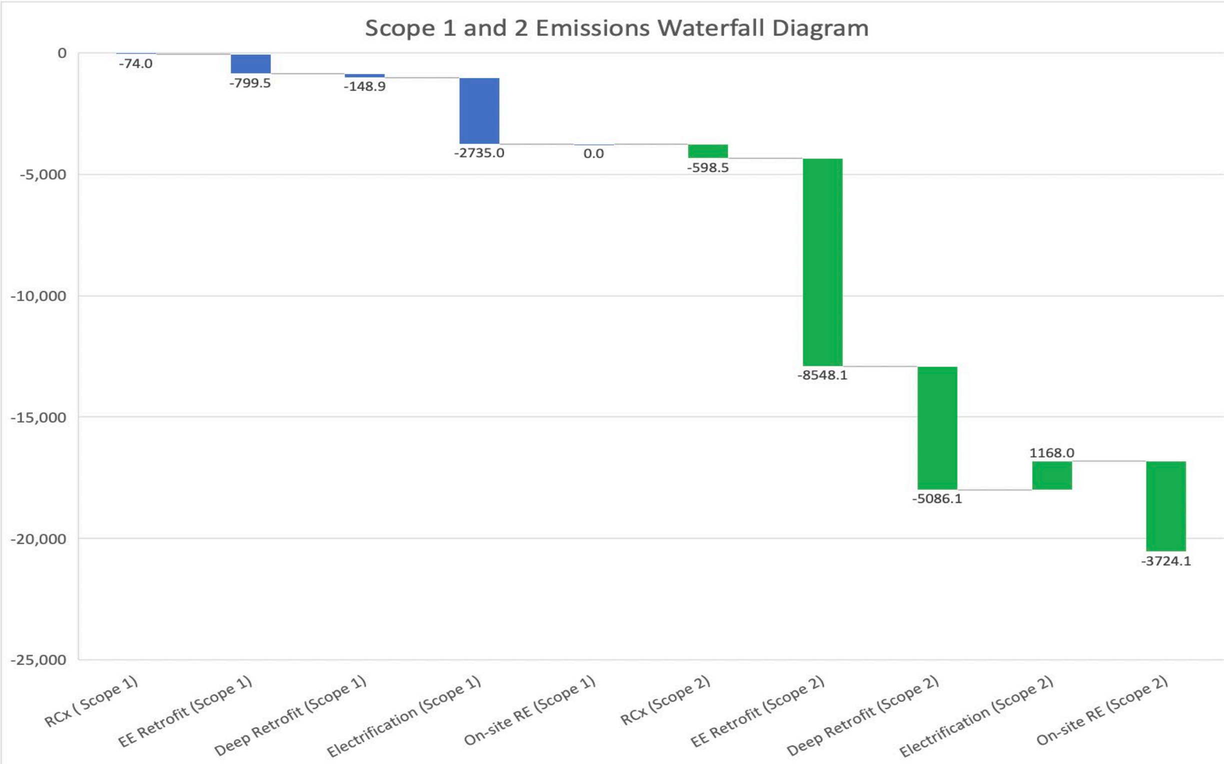

Figure 5 – Sample *Emissions Waterfall Chart*

Supplemental Analysis

The output data from the *Dashboard Worksheet* can be easily copied into another worksheet to perform additional analyses such as ranking buildings based on total emission reductions, cost per emissions avoided, payback, net present value (NPV), or building size. These supplemental analyses can be used to further adjust the building prioritization based on additional criteria. Additional charts can also be created to visualize and communicate the analysis results. In a production version of the tool, these data sorts and information display options should be available as standard user selections.

The following shows a sample chart of the cost per metric ton of avoided emissions for the 25 selected GSA office buildings. This type of analysis could be used to optimize measure selection from an economic perspective, by modifying high cost recommended measures.

