U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Federal Campuses Handbook for Net Zero Energy, Water, and Waste

Prepared for the U.S. Department of Energy Federal Energy Management Program

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August 2017

FEMP Federal Energy Management Program

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Acknowledgements

The project team would like to thank the U.S. Department of Energy's (DOE) Federal Energy Management Program (FEMP) for its leadership in the development of this handbook. Rachel Shepherd and Nic Baker were critical to the success of this document through their technical leadership and review of the product, and their ability to bring together a variety of stakeholders to contribute to the product. Elena Meehan of SRA International, Inc. was a key member of the FEMP team ensuring that we addressed the comments from the reviewers. The Department of Defense (DOD), General Services Administration (GSA), Building Technologies Office, and the National Renewable Energy Laboratory provided reviews of the technical content that were valuable in the framing of the document. Reviewers included: Tim Unruh (DOE), Lieutenant Colonel Travis Leighton (DOD), Kristine Kingery (DOD-Army), Paul Volkman (DOD-Army), Marc Kodack (DOD-Army), Wanda Johnsen (DOD-Army), Kevin Kampschroer (GSA), Kinga Porst (GSA), Natalie Huber (GSA), and Lance Davis (GSA). At the Pacific Northwest National Laboratory (PNNL), in addition to the authors that contributed to the technical content, Delphine Appriou developed the graphics and Supriya Goel provided the technical peer review. The project team greatly appreciates the contributions made by the organizations and individuals that provided input to this document.

The PNNL information release number for this report is: PNNL-26636.

Abbreviations and Acronyms

AD	Anaerobic digestion
ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers
BMP	best management practice
Btu	British thermal unit
CFR	Code of Federal Regulations
DHW	domestic hot water
DOE	U.S. Department of Energy
EERE	Energy Efficiency and Renewable Energy
EISA	Energy Independence and Security Act of 2007
FEMP	Federal Energy Management Program
GSF	gross square feet
HVAC	heating, ventilation, and air conditioning
LED	light-emitting diode
LFG	landfill gas
MMBtu/sf	Million British thermal units per square foot
MSW	Municipal Solid Waste
O&M	operations and maintenance
PNNL	Pacific Northwest National Laboratory
REC	Renewable energy certificates
U.S.	United States
WTE	waste-to-energy

Contents

1 Introduction

Net zero energy buildings have been a growing target in the federal and private sector. For the commercial and residential building sectors the International Living Future Institute has developed a building certification system for net zero buildings called the Living Building Challenge. Over 300 buildings have been registered in 29 countries, and 43 case studies of certified buildings are available to the public.[1] The World Green Building Council and Architecture 2030 launched a project in 2016 focused on net zero carbon buildings with the goal of all buildings being net zero carbon by 2050.[2] And non-profit organizations, such as the Zero Energy Project, are focused on increasing the number of residential properties that achieve net zero goals along with the and private sectors.[3]

In 2015, the Department of Energy's (DOE) Energy Efficiency and Renewable Energy (EERE) office defined a zero energy campus was defined as "*an energy-efficient campus where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy*." The definition was developed through the survey of existing publications, interviews with subject matter experts (SMEs), and a public comment period. The definition report emphasized that zero energy buildings use all cost-effective energy efficiency measures and then include renewable energy systems that address the power needs, noting that reduced energy consumption makes it less expensive to achieve the zero energy goal. The goal of reducing energy consumption includes integrated design, energy efficiency measures, reduced plug load, and occupant behavior change programs.[4]

This handbook is focused on applying the EERE definition to federal sector campuses. The Pacific Northwest National Laboratory (PNNL), commissioned by DOE's Federal Energy Management Program (FEMP), prepared the handbook incorporating inputs from the Department of Defense, General Services Administration, and the National Renewable Energy Laboratory.

In the federal sector, the net zero efforts include net zero **energy**, **water**, and **waste**. The Federal campuses being addressed in this handbook are owned by the federal government and the occupants are federal employees, and thus do not have an equivalent to building owners or consumers in the commercial and residential building sectors. Federal energy, water, and waste management has a strong history of focusing on minimizing use first and then looking for alternatives to achieve the net zero target. Many energy, water, and waste regulatory

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[1] For information on the Living Future Institute net zero building certification system see: https://living-future.org/net-zero/

[2] For more information on the World Green Building Council see: https://www.environmentalleader.com/2016/07/net-zero-green-building-certification-coming-soon/

[3] For more information on residential net zero energy activities see: http://zeroenergyproject.org/, https://energy.gov/eere/buildings/zero-energy-ready-home, and https://www.wsj.com/articles/builders-new-power-play-net-zero-homes-1421794129

[4] *A Common Definition for Zero Energy Buildings* available online at http://energy.gov/sites/prod/files/2015/09/f26/bto_common_definition_zero_energy_buildings_093015.pdf

requirements and mandates exist that drive the federal sector toward reducing consumption first, then encouraging alternative paths to reducing resource use, impact, and costs. This document offers strategies that are in support of, but are not intended to replace, substitute, or modify any statutory or regulatory requirements and mandates. Following the culture of promoting reduction and efficiency first, the recommended strategies for net zero energy, water, and waste federal campuses are outlined below.

- A net zero energy federal campus reduces overall energy use, maximizes efficiency, implements energy recovery and cogeneration opportunities, and then offsets the remaining demand with the production of renewable energy from on-site sources, such that the campus produces as much renewable energy as it uses over the course of a year.

- A net zero water federal campus minimizes total water consumption, maximizes alternative water sources, minimizes wastewater discharge, and returns water to the original water source such that the annual water consumption is equivalent to the alternative water use plus the water returned to the original water source over the course of a year.

- A net zero waste federal campus reduces, reuses, recycles/composts, and recovers solid waste streams (with the exception of hazardous and medical waste), converting them to resource values, resulting in no waste disposal to landfills or incinerators.

Federal agencies should look to pursue net zero where it helps achieve statutory or regulatory requirements and mandates. Net zero energy, water, or waste will not be feasible for all federal buildings as it may not be life-cycle cost-effective. Federal agency activities that may not be applicable for net zero include:

- An intelligence activity of the United States, and related personnel, resources, and buildings;

- Law enforcement activities of the agency, and related personnel, resources, and buildings;

- Law enforcement, protective, emergency response, or military tactical vehicle fleets of the agency;

- Particular agency activities and buildings where it is in the interest of national security; and

- Buildings outside of the United States unless the head of an agency determines otherwise.

2 Federal Campus Boundaries

Net zero efforts begin with identifying the federal campus boundary. A campus boundary delineates the area that is functionally part of the campus. Simply stated, the boundary is at or within the legal property boundary, ideally including the point of utility interface. To define a federal campus boundary, the property must be owned or managed by the agency, include the buildings that are being targeted for net zero, and can include contiguous property that hosts space, technologies, or systems that contribute to the campus' ability to achieve net zero energy, water, or waste. A campus boundary allows for the buildings and net zero assets on a campus to be aggregated to achieve net zero.

The following figures represent net zero energy, water, and waste boundaries. Figure 1offers a net zero energy boundary condition. The net zero energy boundary could include energy use, on-site renewable energy production, energy storage, delivered energy, and exported energy. The renewable energy certificates (RECs) for the on-site renewable energy must be retained. If the RECs for the on-site renewable energy are sold, they must be replaced.

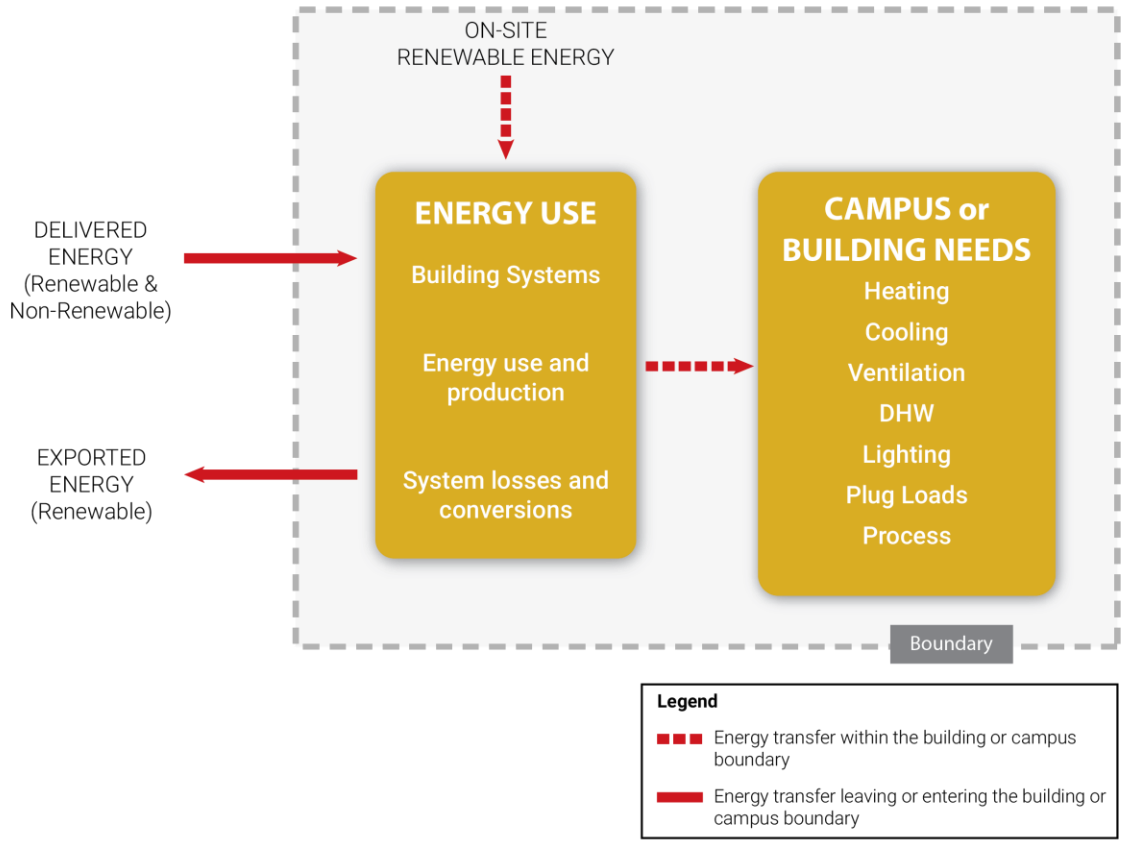

Figure 1. Conceptual depiction of site boundary for energy balance. [5]

[5] Figure was adapted from *A Common Definition for Zero Energy Buildings* available online at http://energy.gov/sites/prod/files/2015/09/f26/bto_common_definition_zero_energy_buildings_093015.pdf

DHW refers to domestic hot water

Figure 2 offers a net zero water boundary condition. The net zero water boundary could include potable and non-potable water use, on-site alternative water sources, freshwater supply, alternative water supply, and water returned to the original water source. If the campus is not within the watershed or aquifer of the original water source, then returning water to the original water source will be unlikely. In those cases, achieving net zero water would depend on alternative water use.

