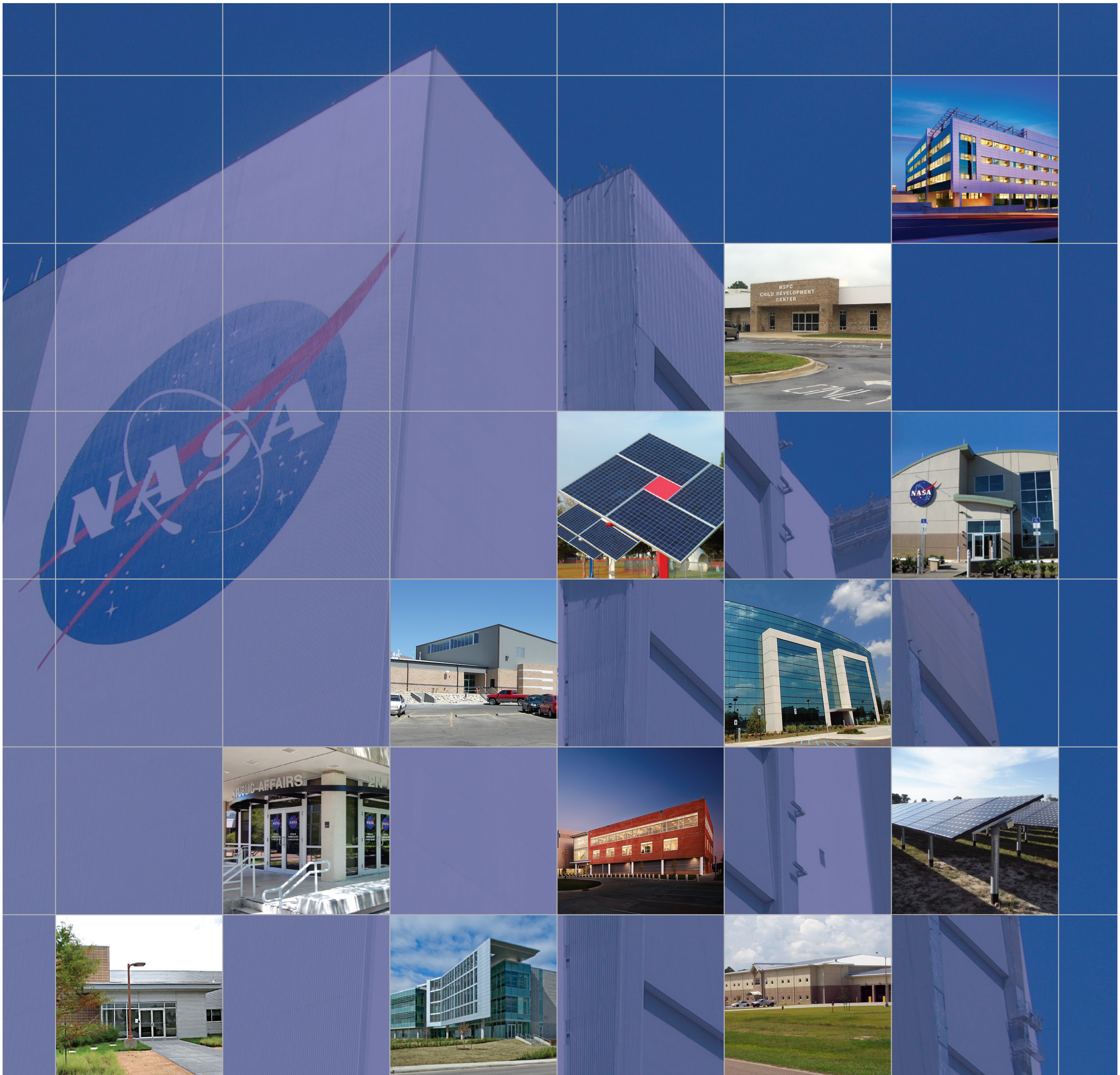
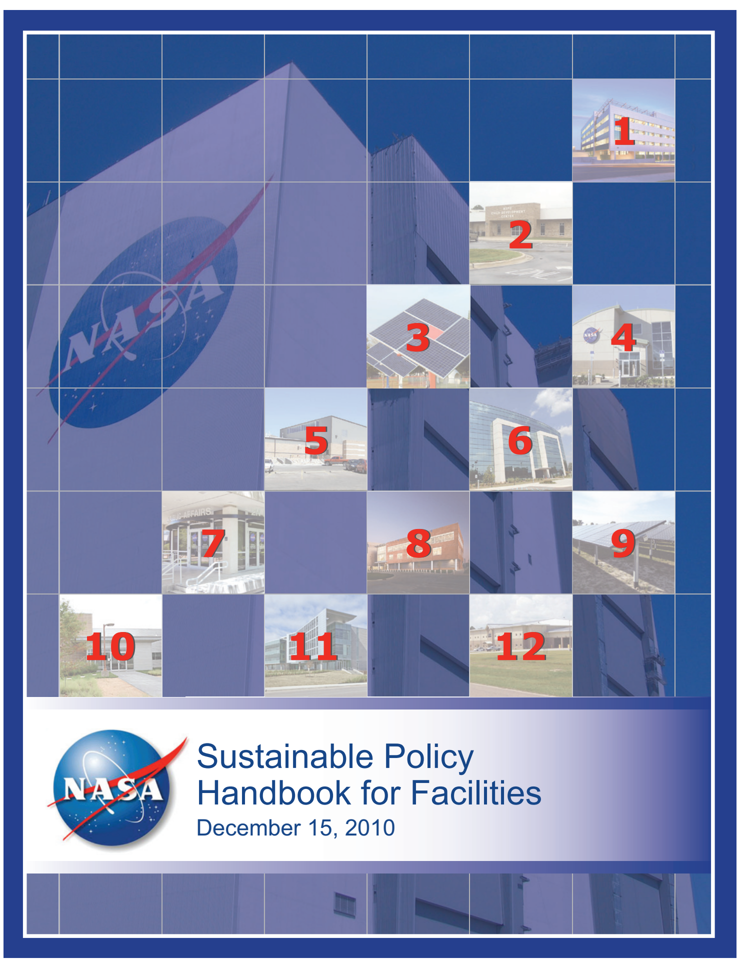


Sustainable Policy Handbook for Facilities

December 15, 2010



Cover Key

1. Building 321 – Jet Propulsion Laboratory
2. Building 4346 – Child Development Center – Marshall Space Flight Center
3. Building 211 – Child Day Care Center – Johnson Space Center
4. Propellants North Building – Kennedy Space Center
5. Building 107 – Columbia Health and Fitness Center – White Sands Test Facility
6. Building 4600 – Marshall Space Flight Center
7. Building 2 North – Johnson Space Center
8. Building 34 – Goddard Space Flight Center
9. Photovoltaic Farm – Kennedy Space Center
10. Building 27 – Johnson Space Center
11. Building 20 – Johnson Space Center
12. Building 8000 – Stennis Space Center

EXECUTIVE SUMMARY

The National Aeronautics and Space Administration's (NASA) unique and complex mission inherently inspires and drives leaping advances in technology that improves lives. As sustainable practices continue to mature in the building industry, NASA's Facilities Engineering Division (FED) has made notable advances over the last decade and these efforts have begun to permeate every phase of our facilities' life cycle from initial planning through maintenance and operation. FED remains committed to Federal sustainability policy, implementing goals and objectives in a practical and effective manner that benefits NASA's mission, the environment and surrounding community.