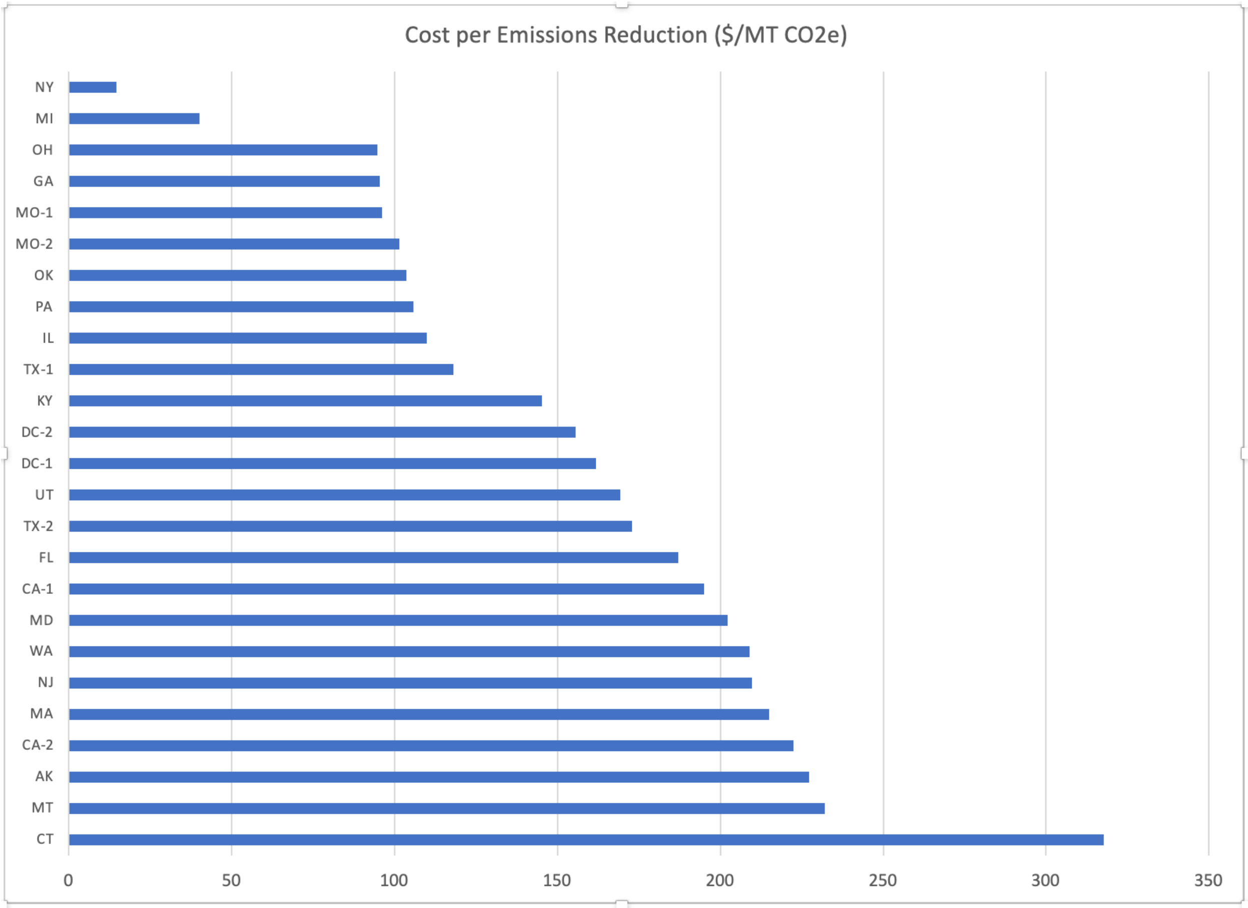

Figure 6 – Sample *Cost of Avoided Emissions Chart*

Potential Tool Enhancements

One potential future enhancement of the proposed BDS tool is to provide an option to use projected future grid emissions factors in portfolio screening and analysis. A "one-off" version of the prototype BDS tool was developed using the Cambium database created by the National Renewable Energy Lab (NREL) – specifically, 2032 Cambium mid-case long-run marginal emissions rate (LRMER) to determine the potential impact. Using the GSA 25 office building example dataset and 2032 projected emission factors, the number of buildings prioritized for electrification increased from 8 to 10 and those prioritized for on-site renewables decreased from 6 to 1. Another potential enhancement would be to estimate annual building emissions and reductions based on projected regional decarbonization trends of the electric grid.

Appendix C: Building Decarbonization Implementation Tool Concept Specification

INTRODUCTION

The Green Building Advisory Committee's Federal Building Decarbonization Task Group (FBDTG) also focused on helping identify means to accomplish efficient and cost-effective decarbonization measures for the majority of existing federal facilities. Specific emphasis was placed on smaller to medium sized facilities that usually do not get improved with typical energy saving procurement processes. Whereas the proposed Building Decarbonization Screening (BDS) Tool (Appendix B) is aimed at helping GSA and other agencies prioritize buildings for decarbonization actions at the portfolio level, the Building Decarbonization Implementation Tool Concept Specification was drafted to answer the question of how to proceed once buildings have been identified, using more detailed building-specific information.

PROBLEM STATEMENT

Existing federal buildings vary in terms of age, condition, historic value, envelope efficiency, mechanical system replacement cycles, regional grid fuels, and many other factors. There are some guiding principles that transcend this problem of determining a logical means to decarbonize existing operations. It's valuable to understand what the best solution set could be and where returns on investment begin to diminish.

For smaller buildings with packaged equipment, technical experts are rarely available to support initial project development. In this case, data collected from basic building audits can be used to determine standard decarbonization retrofit packages, timelines, and estimate approximate project costs and impacts in a building decarbonization roadmap. The roadmap focuses on implementing enabling steps that allows for future optionality as technology evolves. This framework allows the federal agency or building manager to act now instead of waiting for better technology and potentially renewing a fossil-fueled powered energy system for another life cycle. Measures and sequencing will be highly specific to any given building, but federal agencies can use this bucketed framework to place actionable projects in context of an overarching decarbonization roadmap.