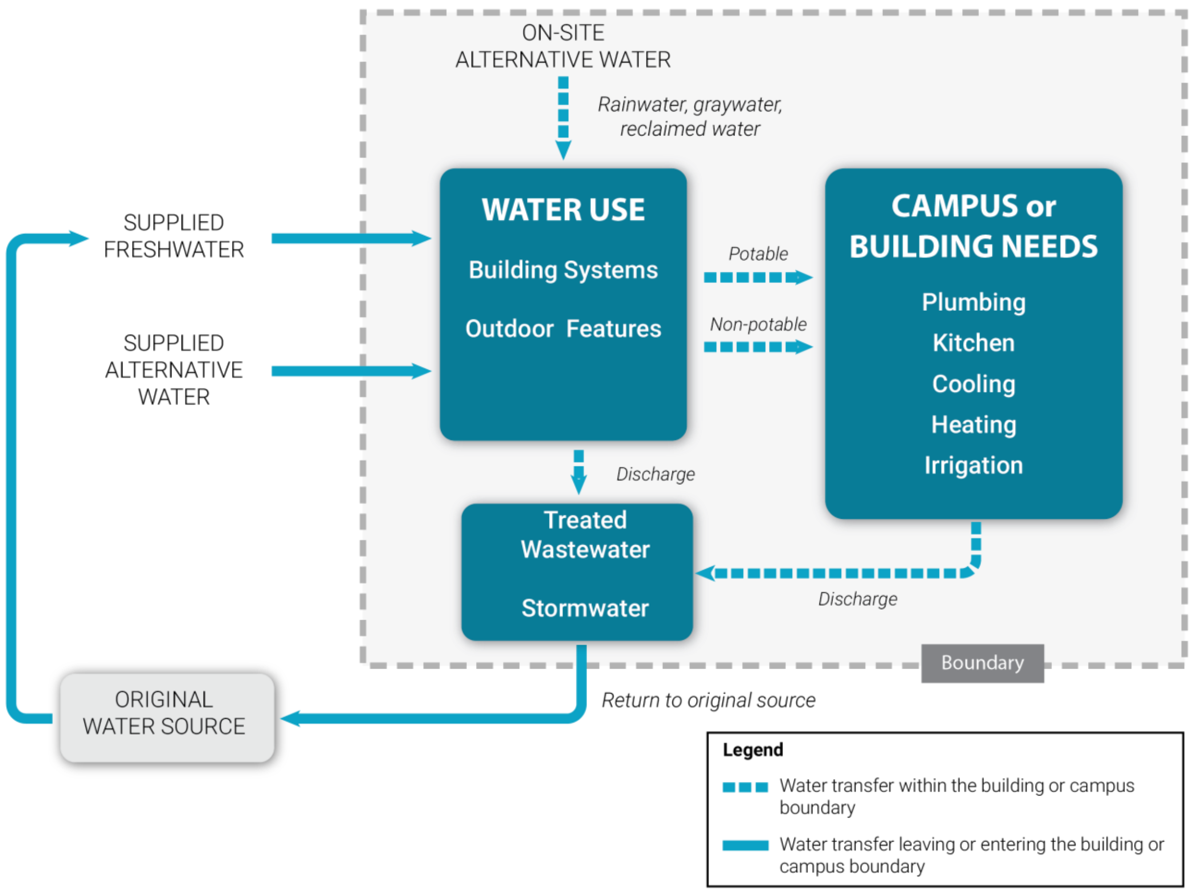

Figure 2. Conceptual depiction of site boundary for water balance.

Figure 3 offers a net zero waste boundary condition. The net zero waste boundary could include material use and waste generation, on-site reuse and compost centers, green procurement, and partnerships with entities to recycle, compost, reuse, and generate energy through waste-to-energy (WTE) plants. Construction and demolition waste is not considered part of the net zero waste boundary.

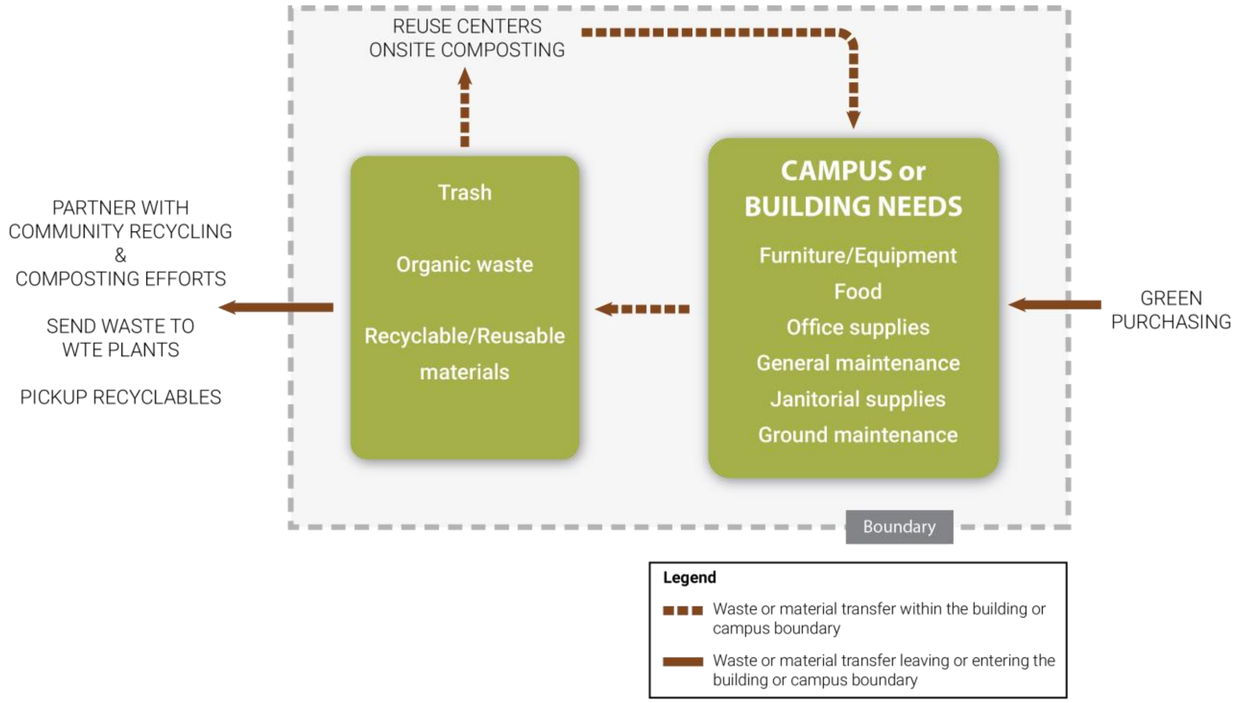

Figure 3. Conceptual depiction of site boundary for waste balance.

3 Net Zero Applications for Federal Campuses

This guidance document provides a net zero application for modernizing a federal campus to achieve net zero. Separate guidance documents address two other net zero applications: designing new net zero federal buildings and renovating existing net zero federal buildings. Each application provides strategies for achieving net zero energy, water, and waste. The campus application addresses connection and coordination, design, construction, and operations considerations. It is recommended that agencies consider the best application to implementing net zero energy, water, or waste for their particular campus. In other words, agencies can determine the boundary that aligns best with their net zero project. Figure 4 provides a visual of the different applications of net zero.

- If considering a net zero federal building, whether new or existing, the area called "*building boundary*" represents a net zero energy building example. Within the boundary line is the building property and the land needed for the on-site renewable energy generation.
- The area called "*designated campus boundary*" represents a net zero water campus. Within that boundary is the set of buildings and water related infrastructure needed for

these buildings to be considered net zero water. There are six buildings inside of that boundary. Depending on whether an agency chooses the number of buildings or square footage, the agency would count all six of those buildings or their total square footage towards meeting the agency net zero target for existing buildings.

- The area called "*property line/campus boundary*" represents a traditional campus boundary definition as it is the actual boundary of the campus. This example is showing elements of a net zero waste campus. If this entire campus was designated as net zero waste, all 17 buildings and their corresponding square footage would count toward the agency's net zero target for existing buildings.