Overview of FED's Mission and Desired Outcome for Sustainable Facilities

The FED works with other Office of Strategic Infrastructure divisions, including Environmental Management Division (EMD) and others to ensure that facilities perform in an optimal manner to safeguard mission success. In its effort to sustain, modernize and revitalize NASA's real property, FED has continued its progress towards notable sustainability achievements and has laid a path towards an everyday work environment that fosters a culture of green building practices. Center activities are driving the evolution - incorporating industry best practices to ensure the most economic life cycle cost with the least impact to the environment. Through shared lessons among NASA's established community of practices and sustainability leaders, our Centers have been successful in delivering facilities that are maximizing the environmental, health, safety and productivity benefits to our building occupants. As the Center's ideas and successes spread further across the agency, NASA is also realizing the benefits of cost savings as we strive to achieve our energy reduction goals.

Sustainability Achievements

We have continued to advance our efforts of applying the US Green Building Council's Leadership in Energy and Environmental Design (LEED®) certification system in meaningful ways. In 2006, our facility requirements policy stipulated facility projects obtain a minimum rating of LEED® Silver and strive towards LEED® Gold when practicable. With the policy in effect, the number of LEED®-certified buildings in our inventory increased from 3 to 16. Our facility program policy also requires annual sustainability reporting so we can continue to measure the number of completed projects that are either eligible or have achieved LEED® certification. Our ability to measure the progress of our sustainability efforts will help to identify where shortcomings remain, and to improve further on our past performance.

Through the progress made in the last few years, we are already postured to immediately put into effect the High Performance and Sustainable Building (HPSB) guidance issued in December 2008 in order to meet the established goals of Executive Order 13423. A selection of NASA's sustainable innovation successes, addressing the five major principles in the HPSB guidance along with associated LEED® criteria are identified in Table 1.

Table 1 - Best High Performance & Sustainable Building Features from NASA Centers

	Employ Integrated Principles	**Optimize Energy Performance**	**Protect and Conserve Water**	**Enhance IEQ**	**Reduce Impact of Materials**	**LEED® Innovation**
ARC Collaborative Support Facility	X	X	X	X	X	X
GSFC Exploration Science Building	X	X			X	X
JPL Flights Project Center	X	X		X		X
JSC Astronaut Quarantine Facility	X	X	X	X		
JSC Exchange Recreation Facility	X	X		X		
JSC LEED® Office for Transition	X	X	X	X	X	
KSC Life Support Facility	X	X	X	X		

	Employ Integrated Principles	Optimize Energy Performance	Protect and Conserve Water	Enhance IEQ	Reduce Impact of Materials	LEED® Innovation
KSC Propellants North Administration & Maintenance Facility	X	X	X	X	X	X
LaRC New Town Phase 1		X	X	X		X
MSFC Office Buildings 4600, 4601 and 4602	X	X	X	X	X	X
SSC Emergency Operations Center & Cryogenics Facility	X	X	X	X	X	

Source: NASA Headquarters, FED.

Purpose of the Sustainable Handbook for Facilities and Intended Use

In accordance with the HPSB guidelines, the NASA Sustainable Handbook contained in this document has been updated to give clarity to how the HPSB principles can be uniformly applied throughout our facility inventory. The handbook also provides a collection of best practices within the NASA Centers through illustrative examples of concept strategies. The primary users of this document will be the facility managers who are responsible for their real property program assets at all our Centers.

The handbook is intentionally organized around the five guiding principles of HPSBs:

- Employ Integrated Principles
- Optimize Energy Performance
- Protect and Conserve Water

- Enhance Indoor Environmental Quality
- Reduce the Environmental Impact of Materials

The handbook purposely promotes the recommended technical strategies to set common targets for building performance. Through a process of standardization and mainstreaming of practices, our Centers will be able to accomplish their sustainability goals more effectively within their limited resources. Best management practices (BMPs) are targeted which are considered to be practical and cost effective.

One chapter is devoted to each of the five principles to guide individual facility decisions and activities. When needed, it will not be necessary for users to read the entire document from cover to cover. Each chapter follows a common format starting with basic description and intent of the guiding principle and associated topics. Tangible implementation steps are listed for each BMP. Each chapter also contains information on design or construction tools as well as references to other sources of information, building codes and standards or background research for each BMP. The level of information should furnish users with a basic understanding of activities involved with the strategies to achieve the desired outcome of the HPSB principle.

The handbook should help users to overcome the steep learning curve associated with either a lack of working knowledge or due to anticipated barriers that could impede progress towards optimizing building design, operations and maintenance by outlining and describing the steps involved with each BMP and pointing facility managers towards available tools and resources. As part of the development of the handbook, a *Feasibility Matrix for Applying Best Management Practices* was developed to furnish a general assessment of anticipated cost impacts, potential savings, timeframes, and applicability of the BMPs with comments on relevant NASA policy or procedures and/or LEED® credit attainment. This Matrix is found in Appendix I.

Relationship to NASA Policy, LEED® Rating Systems, and Federal Regulation

The Sustainable Handbook should be considered supplemental guidance to existing NASA policies and procedures and is intended to compliment the existing documents governing project planning, design, construction, operations, and maintenance. For each chapter and in context with each HPSB principle, related NASA Procedural

Requirements and Policy Directives are identified. Similarly, the handbook also denotes where LEED® credits could be earned during implementation. We encourage the pursuit of credit points towards project certification, and the identification of associated LEED® credits within the handbook should facilitate activities towards attaining certification goals. Applicable federal regulations are also listed in the Introduction to the handbook.

Expectations and Next Step for Centers

The use of this handbook will allow NASA to continue the transformation of our building inventory in a logical, productive manner that will eventually change how we do business every day. If followed, Centers could dramatically improve building performance and will continue to recognize the interdependency of the various architectural, mechanical, electrical, and site systems. Centers will also improve their ability to make comprehensive facility investment decisions that lead to long term operation and capital savings by setting appropriate priorities and performing upgrades in the proper sequence.

Path Forward for the Sustainable Facilities Program

The FED recognizes the need for the continued evolution of this handbook as we gain additional information from tracking building performance and as our Centers continue to learn from lessons gained from their sustainability efforts. As we build our database of knowledge, it may be necessary to delve further into sub-topics of each guiding principle to provide further granularity on certain subject matter areas and identify other action plans where needed. Also, FED's sustainability goals cross over into the traditional purview areas of the Environmental Management Division (EMD). This suggests an opportunity for FED to strengthen the partnership with EMD to better coordinate and synchronize our activities. This strengthened partnership will further enhance our efforts towards retaining the long-term value of our facilities which are vital to accomplishing NASA's mission and retaining the well-being of our business and personnel.

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Table of Contents

CHAPTER 3. PROTECT AND CONSERVE WATER

CHAPTER 4. ENHANCE INDOOR ENVIRONMENTAL AIR QUALITY

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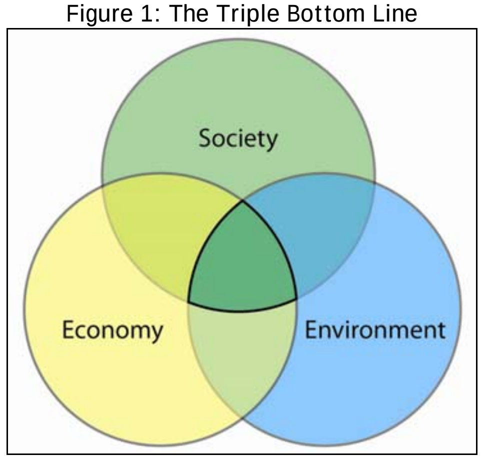
INTRODUCTION

Sustainability attempts to balance societal needs, environmental protection, and financial resources to promote both responsible resource management today and a high quality of life for future generations. Key elements of sustainability include effective use of resources including land, water, energy, and materials; protection of the natural environment including land, water, and air; and creation of a safe and healthy built environment for human societies. Sustainable design, operations, and maintenance principles provide an opportunity for improving resource management by balancing facility life-cycle cost, environmental impact, and occupant health, safety, security, and productivity. Such sustainable principles are often referred to as **green building** principles, which may help eliminate or reduce the negative environmental impacts of buildings, improve building performance, reduce long-term operating and maintenance costs, and increase worker productivity.