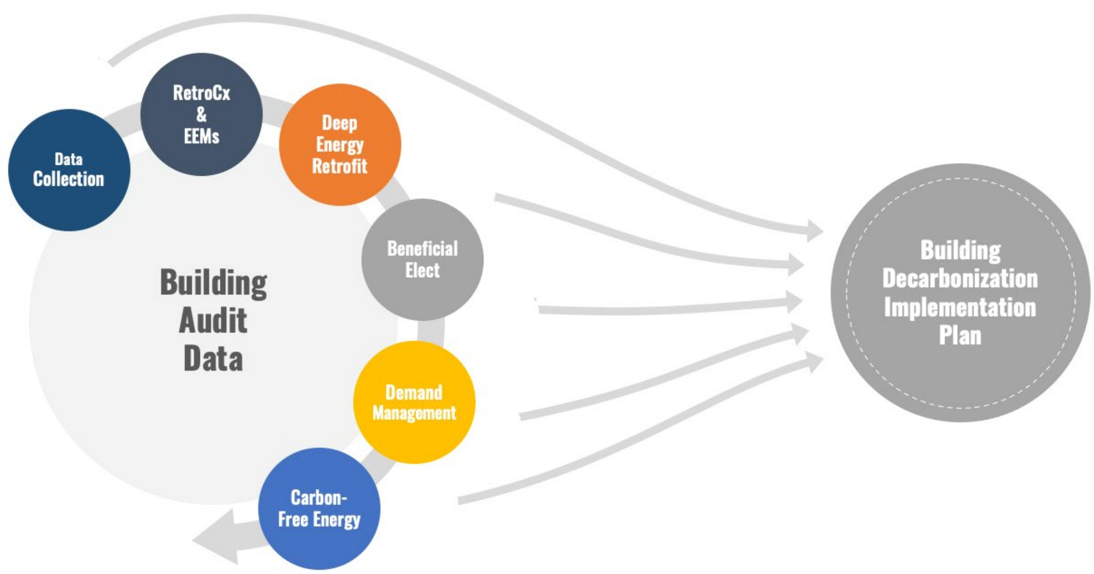

Figure 1. Building Decarbonization Implementation Concept

The FBDTG developed a proof of concept for an online tool that could be used to develop individual building decarbonization roadmaps. The Committee proposes that GSA recommend to DOE the use of this prototype tool to extend the capabilities of DOE's [Building Energy Audit Template tool]() to automatically generate standard retrofit packages, including energy optimization, electrification, demand management, low-GWP refrigerants, and low-carbon energy supply. With the recommended new features, the Audit Template tool would define decarbonization plans with improvements phased over time to coincide with major equipment replacements or other critical events.

AUDIT TEMPLATE TOOL BACKGROUND

The current Audit Template is a free, web-based tool for entering building energy and water audit data, performing data validation, exporting data in various formats, and submitting data to cities that have local energy audit ordinances. The Audit Template follows ASHRAE Standard 211 "Standard for Commercial Building Energy Audits". It is intended to maximize audit data utilization and value through standard formatting, automated error checking, and integration with other DOE tools (e.g., Asset Score, Building Sync and SEED). It produces an audit data report which includes calculated tables outlining building energy use and energy efficiency measures.