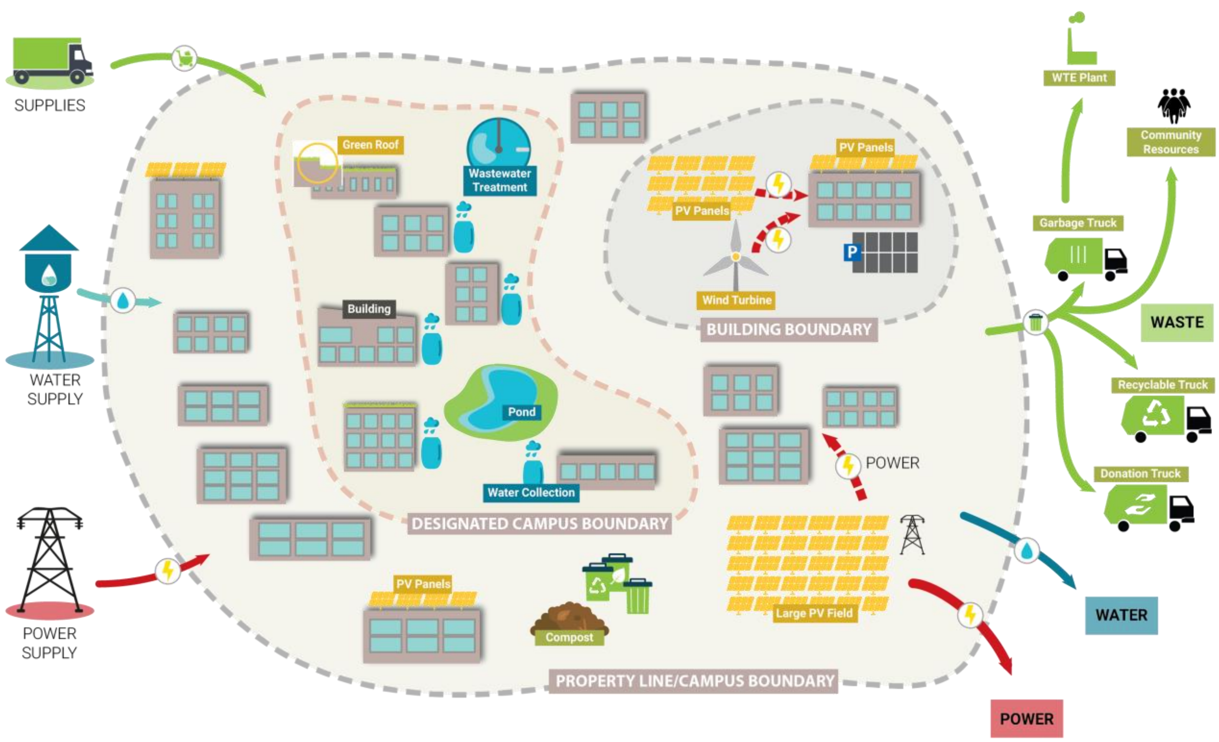

Figure 4. Net Zero Boundary Examples

4 Net Zero Campuses

Campuses allow for coordination of multiple systems across a larger geographical space which may make reaching net zero for a set of buildings more cost-effective. If a campus is determined to achieve net zero, all of the buildings within the designated campus boundary can be counted as meeting net zero.

This section is organized by net zero area in the following order; energy, water, and waste. Each net zero area includes connect and coordinate, design, construction, and operation considerations.

ENERGY

A net zero energy campus minimizes total energy use first through conservation and efficiency and then uses renewable energy to power the campus.

ENERGY Net Zero Connect and Coordinate Elements for Campuses
EA.CC.1 Consolidate functions to reduce building footprint
EA.CC.2 Review/Develop campus master plans and related plans
EA.CC.3 Consider use of central heating or cooling plants and cogeneration
EA.CC.4 Implement campus-wide energy management control systems
EA.CC.5 Coordinate with utility providers

Connect and Coordinate

With a net zero energy campus there is the potential benefit of land availability for renewable energy generation. One of the challenges is to coordinate across the building inventory to meet the net zero objectives, as described by the following elements.

EA.CC.1 Consolidate functions to reduce the building footprint

A net zero energy campus can reduce energy use by consolidating functions and reducing the building footprint. Although this strategy might increase the energy use per square foot of the buildings, it can reduce total campus energy use by closing buildings with inefficient heating, cooling, and lighting systems and/or poor insulation. Consolidating building functions requires the building operators to coordinate with mission leaders to understand the occupant workspace needs and match those needs with available space in more energy efficient buildings.

EA.CC.2 Review/Develop campus master plans and related plans

A net zero energy campus should have a campus master plan that prioritizes projects for implementation and specifies equipment that should be installed in new construction and renovations. A net zero campus master plan should document the net zero energy targets and ensure those targets are systematically implemented. The plan should include energy resiliency solutions, with critical loads and/or buildings identified and coordinated with net zero efforts, design standards for new construction and major renovations, a prioritized list of energy conservation, efficiency, and renewable energy projects with an implementation timeline, a building demolition list to reduce the campus footprint, maps identifying areas for renewable energy generation, and a list of utility infrastructure improvements. The net zero energy campus master plan should consider the expected future load given planned consolidation and demolition efforts and new construction.

EA.CC.3 Consider use of central heating or cooling plants and cogeneration

Central heating and cooling plants can offer energy cost and efficiency savings if designed and implemented properly. District heating and cooling can also be supplied with ground source heat pumps. Evaluate the potential to generate electricity in combination with central plants.

EA.CC.4 Implement campus-wide energy management control systems

Building control systems implemented at individual buildings and renewable energy systems should each be connected to a campus-level energy management control system. This allows all energy data to be viewed in one place, and energy systems can be controlled centrally if needed, such as during emergencies.

EA.CC.5 Coordinate with utility providers

Meet with the electric and thermal energy utility providers to discuss net zero energy goals and potential partnerships, regulations, and potential conflicts of interest. Meeting with utilities early can help identify issues and avoid roadblocks later. Renewable energy system interconnection standards, available incentives, and financing options are some of the topics that will need to be discussed.

Design

A net zero energy campus focuses on reducing energy load first, then supplying renewable energy to match the annual calculated energy use of the campus. Campus design elements that aim at a net zero energy campus are provided below.

ENERGY Net Zero Design Elements for Campuses
EA.D.1 Design buildings to meet or exceed campus master plan expectations
EA.D.2 Measure campus annual energy use
EA.D.3 Design renewable energy system(s) to meet calculated campus annual energy use

EA.D.1 Design buildings to meet or exceed campus master plan expectations

New construction and existing building renovations that impact the net zero energy target should be designed to meet or exceed the campus master plan expectations. Integrated design strategies should be used to identify efficiency opportunities. Strategies that take advantage of building proximities, such as waste heat in one building being recovered for a neighboring building, should be considered.

For net zero energy design, equipment selection should not be based on economic viability alone but should include policy and mission-related considerations, such as energy resiliency. A campus that has a lower demand for energy will be more secure and resilient during emergencies, and will have lower environmental impact on the region, including air quality. An integrated design process should be used to identify efficiency opportunities. Integrated design includes active participation throughout the life-cycle of the design and construction phases by a diverse set of stakeholders such as architects, mechanical engineers, electrical engineers, future building operators, and future occupants.

If new buildings are added to the campus, the new net zero energy building design should aim at maximizing energy efficiency by including a comprehensive suite of energy efficient elements that address siting and building orientation, building envelope, heating, ventilation, and air conditioning (HVAC) equipment, lighting, miscellaneous load, energy recovery, and controls (Table 1). The highest priority for an existing building to become net zero energy should be to aggressively reduce the energy use. The building should be renovated with energy-efficient equipment and a high-performance envelope. For more information on net zero strategies for new buildings, refer to the *Federal New Buildings Handbook for Net Zero Energy, Water, and Waste*.

Table 1. High Performance Design Considerations for New Net Zero Energy Buildings

High performance design options	Considerations
Siting & Orientation	Select the building site and orient the building design to allow for passive solar design, to optimize shading benefits, and allow for on-site renewable energy generation.
Building Envelope	Minimize energy loss and attain appropriate solar gain with air barriers, the window-to-wall ratio, and insulation levels.
HVAC Equipment	Right-size a best-in-class HVAC system with local or zone controls that leverages efficient design elements, including waste heat recovery, if possible. District-level solutions, such as central heating and cooling plants, can provide significant energy efficiency benefits and should be considered where appropriate.
Lighting	Optimize daylighting potential, specify light-emitting diodes (LED) lighting, and use daylighting sensors and lighting controls.
Controls	Use a building control system to monitor and control HVAC systems, lighting, and renewable energy generation systems.
Miscellaneous Loads	Evaluate and understand expected plug and process loads, and then reduce to the maximum extent possible.

Approaches to achieve a net zero energy building through renovations are outlined in Table 2**Error! Reference source not found.**. For more information on net zero strategies for existing uildings, refer to the *Federal Existing Buildings Handbook for Net Zero Energy, Water, and Waste*.

Table 2. Energy Efficiency Strategies for Existing Buildings

Strategy	Considerations
Energy audit	Conduct detailed energy audits to identify energy conservation and efficiency improvement opportunities.
Benchmarking	Benchmark the building's energy performance using ENERGY STAR Portfolio Manager® and use the benchmark information to understand the building's energy performance potential.
Energy modeling	Build an energy model of the building to evaluate the investment value of various conservation and efficiency measures.
Third party financing	Explore a performance contract such as an energy savings performance contract or utility energy services contract where the private sector or utility helps determine potential savings and energy conservation measures.
Control system	Install and use a building automation system to manage building equipment schedules and temperature setting, at a minimum.
Fuel switching	Consider switching between energy types or sources when selecting efficiency upgrades. For example, heat pumps could be powered with renewable electricity rather than natural gas heating systems.

EA.D.2 Measure campus annual energy use

Metering of the energy loads and on-site generation is needed at the campus and building levels. The campus level metering is used as a baseline for determining the quantity of renewable energy that needs to be generated. Future construction plans should also be accounted for to estimate the anticipated future load according to the campus master plan. Building models or rough estimates may need to be used. This combination of metered energy use and estimated growth or reduction is site energy and thus it must be converted to source energy. Meters for individual buildings should be used to identify opportunities for energy conservation and efficiency improvements.

To convert site energy to source energy, several other factors must be accounted for including: energy consumed in the extraction, processing and transport of primary fuels such as coal, oil and natural gas; energy losses in thermal combustion in power generation plants; and energy losses in transmission and distribution to the building site. The conversion factors listed in Table 3**Error! Reference source not found.** can be used to:

1) convert site energy to source energy, and

2) develop a source energy equivalent value of on-site renewable energy generation that is exported from the net zero energy site to the electric grid, since it displaces electricity that would otherwise be generated from conventional sources.

Table 3. National Average Source Energy Conversion Factors[6]

Energy Form	Source Energy Conversion Factor
Imported Electricity	3.15
Exported Renewable Electricity	3.15
Natural Gas	1.09
Fuel Oil (1,2,4,5,6)	1.19
Propane & Liquid Propane	1.15
Steam	1.45
Hot Water	1.35
Chilled Water	1.04
Coal or Other	1.05

To estimate the total source energy consumption, the amount of each delivered energy type is multiplied by the conversion factor to determine source energy. For example, a building using electricity and natural gas would multiply each fuel type in British Thermal Units (Btus) by the appropriate conversion faction listed in Table 3**Error! Reference source not found.**. These end se values would be summed to represent the total source energy use for the building or campus. The renewable electric energy generated on-site and exported to the grid would be multiplied by the electricity conversion factor and be subtracted from the sum of the energy use. A campus would be considered net zero when the difference between energy use and energy generation is equal to zero or a negative value.