At NASA, sustainability means incorporating appropriate sustainable design practices, maintainable design elements, building commissioning processes, safety, health and security features into facility planning, design, construction, activation, operation and maintenance, and decommissioning to enhance and balance facility **life-cycle cost**, environmental impact, occupant health, safety, security, and productivity. Done properly, sustainability will optimize the facility acquisition process to ensure the "best fit" of the built environment to the natural environment. Sustainability also requires a practical and balanced approach to responsible stewardship of natural, human, and financial resources.[1] This balanced approach is also referred to as the **triple bottom line** approach.

Calculating the triple bottom line is difficult because societal concerns and environmental benefits are often non-quantifiable. Traditional first-cost approaches may devalue the impact of decisions that benefit the environment or human health and safety. Life-cycle costs allow for long-term payback periods that capture incremental savings from improved efficiency, waste reduction, or benefits to health, safety, or environmental well-being.

Figure 1: The Triple Bottom Line



Challenges

Sustainability policy implementation is limited by a number of challenges. Although many policies and building improvements can be implemented at little cost, achieving some goals may require significant financial resources for construction or renovation. Funding for these expenses may exceed the normal yearly operating budget, so creative financing may be required. Implementing other policies or improvements require simple technology or procurement changes that are of a low cost when compared with the scale of a facility's annual operations and maintenance budget, but require increased staff time for documentation, enforcement, tracking, or other tasks.

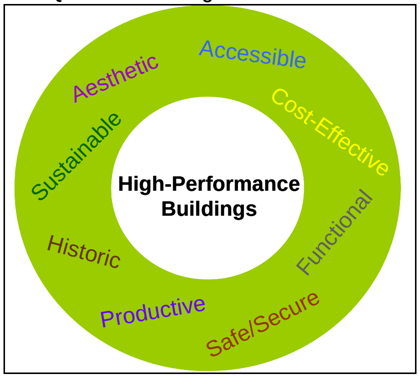
A second major challenge to implementing sustainability is balancing conflicting goals.

[1] NPR 8820.2F Facility Project Requirements.

For example, energy consumption goals must be balanced with occupant comfort in the warm summer months, especially in the southern United States. In other facilities, the nature of the work done in the building or the building type itself may conflict with sustainability goals. One example is data centers that consume large amounts of energy to perform critical functions and to maintain appropriate indoor temperature and humidity levels for the electronic equipment.

Lastly, Center resources must be dedicated to make sustainability a priority for facility managers. While some of those resources must be financial, the most important resource is time. Planning and documentation of sustainability measures are critical in achieving initial goals and maintaining the benefits of sustainable buildings. For many Center staff, the move towards sustainable buildings is a new process requiring a significant increase in understanding.

Figure 2: Qualities of High Performance Buildings



Utilizing the Sustainable Policy Handbook

In order to standardize and streamline NASA's sustainability goals, the *Sustainable Policy Handbook for Facilities (Handbook)* addresses the mission to manage facilities in the utmost sustainable manner that is economically responsible and feasible. NASA is developing strategies and best practices to meet federal goals and guidelines for high performance and sustainable buildings. The guidelines that become a foundation for agency policy will direct NASA toward meeting the federal requirements for specific sustainability goals for all agency-owned and operated facilities.

In this *Handbook*, sustainable principles will be discussed as they apply to NASA-wide facility management decisions regarding planning, design, construction, activation, operations and maintenance, and decommissioning. This *Handbook* provides basic-level information relevant to all facility managers. It also provides helpful links to websites and documents where other, more in-depth information can be found relating to specific sustainability goals, environmentally-friendly products, industry practices, or sample policies.

For the purpose of this *Handbook*, sustainability has been divided into several sections: Employ Integrated Principles, Optimize Energy Performance, Protect and Conserve Water, Enhance Indoor Environmental Quality, and Reduce Environmental Impact of Materials. In each area, the *Handbook* highlights practical actions that facility managers, planners, and design and construction staff can take to limit natural resource use, improve the comfort and productivity of building occupants, and reduce long-term facility costs.

Each section will follow the subject format and content identified within the *Guiding Principles for High Performance and Sustainable Buildings* (*Guiding Principles*). The best management practices (BMP) are derived from the *Guiding Principles*, existing NASA policy, and other sustainability standards. Each of the BMPs includes implementation steps for NASA facilities. Each BMP also includes related NASA activities and accomplishments, related Leadership in Energy and Environmental Design (LEED®) requirements, and tools that provide additional information or assistance. The sections and BMPs of the *Handbook* can be read independently, or all at once.

Existing Guidelines

In recent years, sustainability has become a priority for federal facilities management programs. The federal government now requires facility managers to be proactive in their efforts to reduce resource consumption, reuse and recycle materials, and lessen the impact of federal activities on the environment. State and local governments, non-governmental organizations, and private industry have expanded their role in promoting sustainable practices. NASA's own sustainability goals build upon existing federal regulations, established BMPs, and industry standards. Key requirements, regulations, and guidance are summarized below.

Federal Law	
Resource Conservation and Recovery Act	
	The Resource Conservation and Recovery Act (RCRA) 6002 established a federal mandate to "buy recycled" beginning in 1976. RCRA 1008 and 6004 also required all federal agencies generating solid waste to take action to recover it.
	www.epa.gov/lawsregs/laws/rcra.html
	www.epa.gov/wastes/inforesources/online/index.htm
Energy Policy Act of 2005	
	The Energy Policy Act of 2005's **(**EPAct 2005) stated goal is to ensure jobs for the future with secure, affordable, and reliable energy. EPAct 2005 updates polices from EPAct 1992 by providing revised annual energy reduction goals for federal facilities and revises renewable energy purchase goals. EPAct 2005 also reauthorizes the use of Energy Savings Performance Contracts (ESPC) through 2016. It requires procurement of energy-efficient products and provides updated federal green building standards with emphasis on energy efficiency and sustainable design principles.
	http://www1.eere.energy.gov/femp/regulations/epact2005.html
Energy Independence and Security Act of 2007	
	The Energy Independence and Security Act of 2007 (EISA 2007) includes the goal of moving the United States toward greater energy independence and security; increasing the production of clean renewable fuels; increasing efficiency of products, buildings, and vehicles; promoting research and development of greenhouse gas capture and storage options; and improving the energy performance of the federal government. It requires greater tracking of green initiatives in federal facilities and provides new oversight of federal high performance and green building activities.
	http://www1.eere.energy.gov/femp/regulations/eisa.html

Executive Order (EO)
EO 13058 of August 9, 1997, "Protecting Federal Employees and the Public from Exposure to Tobacco Smoke in the Federal Workplace."
EO 13058 mandates that federal workplaces be smoke-free environments by prohibiting smoking in all interior spaces owned, rented, or leased by the executive branch of the federal government and in any outdoor areas in front of air intake ducts that are under executive branch control. The EO recommends that each agency establishes and maintains a smoking ban around building perimeters or within certain distances of doorways but does not provide guidance as to the extent of the area outside of the building that should be smoke free.
http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=1997_register&docid=fr13au97-133.pdf
EO 13423 of January 24, 2007, "Strengthening Federal Environmental, Energy, and Transportation Management."
EO 13423 requires that federal agencies conduct their environmental, transportation, and energy-related activities in an environmentally, economically, and fiscally sound, integrated, continuously improving, efficient, and sustainable manner. It requires reductions in greenhouse gas emissions, increases in renewable energy use, greater water efficiency, and procurement of sustainable and efficient products. In addition, it requires incorporating the *Guiding Principles for Federal Leadership in High-Performance and Sustainable Buildings* into 15 percent of the capital asset building inventory by the end of 2015. Finally, it requires agencies to implement environmental management systems (EMS).
http://www1.eere.energy.gov/femp/regulations/eo13423.html
EO 13514 of October 5, 2009, "Federal Leadership in Environmental, Energy, and Economic Performance."
EO 13514 requires that federal agencies establish and report an annual comprehensive inventory of scope 1, 2, and 3 greenhouse gas emissions, as well as a greenhouse percentage reduction target. It requires improvements in water use efficiency and management, as well as promoting pollution prevention and eliminating waste. Furthermore, it requires agencies designate a Senior Sustainability Officer as well as to develop, implement, and update an integrated Strategic Sustainability Performance Plan (SSPP). The SSPP provides overall policy guidance for multiple sustainability-related topics and activities.
http://www1.eere.energy.gov/femp/regulations/eo13514.html