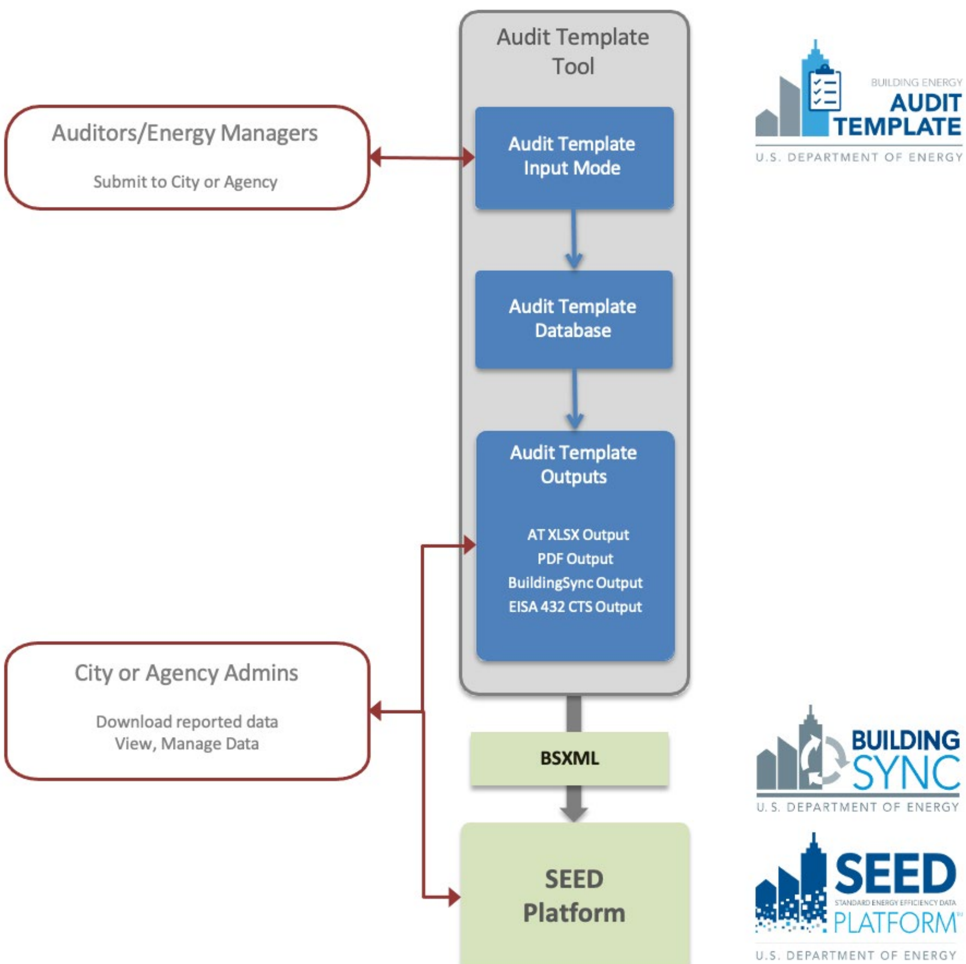

Figure 2. Current Audit Template Workflow

SEQUENCING GUIDANCE

This following guidance should be built into the tool on how to approach the development of a long-term plan for a building's decarbonization retrofits to achieve operational carbon neutrality.

Ideal Sequencing

Building systems impact each other. Priority should be given to energy efficiency before fuel switching alternatives are considered for reducing GHG emissions. The first priority should be to reduce the building component's energy use, no matter its fuel source. Once the building energy performance has been optimized, fuel switching, and on-site/off-site renewable energy generation should be evaluated to accomplish operational carbon neutrality.

The timing of construction projects can impact installation costs and disruption. Using incentives or rebates that may be available in the short term frees up capital to invest in incremental improvements further into the future.

Poor sequencing misses the opportunity to combine efforts or does not address interactive building systems holistically. A long-term plan allows for coordinated efforts that will increase the efficiency of implementing a deep energy retrofit.

Space Turnover

When tenants vacate spaces, building owners and staff have the opportunity to make energy efficiency improvements in addition to repairs or aesthetic upgrades. This includes air sealing in places that may be hard to reach when spaces are occupied, standardizing equipment, and replacing or upgrading equipment such as air conditioners or terminal units.

Existing Building System Optimization

Prioritize implementation of measures that reduce heating and cooling loads, such as air sealing, heating system controls and distribution repairs, and lighting and appliance upgrades as soon as feasible. By reducing heating and cooling needs, these measures allow for purchase of smaller and less expensive equipment when the time comes for future system upgrades, as well as tending to improve comfort and health for occupants through improved air quality, temperature control, and safety.

The energy cost savings from reduced heating and cooling loads in the short term can also be applied toward capital expenses for future, larger-scale measures.

Existing Building System End of Life

Upgrades to building systems are often most cost-effective at the time when major equipment is at the end of its useful life and due for replacement. It is recommended to capitalize on these times where investments are already required to upgrade key systems or choose additional systems that can easily be completed at the same time. While the exact time for replacement may not be known, it is good practice to plan around the equipment's expected useful life. This also helps minimize the risk of expensive emergency repairs or replacements.

There may only be one opportunity between now and 2035 to take advantage of the replacement systems, such as heating and cooling plants, so it is recommended to plan well in advance of these time windows to develop the strategy that will maximize the efficiency and cost-effectiveness of improvements.

RECOMMENDED CAPABILITIES FOR DECARBONIZATION ASSESSMENTS

The following capabilities added to Audit Template would allow it to provide a high-level roadmap of prioritized decarbonization measures to guide the agency or facilities manager on future building decisions that impact decarbonization goals.

Input Data

The current input data collection allows automatic import of data from ENERGY STAR Portfolio Manager data and monthly metered data for each utility. Additional input data capability proposed for decarbonization would include:

- Prioritization Tool Asset input data (refer to Appendix B)
- Systems/operations contributing to emissions
- Equipment useful life and year of manufacture
- Potential for using clean energy generated on site
- Utility service provider (to identify grid emissions intensity)
- Additional information on building operational schedules
- Estimated operational GHG emissions (Scope 1 and Scope 2), and emission reduction targets
- Evaluation of solar readiness (space availability for rooftop solar or on-site solar)

Assessment

The purpose for which this tool is proposed is to identify decarbonization measures for efficiency, electrification, and on-site renewable energy as listed in the Output Report section below. That said, the decarbonization measures identified are not intended to be actionable and final. They would still require assessment for on-site applicability and a detailed evaluation for savings and cost. The packages defined are intended to provide an initial assessment of suggested approaches to strategic decarbonization of the building based on existing building systems.