Total Energy Use = [Site Energy Use by Fuel Type(s) * Source Energy Conversion Factor(s)] – [On-site, Exported Renewable Energy by System* Source Energy Conversion Factor(s)]

If a campus uses the renewable energy directly, then the site energy use of the campus would be reduced by the site renewable energy used and the remainder of the site energy use would be converted to source energy as described above.

EA.D.3 Design renewable energy system(s) to meet calculated campus annual energy use

A net zero energy campus minimizes energy use and then generates renewable energy greater than or to equal the annual source energy consumption. The optimal mix of renewable energy technologies for a net zero campus is site-specific. Renewable energy includes technologies that can harness solar power, wind power, hydropower, geothermal energy, biomass, and biofuels. To determine which technologies are best for a campus, a renewable energy assessment should be

[6] Table was recreated from *A Common Definition for Zero Energy Buildings* available online at https://energy.gov/sites/prod/files/2015/09/f26/bto_common_definition_zero_energy_buildings_093015.pdf

performed. An assessment will identify which renewable energy sources could potentially work at the site, how much energy they could generate given site constraints, and which options are cost-effective for the campus. The renewable energy design would include appropriate wiring, controls, interconnection point(s), net metering, and coordination with utility providers.

Construction

During the construction phase, the net zero energy elements identified during the design phase will be put into practice. For a campus, the existing buildings will likely be the focus. Net zero energy construction elements to consider are provided below.

ENERGY Net Zero Construction Elements for Campuses
EA.C.1 Contract language for net zero related features
EA.C.2 Commission, recommission, or retrocommission the energy systems

EA.C.1 Contract language for net zero related features

Contract language should ensure the net zero energy elements are installed per the design. This language should include that the equipment specifications identified in the design phase are cross-walked with the contractor's procurement documentation to ensure that the correct equipment is purchased and installed. Furthermore, the contract should be developed to include energy use and power generation performance metrics to ensure the building meets the design expectations. Include a requirement to meter each building's energy use by fuel type, with sub-meters for large end uses as appropriate, as well as all renewable energy generation.

EA.C.2 Commission, recommission, or retrocommission the energy systems

Contract language should require that all net zero energy technologies and systems, whether energy efficiency or power generation related, are commissioned, recommissioned, or retrocommissioned. New equipment should be commissioned during the construction phase as well as upon completion of renovation of a building. Existing equipment should be recommissioned or retrocommissioned to ensure that the existing equipment is operating as intended. A commissioning plan should be prepared that includes the overall objectives, commissioning strategies, project team, and schedule for future recommissioning efforts.

Operations

Operations and maintenance (O&M) can be one of the most cost-effective ways to reduce energy use. The net zero energy operation elements that contribute to a campus meeting its net zero energy goals are described below.

ENERGY Net Zero Operation Elements for Campuses
EA.O.1 Campus operation plan addresses O&M of energy efficiency design features and renewable energy systems
EA.O.2 Meter energy use and benchmark performance
EA.O.3 Occupants are engaged with achieving the expected energy performance
EA.O.4 Measure and verify the campus is operating at net zero over a one-year timeframe

EA.O.1 Campus operation plan addresses O&M of energy efficiency design features and renewable energy systems

A campus operation plan needs to address the key areas of operational efficiency for the critical buildings on the campus. The plan should include the description of the measure, action items that should be performed, the frequency it should occur, and the personnel that are responsible for the action. Key actions toward the goal of operational efficiency include:

- Tracking O&M activities and reporting on status of O&M investments,
- Using data to identify energy technologies or systems that are operating outside of their expected performance parameters,
- Committing to addressing the identified technology or system performance issues, and
- Documenting changes made and tracking subsequent performance changes.

EA.O.2 Meter energy and benchmark performance

Buildings on the federal campus should have advanced meters collecting data on at least an hourly basis.[7] Advanced meters need to be installed for all building energy use and on-site power generation. Energy use data must be collected and analyzed to identify use trends and potential opportunities for efficiency opportunities. The monthly energy use data must be benchmarked using the Environmental Protection Agency's ENERGY STAR Portfolio Manager®.[8] The monthly power generation data must be compared to modeled or manufacturer-specified output to verify proper operation. If actual power generation is lower than expected, investigate potential causes and address the issue.

To verify that the campus is operating at net zero, energy generation data must be compared to energy use. The steps to follow to calculate net zero energy status are:

- A year of campus energy use is collected for all sources such as electricity, steam, and natural gas.
- Campus site energy is converted to source energy using conversion factors offered in Table 3**Error! Reference source not found.**. To estimate the total source energy onsumption, the amount of each delivered energy type is multiplied by its respective conversion factor to determine source energy.
- A corresponding year of renewable energy generation data is collected for all renewable energy generated within the campus boundary and which was exported to the grid. The exported renewable electricity is converted into a source energy equivalent by using the conversion factor from Table 3**Error! Reference source not found.**.

EA.O.3 Occupants are engaged with achieving the expected energy performance

To successfully operate a net zero energy campus, tenants/occupants must be engaged and knowledgeable about the campus' net zero energy elements and functions. A behavior change program can be an effective approach to training occupants on key net zero features of the

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[7] See Federal Building Metering Guidance at: http://energy.gov/sites/prod/files/2014/11/f19/metering_guidance.pdf

[8] See Federal Building Energy Use Benchmarking Guidance at: https://www.energy.gov/sites/prod/files/2014/09/f18/benchmarking_guidance08-2014.pdf

buildings. Example elements of a behavior change program for encouraging energy conservation and efficiency include:

- training occupants on interactive energy design features such as lighting or plug load controls,
- billing or mock billing of tenants,
- holding competitions to inspire occupant energy conservation efforts,
- informing campus occupants about the building's energy use through staff meetings, newsletters, email announcements, and social media announcements, and
- providing awards for occupant-led energy conservation efforts.

EA.O.4 Measure and verify the campus is operating at net zero over a one-year timeframe

To verify that the campus is operating at net zero, energy generation data must be compared to energy use. The steps to follow to calculate net zero energy status are:

- A year of campus site energy use is collected for all energy sources such as electricity, steam, and natural gas.
- Campus site energy is converted to source energy using conversion factors offered in Table 3**Error! Reference source not found.**. To estimate the total source energy onsumption, the amount of each delivered energy type is multiplied by its respective conversion factor to determine source energy.
- A corresponding year of renewable energy generation data is collected for all renewable energy generated within the campus boundary and which was exported to the grid. The exported renewable electricity is converted into a source energy equivalent by using the conversion factor from Table 3**Error! Reference source not found.**.

If the total campus source energy use data is less than or equal to the total renewable energy exported (after conversion to a source energy equivalent), the campus is considered net zero energy.

WATER

A net zero water campus minimizes total water consumption, maximizes alternative water sources, minimizes wastewater discharge, and returns water to the original water source.

WATER Net Zero Connect and Coordinate Elements for Campuses
WA.CC.1 Identify opportunities to consolidate functions and reduce footprint
WA.CC.2 Develop a campus operation plan focused on synergies of water-related systems
WA.CC.3 Improve utility infrastructure
WA.CC.4 Develop campus master plans and related plans to establish design and performance expectations

Connect and Coordinate

A net zero water campus must coordinate across the building inventory to meet these net zero objectives, as described by the following elements. The original water source includes sources within the same local watershed and aquifer of the campus' water supply.[9] The goal of net zero water is to preserve the quantity and quality of natural water resources with minimal deterioration, depletion, and rerouting due to the campus' water use by utilizing potential alternative water sources and water efficiency measures to minimize the use of supplied freshwater.

WA.CC.1 Identify opportunities to consolidate functions and reduce footprint

A net zero water campus can reduce water use by consolidating functions. Review real property data including buildings by type, age, occupancy, capacity, and function to identify buildings that are no longer being used to full capacity, whereby occupants can be consolidated into a smaller number of total buildings. Reducing the number of buildings may save water by eliminating leaking distribution lines that serve the buildings. Unoccupied buildings should be demolished to eliminate the need for the buildings to be supplied water for fire-fighting purposes. To maximize water reduction, consolidate buildings to a core campus that are co-located and look to demolish buildings that are on the outskirts of the campus to shut off supply on long distribution lines.

WA.CC.2 Develop a campus operation plan focused on synergies of water-related systems

Include the following elements in a campus operation plan that will assist in understanding water use across the campus to improve overall water management:[10]

- A list of all water-related equipment and processes
- Water balance results provide a breakout of water use by major equipment type

[9] If the campus is not located within the watershed or aquifer of the original water source, then returning water to the original water source will be unlikely. The option for net zero water strategy would therefore have to depend on using alternative water to offset the use of freshwater.

[10] For more information, go to FEMP's Water Management Plan website: http://energy.gov/eere/femp/developing-water-management-plan

- Metering plan that prioritizes buildings and processes for water meters and specifies how metered data will be used for operational improvements[11]
- O&M plan that includes specific actions for improving water management

WA.CC.3 Improve utility infrastructure

Water distribution system infrastructure at federal campuses can be aging and in disrepair depending on when the campus was constructed. An aging distribution system can have a high leak rate, wasting a significant amount of water. A net zero water campus should have an active leak detection and repair program that includes annual surveys or technology in place that actively listens for water leaks. In addition, an aging water distribution system should be reviewed and replacement projects prioritized. This process should include a review of the pipe material, age, and leak history. This can help identify the areas of the system that are in the greatest need for replacement. For example, it is common for aging cast iron pipes to have high leak rates, which could be slated as high priority for replacement.[12]

WA.CC.4 Develop campus master plans and related plans to establish design performance expectations

A net zero water campus should have a campus master plan that prioritizes projects for implementation and specifies equipment that should be installed in new construction and renovations. The campus master plan should include elements that ensure net zero water goals are systematically implemented including the following:

- Prioritized list of water efficiency and infrastructure replacement projects with a targeted water reduction goal and implementation timeline
- Prioritized list of alternative water systems projects with a targeted production goal and implementation timeline
- Prioritized list of on-site wastewater treatment and green infrastructure projects with a targeted goal for water returned to the original water sources and implementation timeline
- Water-efficient equipment specifications that are required for all new construction and renovations
- Opportunities for green infrastructure projects to support sustainable water management
- Alternative water and wastewater system specifications to ensure that systems are implemented to meet performance criteria
- Building demolition list with the goal to consolidate the campus into a core area

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[11] For more information, go to FEMP's Prioritizing Building Water Meter Applications: http://energy.gov/eere/femp/prioritizing-building-water-meter-applications

[12] For more information, go to FEMP's BMP: http://energy.gov/eere/femp/best-management-practice-3-distribution-system-audits-leak-detection-and-repair

Design

A net zero water campus is achieved when the amount of alternative water consumption and water returned to the original water source is equivalent to the campus' water consumption.[13] Ultimately, a net zero water campus completely offsets the campus' water use with alternative water plus water returned to the original water source, represented by the formula below (definitions for the variables in the equation can be found in the Glossary). It is vital to include specific design goals for a net zero water campus.

$$\left\{\begin{matrix}\text{Total Annual}\\\text{Water Use}\end{matrix}\right\} = \left\{\begin{matrix}\text{Total Annual}\\\text{Alternative Water Use}\end{matrix}\right\} + \left\{\begin{matrix}\text{Total Annual Water Returned/Discharged}\\\text{to the Original Source}\end{matrix}\right\}$$

The design elements for a campus to achieve a net zero water target are provided below.