Code of Federal Regulations (CFR)	
10 CFR 433	
	This regulation establishes energy-efficiency performance standards for new federal commercial and multi-family high-rise buildings, for which design for construction began on or after January 3, 2007.
	http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title10/10cfr433_main_02.tpl
10 CFR 436	
	This regulation establishes procedures for determining the life-cycle cost effectiveness of energy conservation measures and for setting priorities for energy conservation measures in retrofits of existing federal buildings. Subpart B establishes an ESPC program to accelerate investment in cost-effective energy conservation measures in federal buildings.
	http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title10/10cfr436_main_02.tpl
48 CFR 23	
	This regulation prescribes acquisition polices to support the government's program for protecting and improving the quality of the environment by controlling pollution; efficiently managing energy and water use in federal facilities; using renewable energy and renewable energy technologies; and acquiring energy- and water-efficient products and services, environmentally preferable products, and products using recovered materials.
	http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title48/48cfr23_main_02.tpl

Other Federal Guidance

Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding (MOU)

Through this MOU signed in January 2006, the signatory agencies, including NASA, committed to federal leadership in the design, construction, and operation of high-performance, sustainable buildings. The goals of the MOU include developing principles to guide federal agencies in reducing the total ownership cost of facilities; improving energy efficiency and water conservation; providing safe, healthy, and productive built environments; and promoting sustainable environmental stewardship.

http://www.fedcenter.gov/_kd/Items/actions.cfm?action=Show&item_id=4713&destination=ShowItem

Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings

The *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings (Guiding Principles)*, initiated by the Federal Leadership in High Performance and Sustainable Buildings MOU, provides direction to facility planners, designers, and managers regarding integrated design and maintenance, energy performance, water conservation, indoor environmental quality, as well as materials and resource use. This document is split into two sections: the *Guiding Principles for Sustainable New Construction and Major Renovation* and the *Guiding Principles for Sustainable Existing Buildings*.

http://www.wbdg.org/references/fhpsb.php

Office of Management and Budget Scorecards

In January 2006, the Office of Management and Budget (OMB) introduced scorecards for Energy and Environmental Stewardship to track how well Agencies are executing targeted government-wide management initiatives. These scorecards draw upon existing requirements and focus on the progress and results of Agencies in meeting established goals. The Energy Scorecard tracks renewable energy projects, renewable energy purchase, energy-use reduction, energy auditing, ESPCs, and Utility Energy Services Contracts (UESC), sustainable design principles, and training for staff relating to energy-efficiency. The Environmental Stewardship Scorecard tracks Agency progress on meeting EMS protocol, comprehensive green purchasing, green building, electronic stewardship, and compliance with management plan goals.

http://www.fedcenter.gov/Documents/index.cfm?id=14814&pge_id=1854

NASA Policy Directives and Procedural Requirements

Multiple NASA Policy Directives (NPD) and NASA Procedural Requirements (NPR) relate to the Agency's sustainability goals. The following NPRs and NPDs are official NASA policy.

For more information: http://nodis3.gsfc.nasa.gov/main_lib.html

NASA Policy Directive and Procedural Requirements	
Program Formulation	NPD 7330.1H, Approval Authorities for Facilities Projects
	NPR 7120.5, Program and Project Management Processes and Requirements
Program Management	NPD 8500.1B, NASA Environmental Management
	NPD 8800.14D, Policy for Real Estate Management
	NPD 8810.2A, Master Planning for Real Property
	NPD 8820.2C, Design and Construction of Facilities
	NPD 8831.1E, Maintenance and Operations of Institutional and Program Facilities and Related Equipment
	NPR 8530.1A, Affirmative Procurement Program and Plan for Environmentally Preferable Products
	NPR 8553.1B, NASA Environmental Management System
	NPR 8570.1, Energy Efficiency and Water Conservation
	NPR 8580.1, Implementing the National Environmental Policy Act and EO 12114
	NPR 8800.15B, Real Estate Management Program
	NPR 8810.1, Master Planning Procedural Requirements
	NPR 8820.2F, Facility Project Requirements
	NPR 8831.2E, Facilities Maintenance and Operations Management
Other Directives and Requirements	NPR 3600.1A, Attendance and Leave

NASA Strategic Sustainability Performance Plan

The SSPP is a planning document by which sustainability and sustainable practices will be integrated into NASA efforts, activities, and culture. NASA's SSPP has three areas of emphasis:

- To set forth NASA's overarching strategy and framework for achieving the long-term sustainability goals contained in existing statutory requirements and executive orders.
- To describe the management methods and approaches that integrate external requirements related to national prosperity, energy security, and health environment into a single framework for aligning NASA activities, processes, and resources to achieve NASA's sustainability goals and targets.
- To describe the approach for annually reporting process, successes, and challenges, and evaluating performance to drive continuous improvement.

http://www.nasa.gov/agency/sustainability/index.html

Sustainable Design Guidance

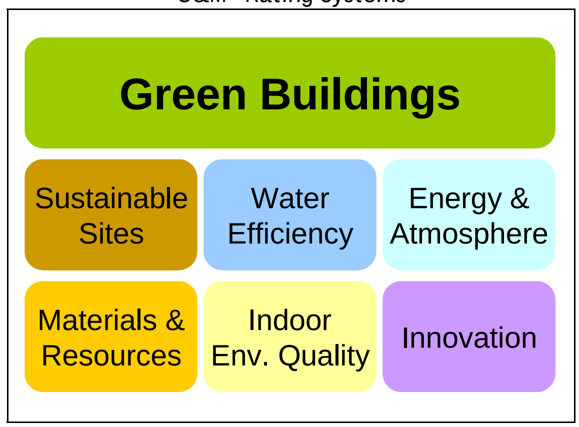
Leadership in Energy and Environmental Design Building Certification

The Leadership in Energy and Environmental Design (LEED®) Certification Program was developed by the United States Green Building Council (USGBC) as a way to define and measure sustainably designed buildings. The LEED® Rating System is voluntary, consensus-based, and market-driven. It evaluates environmental performance from a whole-building perspective over the building's life cycle. When used in conjunction with a sustainability rating program such as LEED®, this *Handbook* should assist in compiling the necessary documentation required for certification.

LEED® certifications exist for New Construction and Major Renovations (LEED-NC®), Commercial Interiors (LEED-CI®), Core and Shell (LEED-CS®), Schools (LEED-S®), Healthcare (LEED-HC®), Retail (LEED-R®), Homes (LEED-H®), and Neighborhood Development (LEED-ND®). In addition, the LEED® Existing Buildings: Operations and Maintenance (LEED-EB: O&M®) certification focuses solely on maintaining existing facilities in a sustainable manner. Most NASA facilities will be eligible for either LEED-NC® or LEED-EB: O&M® certification and may also be eligible for LEED-ND®. NASA has set an Agency-wide goal of achieving LEED-NC® Silver certification for its new construction projects. LEED-EB: O&M® certification is recommended for existing buildings, when cost-effective.