Output Report

Under this suggested approach, Audit Template could create a PDF report that would include all the buildings data reported. The report is proposed to include a list of the identified potential decarbonization measures prioritized into the following packages targeting different scenarios towards operational GHG emission reductions:

- Package 1 – Deep Optimization (Retro-commissioning)
- Package 2 – Energy Efficiency Measures
- Package 3 – Deep Energy Retrofit
- Package 4 – Beneficial Electrification, Demand Management, and Low GWP Refrigerants
- Package 5 – Low Carbon Energy Supply and Offsets

The report is also proposed to show the following:

1. Show potential range of ***annual site energy use reductions*** for the building and for each package using a bar graph. Annual site energy use would be for each energy supply, shown in kBTU/SF-yr. Estimates should include total reductions and percentages.

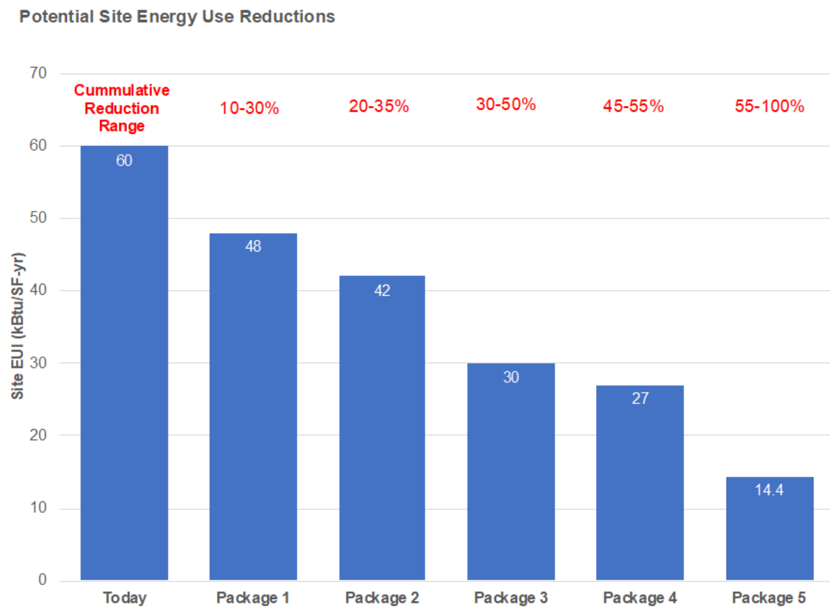

Figure 3. Sample Site Energy Use Reduction Chart

2. Show potential range of ***operational annual GHG emission reductions*** for the existing building and for each package using a bar graph, shown in metric tons of carbon dioxide equivalent (CO_2e) . Estimates should include total reductions and percentages.

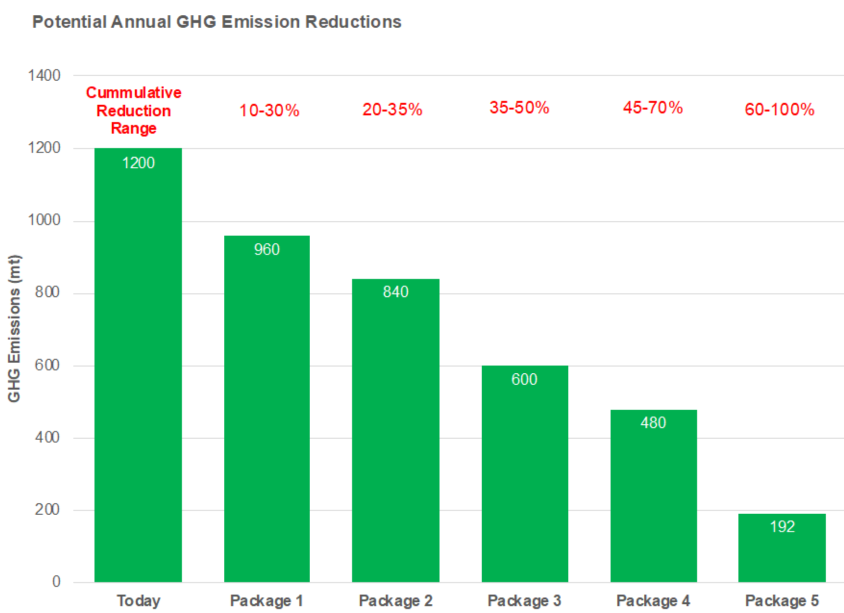

Figure 4. Sample GHG Emission Reduction Chart

3. Provide *approximate* payback period for each package.
4. Provide a list of the specific measures included with each package along with descriptions of the measures and health and comfort impacts, when appropriate. A sample is shown in Figure 5.