WATER Net Zero Design Elements for Campuses
WA.D.1 Design buildings that meet or exceed campus master plan expectations
WA.D.2 Determine campus annual water use and water balance
WA.D.3 Design alternative water systems and systems to return water to the original water source to meet estimated Campus annual water use
WA.D.4 Treat wastewater on-site and return to the original water source
WA.D.5 Design green infrastructure features to return water to its original water source
WA.D.6 Minimize the impact of design reviews or value engineering on the net zero target

WA.D.1 Design buildings that meet or exceed campus master plan expectations

New construction and existing building renovations that impact the net zero water target should be designed to meet or exceed the campus master plan expectations. Integrated design strategies should be used to identify efficiency opportunities. Strategies that take advantage of building proximities, such shared landscaping, should be considered.

For net zero water design, equipment selection should not be based on economic viability alone. When designing a net zero water campus, non-market considerations should be included such as ecosystem impacts and water security and resiliency. A campus that has a lower demand for water will help preserve regional water sources, and also be more secure and resilient during water restrictions or emergencies.

If new buildings are added to the campus, the new building designs should aim to maximize water efficiency while simultaneously minimizing demand by including a comprehensive suite of water efficient elements that include all water consuming equipment inside the building as well as outdoor water use, as shown in Table 4**Error! Reference source not found.**.[14] For more

[13] If the campus is not located within the watershed or aquifer of the original water source, then returning water to the original water source will be unlikely. The option for net zero water strategy would therefore have to depend on using alternative water to offset the use of freshwater.

[14] For information, go to FEMP Water Efficiency Best Management Practices (BMPs): http://energy.gov/eere/femp/best-management-practices-water-efficiency

nformation on net zero strategies for new buildings, refer to the *Federal New Buildings Handbook for Net Zero Energy, Water, and Waste*.

Table 4. High Performance Design Considerations for New Net Zero Water Buildings

End-Use	High performance design options	Considerations
Plumbing	High efficiency and WaterSense-labeled equipment[15]	Specify the most efficient equipment available
Commercial Kitchen	WaterSense and ENERGY STAR-labeled equipment	Specify the most efficient equipment available
Landscape	Low-water using landscaping	Incorporate low-water using landscape principles
Cooling and Heating Systems	High efficiency system design	If applicable, consider passive heating and cooling systems to reduce the need for water-based systems

The highest priority for an existing campus to become net zero water should be to aggressively drive down the water demand. The campus should be renovated with water-efficient equipment and landscape. The renovations should include a comprehensive suite of water efficient elements, as shown in Table 5**Error! Reference source not found.**.[16] For more information on et zero strategies for existing buildings, refer to the *Federal Existing Buildings Handbook for Net Zero Energy, Water, and Waste*.

Table 5. High Performance Design Considerations for Existing Net Zero Water Buildings

End-Use	High performance design options	Considerations
Plumbing	High efficiency and WaterSense-labeled equipment	Retrofit with the most efficient equipment available
Commercial Kitchen	WaterSense and ENERGY STAR-labeled equipment	Install the most efficient equipment available
Landscape	Low-water using landscaping	Remove high-water consuming landscape and retrofit with low-water using landscape
Cooling and Heating Systems	High efficiency system design	For water cooling and heating, install control and water treatment systems that manage water systems to efficiency targets

[15] For information, go to EPA's WaterSense website: https://www.epa.gov/watersense

[16] For information, go to FEMP Water Efficiency BMPs: http://energy.gov/eere/femp/best-management-practices-water-efficiency

WA.D.2 Determine campus annual water use and water balance

Use available metered data to estimate the campus' annual water use. Also, develop a water balance to estimate water use by major equipment type to help focus efforts on large water consuming equipment.[17] A water balance can also help to identify the best uses for alternative water sources such as irrigation and cooling tower makeup. The water balance should be used to target projects that have the best potential for the campus to achieve net zero.

WA.D.3 Design alternative water systems and systems to return water to the original water source to meet estimated Campus annual water use

A net zero water campus produces alternative water and returns water to the original water source in an equivalent amount to the total campus water use.

Freshwater is sourced from surface water (e.g., lakes, rivers) or groundwater (e.g., aquifers). Alternative water is from sources that are ***not*** derived from freshwater, including harvested rainwater and stormwater, sump pump water, graywater, air cooling condensate, reclaimed wastewater, or water derived from other water reuse strategies (Table 6**Error! Reference source ot found.**). A net zero water systems should be designed to capture alternative water sources and use them in applications such as flushing toilets and urinals, irrigation, and cooling towers.[18]

Table 6. Alternative Water Source Examples

Alternative Water Source	Potential Applications	Considerations
Rainwater	Irrigation, toilet and urinal flushing	Minimal treatment is needed for irrigation
Stormwater	Irrigation, cooling tower make-up, industrial uses	Foundation drain water can be reused similarly to stormwater
On-site Reclaimed Wastewater	Irrigation, cooling tower make-up, industrial uses	Substantial filtration and disinfection is required
Graywater	Toilet and urinal flushing, irrigation	Design building with dual plumbing system for toilet and urinal flushing; subsurface irrigation is most appropriate unless water is disinfected
Air Handling Condensate	Cooling tower make-up, industrial uses	Condensate water can be corrosive to metals because condensate can be slightly acidic; water may absorb copper from cooling coils

Capturing alternative water may require a dual plumbing system, which is a system with two separate distribution networks to deliver potable water and alternative non-potable water to

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[17] For more information on how to construct a water balance, go to FEMP's Water Management Plan website: http://energy.gov/eere/femp/developing-water-management-plan

[18] For information, go to FEMP BMP on Alternative Water Sources: http://energy.gov/eere/femp/best-management-practice-14-alternative-water-sources

separate end-uses. A dual plumbing system minimizes potable water use for only those applications that interface directly with occupants, namely in restroom faucets and showers and kitchen facilities.

WA.D.4 Treat wastewater on-site and return to the original water source

A net zero water campus closes the water system loop by returning water to the original water source. The original water source is considered fresh surface water and groundwater sources that are within the same local watershed or aquifer as the campus' supply water. For instance, recharging water to the original source can be accomplished through an on-site septic system (if the campus is located within the same watershed or aquifer as the original water source) or wastewater treatment system that discharges treated wastewater to the original water source. Treated wastewater can also be reclaimed as an alternative water source and reused on the campus with proper sanitary and regulatory controls. Wastewater treatment must meet local and federal requirements.[19]

Treating wastewater on-site may not be a viable solution because of space and cost constraints. If this is the case, the campus will have to use alternative water to offset the use of freshwater and/or return water back to the original source through green infrastructure.

WA.D.5 Design green infrastructure features to return water to its original water source

Another option for returning water to the original water source is through green infrastructure (also referred to as low impact development). Green infrastructure includes features that retain stormwater on-site and return it to groundwater. These features minimize water loss because of runoff and allow infiltration of water through the soil into the local water table. This process preserves the natural flow of water and prevents water flowing on the hardscape where water may be more exposed to contaminants (affecting water quality) and may more readily be lost into the atmosphere (through evaporation). Green infrastructure examples include bioswales, raingardens, and permeable pavement.[20]

If the campus is not located within the watershed or aquifer of the original water source, then returning water via green infrastructure to the original water source will be unlikely. The option for net zero water strategy would therefore have to depend on using alternative water to offset the use of freshwater.

WA.D.6 Minimize the impact of design reviews or value engineering on the net zero target

When designing a net zero water campus, it is important to incorporate the design elements and strategies discussed in this section early in the process. This can be achieved by clearly laying out the net zero water goals for the campus at the onset of design (such as a specific water use

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[19] For information, go to Environmental Protection Agency's resources for Septic Systems: https://www.epa.gov/septic, Decentralized Wastewater Treatment Systems: https://www.epa.gov/septic/decentralized-wastewater-systems-technology-fact-sheets, and https://www.epa.gov/npdes

[20] For information, go to Environmental Protection Agency's Green Infrastructure website: https://www.epa.gov/green-infrastructure

intensity, gallons/square feet), and specifying net zero water equipment and elements in a design charrette. It is also important to bring stakeholders to the table at the beginning of the design process, including present and future occupants and operators, to ensure everyone is in agreement on the net zero water goals. During the value engineering phase of the project it is important that an advocate for the net zero water design elements is present and can communicate the impact of design modifications on the net zero water goal.

Construction

During the construction phase, the net zero water elements identified during the design phase will be put into practice. Each of these net zero water campus construction elements are described in more detail below.

WATER Net Zero Construction Elements for Campuses
WA.C.1 Develop contract language for net zero related features
WA.C.2 Commission/recommission/retro-commission buildings and alternative water and wastewater systems

WA.C.1 Develop contract language for net zero related features

For all new construction and renovations undertaken on the campus, contract language should be incorporated to ensure net zero water elements are installed based on the requirements of the master plan. Equipment specifications should be cross-walked with the contractor's procurement to ensure that the correct equipment is purchased and installed. Add language to the contract that includes performance metrics on water use, and that requires the building meet the water reduction goals compared to the water balance.