All of the LEED® systems except LEED-ND® divide the points into credits spread across six categories: Sustainable Sites (SS), Water Efficiency (WE), Energy and Atmosphere (EA), Materials and Resources (MR), Indoor Environmental Quality (IEQ), and Innovation. Buildings are eligible to qualify for Certified, Silver, Gold, or Platinum ratings based on the total number of points achieved. The LEED-ND® credit system divides the points into credits across four categories: Smart Location and Linkage (SLL), Neighborhood Pattern and Design (NPD), Green Infrastructure and Buildings (GIB), and Innovation. Facilities and the associated project team must be registered with the Green Building Certification Institute (GBCI), which handles certification of buildings and accreditation of industry professionals.

Figure 3: Components of the LEED-NC® and LEED-EB: O&M® Rating Systems



In 2009, LEED® underwent several weighting and alignment changes to the credits and points. The credits are still organized into the same systems, such as LEED-NC® and LEED-EB: O&M®, but are now referred to as the LEED® 2009 credit systems. **In this document, all LEED® points and credits will follow the 2009 version.**

LEED® for New Construction and Major Renovation.

Design and construction projects for most facilities utilize the LEED-NC® credit system. The LEED-NC® rating system can be used to develop the initial design, or applied later in the process to identify opportunities to improve the facility's performance through design changes. Experienced professionals assist the project team to develop life-cycle cost-effective changes and a feasible implementation strategy. Throughout the design and construction phases, the project team should document their sustainability decisions and submit required credit information for approval.

Renovation projects may also qualify for LEED-NC® certification if they involve replacement or retrofit of one or more major building systems and/or significant interior demolition. LEED-NC® should be considered if the project intends to replace building mechanical systems, provide new windows, upgrade exterior walls, and/or renovate significant amounts of the building's interior.

LEED® for Multiple Buildings and On-Campus Buildings.

Within the LEED-NC® rating system, facility managers can register multiple buildings or a campus of facilities at once. With the Multiple Buildings and On-Campus certification system, project managers can certify three types of construction: a new building within a setting of existing buildings under common ownership and control, a group of new buildings under one rating, or new buildings in which each new building is constructed to the same set of standards. Using LEED® for Multiple Buildings and On-Campus Buildings can significantly streamline the LEED® credit documentation process. Campus-wide credits can be applied to all buildings pursuing certification by only submitting documentation once.

LEED® for Existing Buildings: Operations and Maintenance.

Existing buildings generally qualify for the LEED-EB: O&M® credit system. Certification through LEED-EB: O&M® provides building owners and operators whose buildings have never been LEED® certified with guidance, incentives, and recognition for upgrading existing buildings to more sustainable levels. This program also recertifies buildings previously certified through one of the design/construction-related LEED® rating systems. Recertification helps to ensure that buildings continue to operate in a manner consistent with green practices or identifies where operations can be made more sustainable. Buildings certified through the LEED-EB: O&M® rating system must resubmit credit documentation every five years to maintain certification.

United States Green Building Council

For more information: www.usgbc.org

Green Building Certification Institute Professional Accreditation

The Green Building Certification Institute (GBCI) provides a professional credentialing program for independent administration and verification of LEED® Professional Credentials. Upon completing the program, the credentials demonstrate current knowledge of green building technologies, industry best practices, and the rapidly evolving LEED® credit systems. Due in part to the content and approach of the credit systems, professionals who achieve GBCI accreditation understand integrated and comprehensive approaches to building design and operation.

Green Building Certification Institute

For more information: www.gbci.org

Cradle to Cradle Design

The Cradle to Cradle (C2C) design system models human industry on natural processes, in which material inputs may be continuously reused for high-quality purposes. It seeks to create systems that are efficient and waste-free. The C2C model focuses on the development of sustainable products that meet the goals of the triple bottom line approach: environment, economy, and human health. Often C2C design focuses on industrial processes and materials. The use of synthetic materials and ways that they can be recycled or reintroduced into the natural environment without causing harm is a concern of C2C designers.

While C2C technologies were first discussed in the 1970s, William McDonough and Michael Braungart popularized the term "Cradle to Cradle" in their 2002 book, *Cradle to Cradle: Remaking the Way We Make Things*. Subsequently, a certification program for C2C goods has emerged. The C2C product list is extensive, ranging from cleaning products to building construction materials and clothing.

For more information: www.mbdc.com/c2c

Whole Building Design Guide

The Whole Building Design Guide (WBDG) is a web-based portal that provides government, industry designers, and building managers with facilities-related information for an integrated design approach and team process for high performance buildings. The WBDG is divided into three areas: Design Guidance, Project Management, and Operations and Maintenance. The Guide is provided through the National Institute of Building Sciences (NIBS) with funding support from the Department of Defense (DoD), Naval Facilities Engineering Command (NAVFAC) Engineering Innovation and Criteria Office (EICO), the US Army Corps of Engineers (USACE), the US Air Force (USAF), the General Services Administration (GSA), the Department of Veterans Affairs (VA), NASA, the Department of Energy (DOE), and the assistance of the Sustainable Buildings Industry Council (SBIC).

For more information: www.wbdg.org

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CHAPTER 1. EMPLOY INTEGRATED PRINCIPLES

Background

Facilities designed and operated with an integrated approach can be more sustainable and cost-effective over their entire life cycle than traditionally designed facilities. Integrated design, development, assessment, operations, and maintenance approaches can be achieved through a variety of means. By employing a multi-disciplinary approach to design and operations, project teams can achieve sustainability goals while dramatically improving overall facility performance.

Sustainable design, construction, operation, and maintenance can significantly reduce a facility's energy and water consumption, limit and improve its indoor environmental quality (IEQ). Building 20 at Johnson Space Center incorporated many of these sustainable features, and is pictured in Figure 1.

Existing facilities can also optimize performance through commissioning and re-/retro- commissioning, which ensures that systems are installed and operated according to their design documents and that they are performing efficiently. This standardized, documented process can improve building performance and energy efficiency in a number of ways.

Chapter Outline

To achieve federally mandated goals, each agency should employ a systematic approach to sustainability investment. Integrated principles can be incorporated into facility projects through:

- *Integrated Design & Development*
- *Integrated Assessment, Operations, and Maintenance*
- *Whole Building Commissioning*

Figure 1 – Building 20, Johnson Space Center, Houston, Texas

Source: NASA.

Integrated Design & Development

Successful high-performance and sustainable buildings require significant planning, design, and execution. Integrated design and development requirements for new construction and major renovation projects are found in the *Guiding Principles for Sustainable New Construction and Major Renovations,* which is mandated by Executive Order (EO) 13423.

Best management practices (BMP) for incorporating integrated approaches from the *Guiding Principles for Sustainable New Construction and Major Renovation* include implementation steps for NASA facilities. The BMPs also include discussion of related NASA activities and accomplishments, applicable Leadership in Energy and Environmental Design (LEED®) requirements, and resources for additional information and assistance.

The Integrated Design & Development BMPs for new construction and major renovations include the following requirements:

- Employ an integrated project team as described in the National Institute of Building Science's Whole Building Design Guide (WBDG) in all stages of the project's planning and delivery.
- Establish facility performance goals for siting, energy, water, materials, and indoor environmental quality, in addition to other comprehensive design goals. Establish mechanisms by which to attain these goals throughout the design and life cycle of the building.
- Implement the Office of Management and Budget's (OMB) Circular A-11, Section 7, Exhibit 300, Capital Asset Plan and Business Case Summary.