Package 1 – Deep Optimization Measures

Measure	Description	Health & Comfort
1-E1	Replace worn out weather stripping at exterior doors: Weather stripping helps to reduce the amount of outside air infiltration into the space between the door and the frame. Over time, this weather stripping develops gaps due to normal wear and tear. By replacing worn out weather stripping, energy savings can be realized due to reduced infiltration and, thus, reduced load on the building HVAC equipment.	+
1-E2	Reduce envelope leakage: Energy savings can be achieved by identifying significant air leaks in the building envelope and sealing them. Specific methods of sealing will vary depending on the component(s) being sealed. In general, large gaps should be sealed with structural material before applying caulk. Tools to help identify air leaks include as-built drawings and an infrared camera.	+
1-L1	Calibrate exterior lighting photocells: Photocells that are out of calibration could be causing energy waste or unsafe conditions. If the lights are operating beyond nighttime hours, when they don't need to be operating, energy is being wasted.	
1-M1	Re-enable supply air temperature reset: For multi-zone air systems, whether CAV or VAV, automatically changing the supply air temperature setpoint to better match the needs of the zones is typically more energy efficient than maintaining a constant setpoint, due to reduced amount of zone reheat (simultaneous heating and cooling). The supply air temperature setpoint is typically reset based on an indication of zone demand - e.g., average difference between zone temperature and zone temperature setpoint.	
1-M2	Test and fix chilled and heating water coil valves: Water control valves are a common component of a facility's HVAC system. These valves are typically either open/closed, or modulating. Chilled and heating water systems usually include water control valves as a means of varying flow through a heat exchanger (coil) in response to demand. The actuators for these valves should have sufficient seating force to close the valve completely when commanded to do so against the system's pressure. Over time, valves and actuators can degrade to the point that they are no longer capable of closing completely. When this happens, a small amount of water can leak by to the coil, and this can create an unnecessary heating or cooling load on the system which results in energy waste. More specifically, simultaneous heating and cooling could be taking place. Periodically testing the valves and actuators can identify leaky valves, and corrective action can then be determined and conducted to eliminate the related energy waste.	+
1-M3	Implement a night purge cycle: A night purge cycle is a method of cooling the building at night using 100% outside air (no mechanical cooling), to pre-cool the building for the next day. The night purge cycle typically compares outside air temperature to average indoor temperature and operates for a couple of hours just before the occupied period when the conditions are beneficial.	+

Figure 5. Sample Measure Output Format

5. Offer options for users to tailor results based on building knowledge and their own assessments of feasibility of implementation, etc.
6. Include a building system replacement timeline based on energy audit input data and using ASHRAE equipment life expectancy database.
7. Include Building decarbonization sequencing guidance.
    a. Ideal sequencing
    b. Space turnover
    c. Existing building system optimization
    d. Existing building system end of life

PACKAGE DESCRIPTIONS

This following describes four proposed decarbonization packages that could be available using the expanded Audit Tool with decarbonization functionality.

Package 1 – Deep Optimization (Retro-commissioning)

How a building is controlled, operated, and maintained has a significant impact on energy use. Even buildings with energy efficient systems fall out-of-tune as buildings age and adjustments are made without fully considering energy impacts. Retro-commissioning (RetroCx) measures can improve efficiency of the building envelope, lighting, HVAC, and control systems.

RetroCx seeks to optimize the performance and operation of building systems. RetroCx is typically more appropriate for medium and larger buildings and those with more complex HVAC and energy systems.

Package 2 –Energy Efficiency Measures

Standard energy efficiency measures provide cost-effective and low-risk efficiency upgrade options for incremental capital upgrades to the building. Standard retrofit measures include equipment, system, and assembly retrofits. They are different from the RetroCx process, which alters a building's O&M strategies based on an in-depth investigation, and from deep energy retrofits, which simultaneously retrofit equipment on multiple building systems using an integrated design approach. Standard retrofits are often strategically staged to maximize efficiency and cost-saving gains.

Package 3 – Deep Energy Retrofit

Given the age and condition of assets in the federal governments portfolio, many will require major retrofits over the coming decades, to repair or replace aging building components, systems, and equipment, restoring the assets to a good condition and providing high-quality accommodations for occupants.

As stated in the U.S. Department of Energy's Advanced Energy Retrofit Guide:

> *A deep retrofit project provides an opportunity for a building owner to reduce energy consumption significantly. Deep retrofit projects combine many O&M and standard retrofit measures in an integrated whole-building design approach. These projects affect multiple building systems and assemblies (e.g., envelope, lighting, and HVAC) and the retrofit of each system and assembly must be designed in close consideration of the other retrofits. The upfront cost of a deep retrofit may be difficult to justify on the basis of energy and maintenance cost savings alone. However, the business case is much easier to make when planned upgrades and the avoided cost of equipment and assembly replacements are taken into account.*

This package is proposed to include measures to retrofit the building enclosure and other building systems in a way that results in a high-performance building. This group of measures should result in very low post-retrofit energy use and also provide benefits to building durability, comfort, and indoor air quality (IAQ). By taking a holistic approach, the measures in this package address all major energy and water loads – envelope, space conditioning, lighting, plumbing, appliances, plug and process loads, and energy recovery.