WA.C.2 Commission/recommission/retrocommission buildings and alternative water and wastewater systems

A plan should be developed that prioritizes commissioning, recommissioning, and retrocommissioning across the campus. Water equipment should be commissioned for all new buildings. This will ensure that buildings' new water systems are installed and tested to perform per the specifications of the design. Existing building equipment should be recommissioned and retro-commissioned. Recommissioning ensures that the existing equipment is operating to the original design criteria. On the other hand, retrocommissioning is re-engineering of these systems to determine required changes to improve water efficiency. The plan should identify which activity is most appropriate for each major water system and set a timeline for the recommissioning and retrocommissioning efforts.

Operations

Good O&M practices are key to meeting the designed performance of a net zero water campus. The net zero water operation elements that contribute to the campus meeting its net zero water goals are described below.

WATER Net Zero Operation Strategies for Campuses
WA.O.1 Develop a campus operation plan covering O&M of water features and alternative water systems
WA.O.2 Meter water use and monitor for leaks and operational issues
WA.O.3 Engage occupants with the Campus net zero water program
WA.O.5 Measure and verify the campus is operating at net zero over a one-year timeframe

WA.O.1 Develop a campus operation plan covering O&M of water features and alternative water systems

Ensure the campus operation plan includes specific O&M measures of water equipment. The plan should include the description of the measure, action items that should be performed, the frequency it should occur, and the personnel that are responsible for the action. Table 7 provides examples of O&M measures for water equipment that could be included in the campus operation plan.

Table 7. Example O&M Measures for Water Equipment

End-Use	O&M Measure	Frequency	Responsible Party
Plumbing	Inspect for leaks, long toilet/urinal flush cycles, and broken or missing aerators	Bi-annually	Plumber/building manager
Commercial Kitchen	Ensure that manufacturer specified use and care instructions are being followed, inspect for broken components, loose connections, and leaks	Bi-annually	Commercial kitchen maintenance staff
Landscape/ Irrigation	Aerate turf, alternate turf mowing height, add mulch to landscaped areas, and keep landscaped areas weed free Review irrigation schedule, inspect emitter components for broken heads and leaks, verify system pressure	At the beginning and mid-point of growing season	Grounds maintenance personnel
Rainwater Harvesting System	Inspect the system for leaks and loose connections, test for water quality, change or clean the filter and screens, inspect motors and pumps to ensure they are fully operational	Bi-annually (or per the manufacturers' recommendations)	Building engineer

WA.O.2 Meter water use and monitor for leaks and operational issues

Metered data provides critical information on a campus' water use. Individual buildings on the campus should be metered separately to monitor whole building water use. Water-intensive applications such as irrigation and cooling towers should be sub-metered. Alternative water systems should be metered to monitor water production. It is recommended that on-site wastewater is metered so that the total amount of treated wastewater returned to the original water source can be monitored and measured. Water infiltration of green infrastructure features can also be monitored with flow sensors.

All meters should be advanced meters that have the ability to download data at least in hourly intervals. The interval data can be used to monitor the building and equipment for unusual spikes in water use that can pinpoint leaks or operational issue.[21]

[21] For more information, go to FEMP Metering Best Practices: http://energy.gov/sites/prod/files/2015/04/f21/mbpg2015.pdf

WA.O.3 Engage occupants with the net zero water program

To successfully operate a net zero campus, occupants must be engaged and knowledgeable about the net zero elements and functions. An outreach program should be implemented that help occupants become engaged in the net zero water features. Example elements of a behavior change program for encouraging water conservation include:

- training occupants on how to identify plumbing leaks,
- providing an easy mechanism for reporting leaks,
- setting periodic goals for campus water use,
- billing or mock billing of tenants,
- informing building occupants on water performance through staff meetings, newsletters, email announcements, and social media announcements,
- holding competitions to inspire occupant water conservation efforts, and
- providing awards for achieving water reduction targets.

WA.O.4 Measure and verify the campus is operating at net zero over a one-year timeframe

To verify if the campus is operating at net zero, collect annual data on water use and water discharges considering each specific water pathway, flow, and use within the campus boundary. These pathways will include the following estimates:

- Campus total annual water use for all sources including purchased potable water and on-site alternative water
- Total annual alternative water use (e.g., amount of rainwater captured from roofs and reused within the campus)
- Total annual on-site treated wastewater returned to original water source
- Total annual stormwater infiltrated to original water source through green infrastructure.

Sum alternative water, on-site treated wastewater, and stormwater returned via green infrastructure to the original water source. If this sum is equal to or greater than the annual total water use, then the campus is considered net zero water.

WASTE

Agencies that seek to meet the net zero waste goal for a campus should incorporate strategies to connect and coordinate the campus buildings so that buildings operate under a cohesive waste management plan.

WASTE Net Zero Connect and Coordinate Elements for Campuses
WS.CC.1 Identify and build a team of building waste managers
WS.CC.2 Review/Develop campus operation plan to address campus-level waste minimization and waste management systems
WS.CC.3 Establish agreements with waste and recycling haulers
WS.CC.4 Review/Develop green procurement policies and procedures

Connect and Coordinate

The following elements may assist in connecting and coordinating waste management for the campus buildings.

WS.CC.1 Identify and build a team of building waste managers

Identify and build a team of building waste managers to act as the deciding body for the development and implementation of the waste elements associated with net zero waste goals. Each building waste manager will be responsible to act as the representative for their building and the activities occurring there, as well as interacting with the tenants to ensure that tenants are socialized and committed to the actions identified by the waste team.

WS.CC.2 Review/Develop campus operation plan to address campus-level waste minimization and waste management systems

The team will review and/or develop a plan for managing the solid waste that outlines the intended path for reaching the net zero goals. The plan will include the intended system for collecting, transporting and disposition of both municipal solid waste (MSW) and recyclable materials. This includes both infrastructure and contracts that will be in place with the janitorial staff, grounds maintenance, MSW hauler and other responsible parties. In addition the plan will identify any equipment that is intended to be used at the building for waste treatment (e.g., anaerobic digestion (AD) or food drier), and outline the requirement and responsible party, if not the building waste manager, to perform regularly needed maintenance.

WS.CC.3 Establish agreements with waste and recycling haulers

Campus-level agreements with waste management companies, recycling haulers, community reuse programs, and composting programs should be pursued to minimize the burden of these programs on the site. One of the benefits of pursuing net zero waste at a campus-level is the ability to have larger agreements with these off-site entities which may offer better recycling rates and more waste diversion alternatives.

WS.CC.4 Review/Develop green procurement policies and procedures

Following the agency direction, campus-level green procurement policies and procedures can be developed and tracked to address the unique mission/operations of the campus. The net zero waste advocates need to communicate these policies and procedures to campus residents.

Design

A net zero waste campus should integrate methods to handle the expected waste streams produced by renovation through to operation of the buildings in total, including physical space considerations, local or regional waste disposal programs, green procurement, and any permitting or regulatory requirements that may be needed to support waste diversion and treatment. During the design phase, the following elements may assist in laying the groundwork for a net zero waste campus. Strategies for each of these design elements are provided below.

WASTE Net Zero Design Elements for Campuses
WS.D.1 Assess waste stream composition of the campus and the impact on waste for the renovated building
WS.D.2 Develop green procurement program that minimizes waste generation
WS.D.3 Design reuse, recycling, and compost programs to minimize waste generation
WS.D.4 Identify alternative path for remaining waste streams (e.g., waste-to-energy)

WS.D.1 Assess waste stream composition of the campus and the impact on waste for the renovated building

The first step toward designing a net zero waste campus is to fully define the waste stream expected for each of the existing buildings and the campus in total. This process should be conducted for each building, or set of buildings using the same services, by the identified building waste manager, and together, the waste team should assess the impacts of campus-wide waste generation. In planning for renovation, consider the materials to be used and evaluate where decisions can be made to use materials that are more environmentally preferable. It is also important during the design phase to have a good understanding of how the campus is operated and what waste materials are normally produced. Table 9 summarizes some of the net zero campus considerations.

Table 8. High Performance Design Considerations for a Net Zero Waste Campus

High performance design elements	Considerations
Waste Generation	Office recyclables (e.g., white paper, cardboard, mixed paper, glass, plastic) Compostable waste (e.g., food, landscaping) Other reusable/recyclable items (e.g., appliances, pallets, scrap metal) MSW for use in a WTE plant
Materials Used	Environmentally preferable materials Recycled/reclaimed materials Materials that enable easy diversion Locally/regionally made products
Building Function	Office building Laboratory Data center Housing Manufacturing Vehicle Maintenance

In defining the expected waste streams early in the process, options to reduce the amount of solid waste generated, reuse or repurpose items, and recycling and composting opportunities will be easier to identify.

WS.D.2 Develop green procurement program that minimizes waste generation

Once an assessment of the current waste stream has occurred, campus managers should consider methods by which waste generation can be reduced. All agencies should have green procurement programs in place that can be used by campuses. Green procurement programs should consider recycled content, energy and water efficient products and services, supply chain greenhouse gas management, and biobased products.

Within the design phase, it is helpful to understand what products are easily obtained in the region to help with product selection, and also whether there are local programs that facilitate the reuse of excess materials. Current service contracts may be re-evaluated, and new ones developed, to provide additional services that eliminate waste, such as furniture leasing, rag washing, and entry mat services. Additionally, all service contracts in place or under development should be revisited to include applicable requirements and clauses to ensure that contractors adhere to the same level of compliance. Example service contracts to be considered include custodial, pest control, landscape maintenance, and campus maintenance contracts. The type of contracts used could have an effect on design if there are special requirements needed to support the contractor (area for compost, roll off container for landscape waste, etc.).

WS.D.3 Design reuse, recycling, and compost programs to minimize waste generation

During the design phase, campuses should become familiar with local community programs that facilitate the recycling and composting of solid waste, as well as the design, purpose, and plan for regular building operations. Campuses should also become familiar with and adhere to any permitting or regulatory requirements within the local area that pertain to waste management through recycling or composting. In preparation for the renovation phase, agencies should develop a construction waste plan that outlines the method of construction, supplier considerations for packaging and delivery of construction supplies, specification of materials, and waste stream management. In planning for campus operation, designers should coordinate with other team members early in the design process to understand any changes to planned layout and location of staff to facilitate planning of designated collection spaces and containers (Table 10).