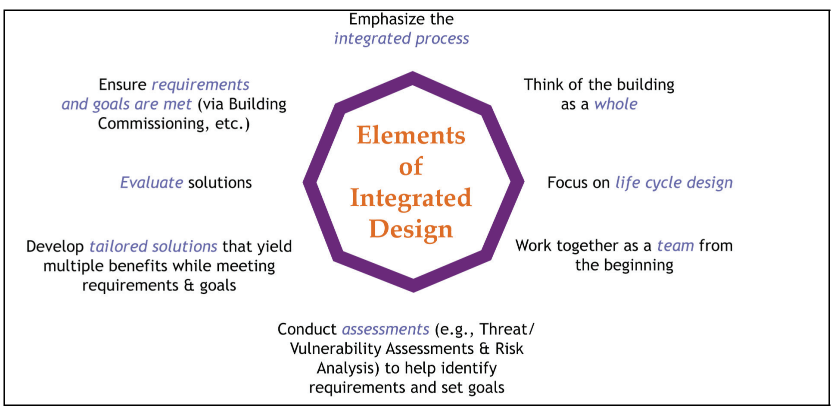
BEST MANAGEMENT PRACTICE – INTEGRATED PROJECT TEAM

Employ an integrated project team as described in the Whole Building Design Guide in all stages of the project's planning and delivery.

The Construction of Facilities (CoF) process at NASA uses a "design for maintainability" approach that considers operations, maintenance, life-cycle costs and other requirements in new facility design. The Agency, through the Engineering and Construction Innovations Committee (ECIC), encourages use of integrated project teams.

The *Guiding Principles* use the WBDG model in its definition of integrated project teams. According to the WBDG, an integrated project team uses an integrated design approach and an integrated team process in all stages of project planning and delivery. Each project should have comprehensive design objectives, including access, aesthetics, cost effectiveness, functionality, historic preservation, productivity, security/safety, and sustainability.[1] The WBDG elements of integrated design are illustrated in Figure 2.

Figure 2 – Elements of Integrated Design



Source: Whole Building Design Guide.

In an integrated process, all team members analyze the project from the perspective of each of these objectives, rather than focusing solely on their own areas of expertise. This approach strives to ensure understanding, shared

[1] Prowler, Don. "The Role of Buildings and the Case for Whole Building Design." Whole Building Design Guide, 2008.

knowledge, and close cooperation among team members throughout the project. In an example of an integrated process, operations and maintenance (O&M) staff would be included in facility design decisions, allowing them better insight into future maintenance requirements and ensuring that their input is considered in equipment purchase and other decisions.

Rule of Thumb

The Facility Project Management Plan establishes a project schedule with well-defined milestones; and assigns roles, responsibilities, and levels of authority to develop and implement the project.

Specific integrated team elements described in NPR 8820.2F include the assignment of a Facility Project Manager (FPM) to lead each CoF project team. The FPM is responsible for organizing, managing, and directing facility project work with the support of a project team. All individuals or organizations responsible for CoF project implementation, including the FPM and project team, are identified in the Facility Project Management Plan.

To support the FPM in planning and managing CoF projects, an integrated project team should be established. The FPM and planning team identify the project's initial goals and objectives. The **Front-End Planning** (FEP) process, which includes all project stakeholders, begins when these goals and objectives have been established. Using the Project Definition Rating Index (PDRI), the FPM and project team evaluate and score the project on scope definition and alignment among team members. This can be performed individually or in a group.

Definition

Front-End Planning

Front-End Planning (FEP) establishes the project requirements and concept and provides the basis for project budget and approval. The primary tool to accomplish FEP is the Project Definition Rating Index (PDRI).

Once the facility project manager and the planning team have identified the initial project goals and objectives, the FEP process starts and continues through the approval of the design statement of work and the start of final design.

Implementing an Integrated Design Team

Table 1 illustrates the steps required to implement an integrated design team. These steps are discussed in detail in the subsequent narrative.

Table 1 - Implementing an Integrated Design Team

	IMPLEMENTATION STEPS
1)	**Define the Need for an Integrated Approach**
□	Identify the facility project manager.
□	Identify project goals and objectives, establish project requirements and concept, and develop the basis for the project budget.
2)	**Charter Development**
□	Expand on the team's purpose, outcomes, responsibilities, and authority.
□	Establish procedures for team membership and external reporting.
3)	**Membership Selection**
□	Include a LEED® AP on the project team.
□	Ensure all necessary skills are represented among team members.
4)	**Team Training**
□	Establish team training requirements.
□	Ensure training is attended by all team members and the team leader.
5)	**Develop Internal Roles and Responsibilities**
□	Determine if a facilitator or other role is appropriate for the project.
□	Develop internal processes such as decision-making, meetings and communication, team dynamics, team self-assessment, and interfacing with external groups.
□	Ensure meeting minutes are taken and distributed.
□	Ensure the team membership list is regularly updated.
6)	**Elaborate Specific Goals**
□	Enhance the detail on each of the project's end products.

1) Define the Need for an Integrated Approach

The FPM must define the need to be addressed by the team if an integrated approach is to be successful. This will occur during the FEP process or during development of the Facility Project Management Plan. As part of the FEP process, the FPM and project planning team identify project goals and objectives, establish project requirements and concept, and develop the basis for the project’s budget.

Identifying stakeholders and determining an appropriate level of involvement for them may assist the FPM with project development. Once the project has been broken into component stages and stakeholder groups have been identified, the FPM may then determine each stakeholder’s involvement in each stage as “support,” “decision-making,” “oversight,” or “none”.

> ***Rule of Thumb***
>
> *The charter should address the following:*
>
> - *Well-defined purpose*
> - *Expected process outcomes*
> - *Authority and decision-making power*
> - *External processes for reporting progress and decisions*
> - *Team membership; both size and composition*

2) Charter Development

Once project goals, objectives, requirements, and concept are established, the project team may benefit from a more detailed charter, which will define the team's purpose, responsibilities, and authority. The FPM will usually assume the role of process leader in developing the charter.

A well-functioning team should have decision-making authority extending from the charter into the project structure. An effective team must be able to enact as many of its recommendations as possible without need for additional levels of approval. Proper anticipation of costs and support are also necessary to establish a successful team.

3) Membership Selection

In addition to a well-designed process, an effective project team needs team members with appropriate interest and knowledge. According to a General Accounting Office (GAO) review of integrated team projects, "research shows that product development responsibility and cross-functional membership are fundamental [team] elements."[2] The FPM should ensure that affected stakeholder groups are adequately represented in the team's membership. The project team should "include all project stakeholders, such as representatives from the using organization, safety, health, engineering, fire protection, security, environmental, acquisition, operations and maintenance, and technicians."[3]

Team members should be chosen based on their specific knowledge or expertise; ensuring that team members possess relevant skills and knowledge is critical. Inclusion of stakeholders who represent all phases of the project's life-cycle also helps ensure early and continuous life-cycle planning.[4]

Leading or participating in a project team is a significant time commitment, and expectations should be discussed with potential team members and their supervisors. To ensure appropriate documentation and record-keeping, FPMs should maintain team membership lists.

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[2] Best Practices: DoD Teaming Practices Not Achieving Potential Results, General Accounting Office, GAO-01-510, April 2001.

[3] NPR 8820.2F, Facility Project Requirements, NASA.

[4] *DoD Integrated Product and Process Development Handbook*, Office of the Under Secretary of Defense (Acquisition and Technology), August 1998.

4) Team Training

After the project team has been established, team members should be trained on project approach, processes, and purpose. Creation of a project team is a substantial undertaking, so proper team training is a worthwhile investment of time and resources. Research on the effectiveness of integrated process teams indicates that "almost universally…an investment in initial training always pays off in terms of time saved downstream."[5] If specific skills training is necessary, that training should be included in the preliminary team training.

5) Develop Internal Roles and Responsibilities

Once training is complete, the FPM and team members should establish roles and procedures governing the project's internal operation. During these discussions, the team should clarify any remaining issues or expectations concerning the FPM's role. If necessary, the team may designate an impartial facilitator to focus on team dynamics and adherence to team agreements and processes. Depending on the nature of the project, the FPM may find it necessary to assign additional roles such as subject matter expert, external group coordinator, and project scheduler.