Package 4 – Beneficial Electrification, Demand Management, and Low GWP Refrigerants

Buildings use various energy and fuel sources to deliver heating and domestic hot water, based on factors such as age, location, and purpose. Heating sources used by buildings include electricity, natural gas, light fuel oil, propane, and district heating. In locations with low-carbon electricity grids, switching from fossil fuel to electric heating can yield significant carbon emissions reductions. Fuel switching measures generally involve the replacement of gas-fired heating furnaces, boilers, water heaters, and distributed equipment with high-efficiency electric heat pump alternatives.

Demand management measures reduce electrical load during periods of high demand and electricity prices or provide compensation for assisting with grid reliability and power quality. These measures could include energy storage options and metering and controls improvements to be responsive to grid signals.

Low global warming potential refrigerant (GWP) alternative measures could be provided based on the refrigeration equipment energy audit data. These measures should focus on replacement equipment low-GWP refrigerants.

Package 5 – Low Carbon Energy Supply and Offsets

This package would include measures to take advantage of on-site renewable energy. On-site measures include photovoltaic, solar thermal, geothermal, and/or wind energy generation on the building and other on-site structures and grounds. Fuel option measures could include renewable gas (RNG) and green hydrogen.

Appendix C Attachment: Sample Building Decarbonization Measures

Early Project Development

Review Opportunities

1. Review facility condition indicators to identify any deferred maintenance projects which could be integrated into the current project.
2. Take advantage of planned HVAC equipment replacements to incorporate complementary building decarbonization/resiliency measures.
3. Review the opportunities for passive design strategies when evaluating strategies for decarbonization
4. Review the opportunities for the use of low-carbon building materials, and especially the use of reused, remanufactured, recycled and locally sourced materials.
5. Evaluate current equipment load trend data and compare with current equipment capacity to identify opportunities for downsizing during replacement.
6. Balance priorities of healthy indoor air quality, resilience, and simplicity alongside efficiency when selecting system options to evaluate.
7. Review structural capacity and roof condition for the ability to add solar panels
8. Assess building automation system and controls to assess whether new controls need to be added to building

Owner Project Requirements (OPR)

1. Develop an operational energy and embodied carbon OPR that covers program-specific performance criteria.
2. Identify a gross EUI target for building.
3. Develop/reset criteria for occupancy, set points, control system and meters

Modeling

1. Conduct a whole-building energy model and life-cycle cost analysis to evaluate measures required to meet compliance targets, the EUI target, and an optimal renewable energy investment target.
2. Use lifecycle cost analysis to determine the most cost-effective carbon reductions which meet financial return targets.
3. Include reduced maintenance costs and replacement reserves (less equipment running less frequently resulting in longer life span); the value of being insulated from future power rate increases, the value of resiliency, and the increase in the value of the building when all of these savings are capitalized and compared to the additional cost of the EE improvements.
4. Evaluate the economic viability of distributed PV, wind, battery storage, CHP, and thermal energy storage
5. Estimate energy savings and carbon reductions for all potential improvement measures to determine which deliver the greatest carbon reductions at the lowest cost.
6. Test whether investing in reducing building air infiltration will result in meaningful energy savings
7. Modify list of efficiency measures listed below after suggested measures have been tested

for their contributions to lowering energy use. Unless there are other reasons to adopt cited measures, only select those that will increase building efficiency as proven in the energy model.

RetroCx Measures

Lighting

1. Calibrate exterior lighting photocells

Envelope

1. Replace worn out weather stripping at exterior doors
2. Reduce envelope leakage

HVAC Air Side

1. Revise air filtration system
2. Increase duct system efficiency
3. Execute complete HVAC duct cleaning services with before/after photo documentation reports
4. Calibrate air sensors
5. Re-enable supply air temperature setpoint reset
6. Reduce HVAC equipment runtime, close outside air damper during unoccupied periods
7. Remove unused inlet guide vanes from supply fan inlet
8. Repair airside economizer and reduce economizer damper leakage
9. Implement a night purge cycle

HVAC Water Side

1. Inspect chiller and cooling tower, clean as needed
2. Test and fix chilled and heating water coil valves
3. Inspect and repair damaged pipe insulation
4. Calibrate water sensors
5. Re-enable chilled water supply temperature setpoint reset
6. Shut down cooling plant when there's no cooling load

Other

1. Implement daytime custodial services
2. Consider conducting blower door tests to check air infiltration and efficacy of tightening building envelope for energy savings

Energy Efficiency Measures

Envelope

1. Conduct blower door testing, address infiltration with air sealing
2. Add exterior window film or window inserts
3. Replace windows. Consider replacements with double or triple-glazed window systems that are operable to increase passive survivability and increase occupant comfort where possible
4. Add exterior window shading and light shelves. Use daylight modeling to study where and how to add these devices
5. Add wall insulation
6. Add roof insulation
7. Add a vestibule
8. Install cool roof