Table 9. Net Zero Waste Program Considerations

Program Areas	Considerations
Reuse	Within the building: Location of reuse center space(s) and a process to educate staff to check these areas before purchasing Beyond the building: Identify potential opportunities for donating to local charities for items that are no longer useful to the agency
Recycling	Within the building: Location of recycling containers and process to educate staff on what can be recycled Beyond the building: Type of service offered (e.g., single stream versus sorted, commodities collected) and the pickup schedules
Composting	Within the building/site: Pest management for the placement of composting containers, availability of compostable materials, and on-site needs for compost Beyond the building: Type of composting services available in the community and local need for compost
Waste Recovery	Availability of MSW for use in a WTE plant

Once an understanding of the available programs and campus layout has been achieved, designers can work to integrate the necessary spaces needed to manage waste generated on-site. In designating spaces, designers should consider that bins are best located in areas that are easily accessible to staff and determine whether there are enough common areas to accommodate collection areas for all staff, or whether other spaces, such as hallways will be needed (and whether those areas are wide enough to place collection bins).

- Compost areas should be sized based on type of collection unit and need identified (traditionally, these are located in kitchens and break rooms). Designers should evaluate the location and accessibility to occupants in determining whether current dumpster areas are sufficient to contain both MSW containers and recycle collection, and whether there are other areas that may be needed to accommodate multiple dumpsters and be accessible from different sides of the building.
- Designers should also consider potential holding areas, either within the building or next to the dumpster area to process bulky items (e.g., pallets, cardboard). An additional area may need to be designated within the buildings to collect items that cannot be accepted in the MSW recycling service, such as lamps, batteries, solvents/paints, and toner cartridges. Designers should also consider space for storing items identified for reuse or sharing; depending on the building size, more than one space may be needed.
- Designers should develop a reuse advertising method so that all campus tenants are aware of items available for reuse in other buildings.
- Designers may also wish to identify and partner with community programs for reuse of items, particularly if items in the reuse areas are not re-utilized within a certain period of time.

- A separate slab/power/water source area may be needed for compost, AD, driers, and/or used cooking oil collection, depending on local services available and methods chosen for managing food and landscape debris.

WS.D.4 Identify alternative path for remaining waste streams (e.g., waste-to-energy)

In order to achieve net zero waste, any remaining waste streams must be managed through other methods, including WTE. Designers should identify what disposal facilities the campus is currently utilizing and if regional facilities are available in the area, including WTE, AD, and landfill gas (LFG) and determine the distance between the campus location and the facility, whether the campus is within the jurisdiction of the alternative disposal facility (or what it would cost to be added into their service domain), whether haulers will deliver collected material to the specified facility, what materials are accepted, how they are collected, and whether there are any special collection requirements. Due to the larger amount of waste available from a campus versus a single building, the waste for a campus may be more desirable to a company because more material is available in one area.

Construction

During the construction or renovation phase, the net zero waste management elements identified during the design phase will start to be put into practice. Contracts with construction companies should have specific clauses to ensure that all debris is handled according to established criteria. Materials used should follow the design, and all debris should be appropriately diverted. A report should be provided that shows total weight of all materials diverted from the construction debris.

The following elements may assist in implementing net zero waste activities while a campus building is under construction or renovation.

WASTE Net Zero Construction Elements for Campuses
WS.C.1 Establish contracts with local entities
WS.C.2 Put systems in place to enforce green procurement and waste management
WS.C.3 Make containers available for reuse, recycling, compost and other waste management

WS.C.1 Establish contracts with local entities

Establishing contracts with local entities to support purchasing, reuse, recycling, compost, and other waste management efforts is one of the net zero waste construction strategies. Campus waste management leaders should work with the community programs and suppliers identified in the design phase to establish or modify the contracting network necessary for implementation of green procurement programs and management of identified waste streams through reuse, recycling, composting, and other methods. Campuses should include net zero waste targets as a selection criterion when soliciting and selecting contractors.

WS.C.2 Put systems in place to enforce green procurement and waste management

During the renovation phase, campuses should implement the systems designed to enforce the green procurement and waste management methods. Contracts should include specifications and clauses that promote the net zero waste targets, along with penalties for non-compliance. Product and material specifications may be written to minimize waste generation and allow for return/reuse of packaging and excess materials. Implement paperwork requirements for removal of materials from the construction site, and ensure that all paperwork is completed to track and monitor waste disposition, including hazardous waste disposition.

WS.C.3 Make containers available for reuse, recycling, compost and other waste management

As building construction or renovation proceeds, ensure that the necessary containers are available, correctly labeled, utilized, and serviced in a timely manner to effectively manage the waste created.

Operations

The net zero waste elements identified during the design phase may need to be adapted while being implemented during operations. The operational elements for net zero waste are described in more detail below.

WASTE Net Zero Operation Elements for Campuses
WS.O.1 Campus operation plan addresses O&M of waste conversion programs
WS.O.2 Implement Reuse/Recycle Program
WS.O.3 Green procurement requirements and waste diversion options are enforced
WS.O.4 Occupants are actively engaged in achieving the net zero waste targets
WS.O.5 Measure and verify the campus is operating at net zero over a one-year timeframe

WS.O.1 Campus operation plan addresses O&M of waste conversion programs

Ensure the campus operation plan includes specific net zero waste elements, such as waste-to-energy, and O&M of reuse, recycling, compost and other waste diversion programs. The plan should include the description of the measure, action items that should be performed, the frequency it should occur, and the personnel that are responsible for the action. The campus operation plan should be reviewed annually to make sure that all components of the plan for waste management are functioning correctly. Table 11 provides examples of waste management measures that could be included in the campus operation plan.

Table 10. Example Waste Management O&M Measures

Area	O&M Measure
Custodial Services	Ensure that custodial service contracts include clauses for transporting recyclables to the hauler collection point or internal collection area for pickup (including food and cooking oil if applicable)
Compost	Ensure service contracts for passive compost units include transporting food scraps to the unit, as well as intermittent cleaning of the unit area (e.g., hose off the pad)
Recycling	Monitor use of the recycle bins to ensure that either liners are appropriately used, or that the bins are cleaned when needed
Occupants	Occupants are informed of how and where to place items for reuse, recycling, and composting, and informed about green procurement programs

WS.O.2 Implement Reuse/Recycle Program

Within the design phase, campus reuse centers or collection areas were identified, and a plan to advertise items throughout the campus was developed. Additionally, community reuse programs and/or partnerships with local charities may be utilized according to the plans developed during the design phase.

Reuse, composting, and recycling areas should be clearly labeled and monitored to ensure that only items suitable for reuse, composting, and recycling are placed in the area. Building signage should be placed in common areas explaining the program and providing information regarding location and use of collection bins and areas. Responsible parties (or building/campus points of contact) should be identified to assist staff with questions and suggestions for improvement. An annual assessment of the reuse, composting, and recycling programs should be conducted regarding location and functionality, and adjustments should be made to allow for optimum implementation of the programs.

WS.O.3 Green procurement requirements and waste diversion options are enforced

Policies and procedures regarding green procurement and waste diversion should be relayed to staff, and all staff involved in the day-to-day operations regarding purchasing and waste management should be trained to provide understanding of the requirements. The agency should put a tracking system in place to monitor that green procurement principles are used at each purchase; this information should be reviewed annually to ensure that the principles are being implemented. Additional materials, such as “quick guides” may be provided to purchasing card holders to aid them in their decision process. Finally, items that are delivered to the campus should be verified that they are in compliance with green procurement requirements.

WS.O.4 Occupants are actively engaged in achieving the net zero waste targets

In order to more actively engage the occupants throughout the campus, agencies may wish to develop incentive programs to motivate staff, and to develop an awards program that acknowledges the contributions of engaged individuals. Training and awareness materials and guidance should be developed and provided to assist both contracting professionals and campus occupants in understanding the net zero waste goals, and their role in meeting those goals. An aggressive education and motivation program may also be instituted, including information about campus progress toward waste minimization and diversion goals. This may include new staff briefings, annual trainings, staff meeting discussions, and newsletter and other social media announcements. Competitions may be held to encourage waste minimization and diversion efforts, and periodic goals may be set for campus waste targets.

WS.O.5 Measure and verify the campus is operating at net zero over a one-year timeframe

To verify if the campus is operating at net zero, the following steps should be taken on an annual basis:

- Review procurement records to verify that they are in compliance with green procurement requirements.
- Verify that applicable net zero waste clauses within service contracts are being honored by the contractor, and that they are managing waste as stated.

- Review recycle/reuse/compost records (e.g., invoices, weight) to verify that waste diversion took place as expected, and that material streams were handled as expected.
- Review WTE records to determine whether any materials were included that should have been diverted through other means.

If waste was reduced or diverted properly through reuse/recycling/composting/WTE/other methods, contractors appropriately handled diverted materials, and no waste was landfilled or incinerated, the campus is considered net zero waste.

5 Summary

FEMP and PNNL recognize there are more strategies and lessons learned from on-going net zero energy, water, and waste efforts on federal buildings and campuses. In 2010 Army launched a net zero energy, water, and waste pilot initiative that involved 17 installations. As of October 2015, this initiative documented an energy reduction of 307 MMBtus and generated nearly 28,700 megawatt-hours of renewable energy; documented a water reduction of 636 million gallons and produced 89 million gallons of alternative water; and documented a waste reduction of 9,400 tons and diverted 58% of the waste from landfill disposal. The Army's net zero energy, water, and waste hierarchy is considered a key element to the initiative's success. The first item on the hierarchy is reducing resource use with the final item being renewable energy generation, groundwater recharge, and waste disposal.[22] The General Services Administration has renovated the Wayne Aspinall Federal Building in Grand Junction, Colorado, a building on the National Registry of Historic Places, to achieve net zero objectives. Some of the energy efficiency features include advanced metering and controls, high-efficiency lighting systems, an improved building envelope, and techniques to manage occupant plug load. Photovoltaic roof panels were installed to generate enough renewable energy to meet the building's electricity needs.[23]

FEMP is eager to learn more about federal agency net zero energy, water, and waste efforts in order to share those strategies and lessons learned with the federal sector. Contact FEMP at: https://www4.eere.energy.gov/femp/assistance/ with your experiences with net zero efforts.

6 Glossary

Terms used in this handbook are defined below. Existing federal or publicly available definitions are referenced. Additional zero energy buildings terms can be found in the EERE *A Common Definition of Net Zero Buildings* report.[24]

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[22] U.S. Army, prepared by PNNL. October 2016. *2015 Progress Report: Army Net Zero Initiative*. U.S. Army Office of the Assistant Secretary of the Army (Installations, Energy and Environment).