Initial team meetings should also focus on establishing internal processes, including decision making, meetings and communication, team dynamics, team self-assessment, and interaction with external groups. The decision-making process is authorized by the charter and is the most important process for the team to develop. Establishing communication methods that ensure fair and balanced participation from all team members is also important.

Rule of Thumb

Taking minutes at team meetings is recommended as a means of enhancing communication and documenting team discussions.[6]

6) Elaborate Specific Goals

The project team's goals, intended outcomes, and other performance measures should be outlined in the team charter, which should also offer detail concerning how these goals and outcomes will be achieved. When establishing goals and milestones, the interests and input of all stakeholder groups should be considered to ensure consensus.

[5] Integrated Project Team Start-up Guide, Mitre Corporation, 2008.

[6] Department of Interior Sustainable Building Assessment and Compliance Tool.

Related LEED® Credits

The LEED® credits related to integrated design teams are illustrated in Table 2. Definitions for all LEED® abbreviations and information about LEED® professional accreditation appears in the Introduction.

Table 2 - LEED® and Integrated Design Teams

LEED-NC®	ID Credit 2: LEED® Accredited Professional
LEED-EB: O&M®	IO Credit 2: LEED® Accredited Professional
LEED-ND®	IDP Credit 2: LEED® Accredited Professional

TOOLS

Whole Building Design Guide

The WBDG is a web-based portal providing integrated design, construction, management, and operations guidance.

For more information:
www.wbdg.org/design/engage_process.php

Project Definition Rating Index

The PDRI is a tool developed by the Construction Industry Institute (CII) to measure project scope definition and to assist project participants. The PDRI is a requirement of all CoF projects in the planning stage, per NPR 8820.2F.

For more information:
www.hq.nasa.gov/office/codej/codejx/Assets/Docs/ProjectDefinitionRatingIndex.pdf

Mitre IPT Start-up Guide

The Mitre Corporation offers a start-up guide for developing, managing, and evaluating integrated project teams (IPT) in federal agencies.

For more information: www.mitre.org/tech/successful_ipts/

LEED® Online

Through LEED® Online, project team members can track progress and communicate with other team members.

For more information:http://www.gbci.org/main-nav/building-certification/leed-online/about-leed-online.aspx

Best Management Practice – Facility Performance Goals

Establish facility performance goals for siting, energy, water, materials, and indoor environmental quality along with other comprehensive design goals. Ensure incorporation of these goals throughout the design and life-cycle of the building.

Integrated and comprehensive design goals help ensure that the completed facility will achieve high performance objectives while meeting stakeholder needs. As an organization, NASA currently pursues a variety of federal and agency sustainability goals. Individual Centers and facilities support the Agency in various ways and may set their own goals that exceed Agency-wide goals. Individual facility goals are established with careful regard for interdependency among facilities.

All phases and aspects of the project should be considered in establishing performance goals as significant interrelationships and interdependencies exist among the various building systems. These relationships should be taken into account early in the programming and planning stage. Accountability for performance and progress toward goals should also be established and documented in a systematic fashion.

A complex but effective method for establishing project objectives is the **design charrette**. A design charrette takes place over several days, bringing many stakeholders together in a collaborative process that improves communication and increases opportunities for consensus. The charrette can also ensure that energy and environmental issues are integrated into every phase of the facility's design, construction, and operation.

NASA Requirement

NPR 8820.2F establishes goals for energy and water use, construction waste, indoor air quality, ventilation, daylighting, biobased and recycled content, and ozone-depleting compounds.

NPR 8570.1 establishes Agency goals for energy and water consumption, greenhouse gas emissions, energy efficiency, renewable energy, and petroleum use. Requirements on energy and water audits, cost analysis, sustainable design principles, and ENERGY STAR products are also provided.

Definition

Design Charrette

A collaborative, structured multi-day process that brings many stakeholders together for group decision-making and project design development. A charrette can greatly enhance the goal-setting process by integrating energy and environmental issues in the facility's design, construction, and operation, in addition to increasing consensus and communication.

Implementing Integrated and Comprehensive Performance Goals

The steps necessary for implementing integrated and comprehensive performance goals are listed in Table 3. These steps are discussed in additional detail in the subsequent narrative.

Table 3 - Implementing Integrated and Comprehensive Performance Goals

IMPLEMENTATION STEPS	
1)	**Consider the Context**
□	Identify existing federal and Agency polices.
□	Identify previous high performance and sustainable building efforts.
2)	**Assess Current Performance**
□	Benchmark current performance through technical assessment or audit.
□	Utilize technologies such as BIM to improve project design.
□	Track performance trends against baseline information.
3)	**Determine Scope**
□	Establish the building or Center goal level.
□	Establish the appropriate time period.
4)	**Establish Goals**
□	Account for all applicable federal and Agency requirements.
□	Utilize a design charrette process.
□	Document building performance goals in construction documents.

1) Consider the Context

Any effort to establish effective performance goals must consider the context in which these goals will be set. Organizations, departments, or individuals may have a specific vision for sustainability, and existing federal and NASA policies provide direction and guidance on many design and operational elements. For example, EO 13423, “Strengthening Federal Environmental, Energy, and Transportation Management,” requires agencies to achieve reductions in greenhouse gas emissions, water consumption, energy consumption, and toxic and hazardous chemical use.

Analysis of best practices established in other high performance and sustainable building projects may help teams to determine if these practices are feasible in new projects. By studying past projects, teams may also develop points of reference for measuring potential energy efficiency or cost savings.

A review of other Centers’ or federal agencies’ goals can help teams to establish feasible performance goals and methods for achieving them. Individual projects can then be designed to meet these individual goals and to comply with federal and NASA requirements.

2) Assess Current Performance

A facility's current design and/or operations should be assessed during the goal-setting process. By assessing the facility's performance and baseline data, project teams can gain a limited point-in-time view of current operating designs or conditions. Data gathered over a longer period of time will provide trending and seasonal performance information for existing facilities.

> ***Rule of Thumb***
>
> *Existing facilities preparing for major renovation can use technical assessments or audits to identify opportunities for operational improvement, and to justify the cost of improvements.*

Audits establish a facility's baseline performance, which ensures that potential goals are based on realistic understanding of the facility's existing condition. Goals established with actual building data and including the consensus of project stakeholders have a better chance of success. Specifically, energy efficiency can be evaluated through energy audits or through the re-/retro-commissioning process. Any audit of energy or water use must be based on careful measurements. In addition, a solid waste audit can identify many opportunities for improvements in waste management.

The re-/retro-commissioning process is detailed on page 1-45. Energy audits consistent with the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) standards are detailed in Chapter 2, page 2-4.

Pre-construction design assessments are also possible through use of technologies such as building information modeling (BIM). BIM technologies can analyze the design and demonstrate the potential impacts of various performance goals, allowing the design team to implement real-time design changes.

3) Determine Scope

Determining the scope of the performance goal requires analysis of two elements; the goal level, and the time period during which the goal is to be attained. Goals for entire organizations exist in federal and Agency regulations, and ultimate performance goals must be achieved throughout NASA. Individual projects, however, can be designed to meet either a building-wide goal or a Center-wide goal, depending largely on the type of project. A Center-wide goal can help to set an example for building occupants as well as for other locations and can provide strategic targets for NASA. A facility-level goal is usually designed to help reach Center-wide goals and can account for each facility's performance based on previous benchmarks or energy audits.

4) Establish Goals

Finally, improvement goals should be established at the appropriate organizational level based on current performance and targets established by existing requirements. Individual goals can take several forms, including “defined reductions,” “best-in-class,” “product efficiency improvements,” and “environmental improvement.”