Lighting

1. Retrofit interior fixtures to reduce lighting power density with lighting controls
2. Install occupancy sensors to control interior lighting
3. Add daylight harvesting
4. Retrofit exterior fixtures to reduce lighting power density, and add exterior lighting control, address light pollution

Plug & Process Loads

1. Add advanced on/off control of office equipment
2. Purchase energy efficient office equipment
3. Control elevator cab lighting and ventilation

HVAC Air Side

1. Ceiling fans can be a low-cost / low energy way of moving air across the body and reducing perceived temperature 3-4 degrees
2. Evaluate utilizing sealed concrete flooring where appropriate as opposed to carpet can enable us to take advantage of the free thermal mass to absorb human and computer heat during the warm summer days while further reducing perceived temperature by putting the occupants in contact with a cool material (concrete floor). It also eliminates the replacement reserve needed for future carpet replacement further reducing operating costs.
3. Add optimum start strategy for HVAC equipment
4. Revise airside economizer damper control
5. Widen zone temperature deadband (replace pneumatic thermostats)
6. Lower VAV box minimum flow setpoints (rebalance pneumatic boxes)
7. Widen zone temperature deadband, add conference room standby control (upgrade to DDC zone control)
8. Lower VAV box minimum flow setpoints, reset duct static pressure (upgrade to DDC

zone control)

9. Add demand-controlled ventilation
10. Replace supply fan motor and Variable Frequency Drive (VFD)

HVAC Water Side

1. Shut down heating plant when there's no heating load
2. Increase efficiency of condenser water system
3. Increase efficiency of condenser water pumping system
4. Change cooling plant pumping system to variable primary
5. Replace cooling and heating plant pump motors
6. Add a VFD to one chiller
7. Add waterside economizer
8. Add chilled water plant heat recovery
9. Replace boilers and change heating plant pumping system to variable flow primary
10. Replace boiler burners with modulating burners
11. Increase the efficiency of the tenant server room pumping system
12. Cool the server rooms with transfer air instead of mechanical cooling
13. Increase the efficiency of the tenant server room cooling units

Building Automation

1. HVAC energy optimization using ASHRAE Guideline 36 sequences
2. Automate SHW system
3. Automated water irrigation

Water

1. Low flow plumbing fixtures
2. Rainwater capture and storage
3. Increase efficiency of service hot water system
4. Replace landscaping with native, drought tolerant plants where appropriate and eliminate all grass lawns (mow & blow is a large carbon contributor).

Other

1. Retrofit electric transformers with higher efficiency models

Deep Energy Retrofit

A deep energy retrofit is a whole-building analysis and construction process that achieves much larger energy cost savings than those of individual energy efficiency measures.

Beneficial Electrification Measures

HVAC

1. Replace gas-packaged heating equipment using high efficiency heat pumps
2. Replace packaged space cooling equipment with high efficiency, low GWP cooling equipment including variable refrigerant flow (VRF) or packaged rooftop units.
3. Replace fossil fuel hot water heating with heat pumps and/or heat recovery chillers - consider size based on capacity required for handling 70-80% of annual heating consumption
4. In very cold climate zones, consider using hybrid heating equipment (dual fuel rooftop units) to provide efficient and resilient operation.
5. Evaluate opportunities to use waste heat

Service Hot Water (SHW)

1. Replace fossil fuel domestic hot water (DHW) heaters with heat pump domestic hot water heaters
2. Consider using waste heat from HVAC system to pre-heat domestic hot water (also reduces water consumption from cooling towers)

Demand Side Management Measures

Energy Storage

1. Battery energy storage
2. Thermal energy storage (hot, chilled, or condenser water)
3. Building mass thermal storage
4. Phase change materials

Metering and Controls

1. Automated building controls with the ability to integrate distributed energy resources and EV charging and provide automated demand response and flexibility services.
2. Energy sub-metering, energy information management systems and automated fault detection and diagnostic systems.
3. Install EV charging stations with the ability to provide smart charging and demand flexibility.
4. Optimize building-grid integration for resilience, energy arbitrage and grid services (spinning reserves, frequency regulation)
5. If replacing parking lot asphalt, evaluate running 4" electrical conduit to 3-4 strategic locations to accommodate future EV charging stations as fleets convert to EV. This accommodates future charging stations (which are not inexpensive) as needed.

Renewable Energy Measures

On-site

1. Solar photovoltaic (PV) panels on building and other on-site structures and grounds. Ensure PV array has internet access for monitoring to ensure any issues with inverters strings are easily tracked and maintenance issues can be handled quickly (considering all cybersecurity requirements).
2. Order one to two inverters as attic stock to prevent long lead times for maintenance and loss of generation capacity if inverters shut down
3. Building integrated PV (roof, façade, windows)
4. Solar thermal heating
5. Geothermal energy