[23] To learn more about the Wayne Aspinall Federal Building go to: https://sftool.gov/plan/422/net-examples#wayneaspinall

[24] U.S. DOE's *A Common Definition for Zero Energy Buildings* available online at http://energy.gov/sites/prod/files/2015/09/f26/bto_common_definition_zero_energy_buildings_093015.pdf

Alternative water – A sustainable water source not derived from fresh, surface or groundwater sources. Alternative water can include harvested rainwater, harvested stormwater, sump pump water harvesting, graywater, air cooling condensate, reject water from water purification systems, reclaimed wastewater, or water derived from other water reuse strategies.

British thermal units – Standard unit of energy.

Boundary – Line that is at or within the legal property boundary that marks the limits of the building or campus across which delivered energy and exported energy are measured.[25]

Cogeneration – The simultaneous production of electric and thermal energy in distributed energy systems; typically, waste heat from the electricity generation process is recovered and used to heat, cool, or dehumidify building space. Neither generation of electricity without use of the byproduct heat, nor waste-heat recovery from processes other than electricity generation is included in the definition of cogeneration.[26]

Commissioning – A systematic process of ensuring that all building systems in a new building perform interactively as intended in the design.

Compost – Degradation of organic waste to form mulch or soil amendment.

Construction – Preliminary planning, engineering, architectural, legal, fiscal, and economic investigations and studies, surveys, designs, plans, working drawings, specifications, procedures, and other similar actions necessary for the construction of a public building. (40 U.S. Code § 3301)

Design – The development of plans and specifications for human living space.[27]

Disposal – Proper disposition of a discarded or discharged material in accordance with local environmental guidelines or laws.

Electric energy – Electric power provided by a utility or generated on-site, usually measured in kilowatt hours (kWh).

Energy conservation measure (ECM) – Life-cycle cost-effective actions or technologies that are applied to an existing ly owned building that improve energy efficiency. ECMs include energy

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[25] Adapted from U.S. DOE. September 2015. A Common Definition for Zero Energy Buildings.

[26] Quote from EIA's Commercial Buildings Energy Consumption Survey Terminology: http://www.eia.gov/consumption/commercial/terminology.php#C An alternative definition can be found at: http://energy.gov/eere/energybasics/articles/glossary-energy-related-terms#E – The generation of electricity or shaft power by an energy conversion system and the concurrent use of rejected thermal energy from the conversion system as an auxiliary energy source.

[27] 10 CFR § 435.502

conservation, cogeneration facilities, renewable energy sources, improvements in operation and maintenance efficiencies, or retrofit activities.[28]

Energy recovery – The exchange of energy from one subsystem with another, typically in the form of thermal energy.

Federal building – Any building, structure, or facility, or part thereof, including the associated energy consuming support systems, which is constructed, renovated, leased, or purchased in whole or in part for use by the federal government and which consumes energy; such term also means a collection of such buildings, structures, or facilities and the energy consuming support systems for such collection.[29]

Federal campus – A U.S. government designation associated with a campus or installation owned or leased by the federal government. This designation is used to identify groups of buildings typically in the same geographic location. It could be the name of a federal campus, or it could be an alphanumeric sequence, like the Installation or Sub-Installation Identifier from the U.S. Federal Real Property Profile, the federal government's centralized real property database.[30]

Freshwater – A surface or groundwater source that has a total dissolved solids concentration of less than 1,000 milligrams per liter (1,000 ppm).

Geothermal heat pump renewable energy – Energy generated from systems that use the constant temperature of the earth as the exchange medium for heating and cooling to reduce and replace the equivalent amount of energy otherwise would be generated from an air-source heat pump.[31]

Graywater – Lightly contaminated water generated by lavatory faucets, showers, or clothes washing machines.

Green procurement – The purchase of new materials or products that are made from the most environmentally preferable materials available, including materials that are easily reused or recycled.

Groundwater – Water beneath the surface of the Earth held in porous spaces in soil, sediment, and rock.

Harvested rainwater – Precipitation collected from a roof surface before hitting the ground.

[28] 10 CFR § 436.31

[29] 42 U.S.C. § 8259

[30] https://portfoliomanager.energystar.gov/pm/glossary

[31] The White House Council on Environmental Quality Office of Federal Sustainability. June 10, 2015. Implementing Instructions for Executive Order 13693 Planning for Federal Sustainability in the Next Decade., page 25.

Harvested stormwater – Precipitation collected on the ground level at the building or campus property that has not entered a surface waterway (such as a parking lot).

Hazardous waste – A waste with properties that make it potentially dangerous or harmful to human health or the environment, requiring special handling and disposal techniques.[32]

Landfill – A disposal system in which the waste is buried between layers of earth.

Life-cycle cost-effective – The proposed building or existing building project has a lower life-cycle cost than the life-cycle costs of the baseline building or project, as described by 10 CFR 436.19, or has a positive estimated net savings, as described by 10 CFR 436.20, or has a savings-to-investment ratio estimated to be greater than one, as described by 10 CFR 436.21; or has an adjusted internal rate of return, as described by 10 CFR 436.22, that is estimated to be greater than the discount rate as listed in OMB Circular Number A-94 "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs.[33]

Measure and verify – Quantifying the performance of energy, water and waste systems compared to expected performance.

Medical waste – Potentially hazardous waste generated at health care buildings that may be contaminated with blood or other potentially infectious material requiring special handling and disposal.[34]

Municipal solid waste – Garbage, refuse, sludge and other waste materials not excluded by federal law or regulation.

New federal building – Any building to be constructed on a site that previously did not have a building or a complete replacement of an existing building from the foundation up, by, or for the use of, any federal agency which is not legally subject to State or local building codes or similar requirements.

On-site renewable energy – Includes any renewable energy collected and generated within the site boundary that is used for building energy and the excess renewable energy could be exported outside the site boundary. The renewable energy certificates (RECs) associated with the renewable energy must be retained or retired by the building owner/lessee to be claimed as renewable energy.

[32] https://www.epa.gov/hw/learn-basics-hazardous-waste#hwid

[33] 10 CFR 435.2

[34] https://www.epa.gov/rcra/medical-waste

Original water source – Surface water and groundwater sources that are within the same local watershed. Local watersheds are defined as a sub-watershed. Each sub-watershed is assigned a 12 digit hydrologic unit code by the U.S. Geological Survey.[35]

Recycle – When the useful life of a material or product has been reached, the material or product is used as feedstock for new materials or products following some form of physical or chemical processing (e.g., aluminum cans to make new aluminum products).

Recommissioning – For an existing building that has already been commissioned, this is the systematic process of checking that all building systems continue to perform interactively as intended.

Reduce – Decrease the amount of solid waste generated on-site that needs to be considered for diversion including intentionally limiting materials brought on-site.

Renewable electric energy – Electric energy produced by solar, wind, biomass, landfill gas, ocean (including tidal, wave, current, and thermal), geothermal, geothermal heat pumps, micro-turbines *(powered by renewable fuel)*, municipal solid waste (*including Waste-to-Energy*), or new hydroelectric generation capacity achieved from increased efficiency or additions of new capacity at an existing hydroelectric project.

Renewable energy certificate (REC) – Documentation that represents the generation of one megawatt-hour (MWh) of electricity from an eligible source of renewable energy.[36]

Renovated building – Construction on an existing building that includes replacement or restoration of major systems, interior work (such as ceilings, partitions, doors, floor finishes, etc.), and building elements and features.

Repurpose – Items that are no longer able to be used for their intended purpose are modified for a different purpose (e.g., wood pallets used to make furniture).

Retrocommissioning – For an existing building that has not been commissioned, this is the systematic process of checking that all building systems are operating interactively as intended.

Reuse – Use materials or products for intended purpose for as long as possible. Reuse can include donations to entities outside of the agency (e.g., furniture to a non-profit).

Site energy – Energy consumed at the building site as measured at the site boundary. At a minimum, this includes heating, cooling, ventilation, domestic hot water, indoor and outdoor

[35] Original water source includes sources within the same local watershed and aquifer of the building's (or campus') water supply. For more information on watershed boundaries, go to: https://nhd.usgs.gov/wbd.html

[36] U.S. DOE FEMP http://www.energy.gov/sites/prod/files/2013/10/f3/rec_guide.pdf

lighting, plug loads, process energy, elevators and conveying systems, and intra-building transportation systems.[37]

Source energy – Site energy plus the energy consumed in the extraction, processing and transport of primary fuels such as coal, oil and natural gas; energy losses in thermal combustion in power generation plants; and energy losses in transmission and distribution to the building site.[38]

Surface water – Water on the surface of the Earth such as a river or lake. Surface water does not include stormwater collected on-site at the building or campus level.

Thermal energy – All forms of non-electric energy which is primarily the energy delivered as heating or cooling. Examples of thermal energy are fuels used in furnaces and solar water heaters and British thermal units of energy received from ground sourced heat pumps.[39]

Thermal renewable energy – Energy generating technologies and approaches that use renewable heat sources, including biomass, solar thermal, geothermal, waste heat, and combined heat and power from renewables.

Total Annual Water Use – The amount of water consumed within the boundaries of a building from all sources (potable and non-potable including freshwater and alternative water) over the course of a year.

Total Annual Alternative Water Use - The amount of water consumed within the boundaries of a building from sustainable water sources not derived from fresh, surface or groundwater sources over the course of a year. In a net zero building, the total annual water use should be offset by alternative water in part or completely.

Total Annual Water Returned/Discharged to the Original Source – The amount of water collected from the building systems (e.g., green infrastructure and on-site treated wastewater) and is discharged back to the original water source over the course of a year. In a net zero building, the total annual water use should be offset by water returned to the original source in part or completely.

Waste-to-energy – The waste treatment process that creates energy in the form of electricity, heat, or transport fuels (e.g., diesel) from a waste source.

[37] U.S. DOE. September 2015. A Common Definition for Zero Energy Buildings.

[38] U.S. DOE. September 2015. A Common Definition for Zero Energy Buildings.

[39] The White House Council on Environmental Quality Office of Federal Sustainability. June 10, 2015. Implementing Instructions for Executive Order 13693 Planning for Federal Sustainability in the Next Decade., footnote 18 on page 20.

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DOE/EE 1643• August 2017

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