At a minimum the goal established should take all federal and NASA requirements into account. It may be beneficial to create “threshold” goals, which define a minimum acceptable level of performance. Another strategy is to implement “stretch” goals which offer incentives for performance beyond requirements; for example, a design team might attempt to attain LEED® Gold when the requirement for new construction is LEED® Silver.

> ***Rule of Thumb***
>
> *The establishment of goals based on realistic schedules and target dates help to ensure that the goals are meaningful and that they promote change at an appropriate pace.*

Often, it is beneficial to set both short- and long-term goals. Short-term goals can help to provide necessary benchmarks for tracking and reporting progress. Long-term goals are shaped by a number of factors, including internal rates of return, internal planning horizons and guidelines, strategic plans, and voluntary commitments to environmental initiatives.

Related LEED® Credits

The LEED® credits related to comprehensive performance goals are illustrated in Table 4. Definitions for all LEED® abbreviations appear in the Introduction.

Table 4 – LEED® and Comprehensive Performance Goals

LEED-NC®	Includes a variety of goals relating to siting, energy, water, materials, and indoor environmental quality.
LEED-EB: O&M®	Includes a variety of goals relating to siting, energy, water, materials, and indoor environmental quality.
LEED-ND®	Includes a variety of goals relating to siting, energy, and water.

TOOLS

National Charrette Institute "Charrette System"

The National Charrette Institute is a nonprofit organization that provides education, research, and implementation strategies to create sustainable, feasible, and collaborative community plans. The "Charrette System" is the cornerstone of their approach.

For more information:
www.charretteinstitute.org/charrette.html

High Performance Building Design Charrette Handbook

The National Renewable Energy Laboratory (NREL) has created a handbook for project design charrettes. The handbook provides information and guidance for all stages of a design charrette, including planning, goal-setting, conducting the charrette, and follow-up.

For more information:
www.nrel.gov/docs/fy03osti/33425.pdf

Facility Performance Evaluation

A Facility Performance Evaluation is a wide-ranging process which can help facility performance post-occupancy and over time. The success of design objectives set in the planning process is systematically evaluated and opportunities for improvement are identified.

For more information: www.wbdg.org/resources/fpe.php

ENERGY STAR® Guidelines for Energy Management Overview

Among other resources, ENERGY STAR® provides a process for setting energy management goals. This seven-step process assists organizations in efforts to improve energy and financial performance.

For more information:
http://www.energystar.gov/index.cfm?c=guidelines.guidelines_index

Building Information Modeling

Building Information Modeling (BIM) provides a way for project managers to generate and maintain project data. BIM allows designers to visualize the design, improve consistency, make real-time design changes, store project information, and analyze all phases of a building's life-cycle.

For more information: *http://bim.arch.gatech.edu/?id=402*

NASA Sustainable Buildings Implementation Plan

The NASA Sustainable Buildings Implementation Plan was submitted to the Office of the Federal Environmental Executive (OFEE) on August 16, 2007. It is currently under review.

For more information: n/a

Department of the Interior Sustainable Buildings Implementation Plan

The Department of the Interior (DOI) created the Sustainable Buildings Implementation Plan in 2008 to assist agencies in complying with the sustainable buildings requirements of EO 13423. The Plan includes guiding principles for modifying and improving DOI's current policies and practices, and can serve as a model for other federal agencies, including NASA.

For more information:
www.doi.gov/greening/buildings/Final%20DOI%20Sustainable%20Buildings%20Implementation%20Plan.pdf

Construction Operations Building Information Exchange

Construction Operations Building Information Exchange (COBie) is a customizable design, construction, and commissioning tool which collects and displays building information as it is developed. Final handover is easier and more efficient because documents containing equipment lists, product data sheets, warranties, spare parts lists, preventive maintenance schedules, and other information are captured and recorded in one database.

For more information: *www.wbdg.org/resources/cobie.php*

BEST MANAGEMENT PRACTICE – OMB BUSINESS CASE SUMMARY

Integrate the use of OMB's Circular A-11, Section 7, Exhibit 300, Capital Asset Plan and Business Case Summary.

One important element of project planning is the budget justification. Agency staff develop budgets and provide federal reporting requirement data to Center administrators and eventually to Congress for approval. Managers of individual projects must complete the *NASA Business Case Guide for Facilities Projects* to demonstrate that the project supports the Agency's Real Property Asset Management Plan and the associated Real Property Management goals.

The *Guiding Principles* require that a specific business case justification template be used as part of a collaborative, integrated planning and design process. This template, the *Circular A-11, Section 7, Exhibit 300, Capital Asset Plan and Business Case Summary* (Exhibit 300) "establishes policy for planning, budgeting, acquisition and management of federal capital assets, and instructs agency staff on budget justification and reporting requirements for major information technology (IT) investments and for major non-IT capital assets."[7]

The Agency's existing Information Resource Management activities and project-specific documentation should provide all the information necessary to complete an Exhibit 300. An Exhibit 300 should be completed by the annual budget submission deadline, and should be fully integrated and updated with the Agency's overall budget submission. The updated Exhibit 300 should include only publicly releasable information and should be posted on the NASA website. Information concerning the projects described in Exhibit 300 documents may be requested by OMB.

NASA Requirement

NPR 8820.2F requires use of life-cycle cost versus first cost in selection of project systems, equipment, materials, and methods.

NPR 8820.2F also includes guidance for completing a Facility Project Cost Estimate, NASA Form 1510.

NPR 8570.1 requires use of life-cycle cost analysis when making investment decisions on products, services, construction, and Operations and Maintenance practices that significantly affect energy and water usage, so that mission requirements will be satisfied at the lowest life-cycle cost.

7 Circular A-11, Section 7, Exhibit 300, *Capital Asset Plan and Business Case Summary*, OMB, June 2008.

Implementing Exhibit 300, Capital Asset Plan and Business Case Summary

The steps necessary for implementing OMB's Exhibit 300 are listed in Table 5. These steps are discussed in additional detail in the subsequent narrative.

Table 5 – Implementing OMB's Exhibit 300

IMPLEMENTATION STEPS	
1)	**Planning and Preparation**
☐	Information gathering as necessary, including market research, architectural drawings, geological studies, engineering and design studies, and prototypes.
☐	Evaluate the service requirement.
☐	Design the investment.
☐	Assess the risks, benefits, and risk-adjusted life-cycle costs of alternative solutions.
☐	Establish realistic cost, schedule, and performance goals.
2)	**Part I - Summary Information and Justification**
☐	All projects must complete the Project Overview, Summary of Spending, Acquisition/Contract Strategy, and Performance Information sections.
☐	IT projects must complete the Security and Privacy as well as the Enterprise Architecture sections.
3)	**Part II - Planning, Acquisition, and Performance Information**
☐	All projects identified as "Planning," "Full Acquisition," or "Mixed Life-Cycle" must complete all sections.
4)	**Part III - Operations and Maintenance Investments**
☐	All projects identified as "Operations and Maintenance" must complete all sections.
5)	**Multi-Agency Collaboration**
☐	All projects identified as "Multi-Agency Collaboration" must complete all sections.

Definition

Performance-Based Acquisition

A performance-based acquisition (PBA) is a technique for structuring all aspects of an acquisition around the purpose and outcome desired as opposed to the process by which the work is to be performed. PBA was formerly known as performance-based contracting.

1) Planning and Preparation

The amount of planning involved in a capital investment will vary depending on the project. During the planning process, it may be necessary to gather information including market research on available solutions, architectural drawings, geological studies, engineering and design studies, and prototypes.

Agency program offices should evaluate their service requirement during the planning stage of a **performance-based acquisition** (PBA). This evaluation determines:[8]

- Whether a performance-related baseline problem exists (cost, quality, timeliness, impact to agency mission)

[8] Circular A-11, Section 7, Exhibit 300, Capital Asset Plan and Business Case Summary.

- The importance of the service to the Agency's mission, or the risk to the mission if the service is not provided
- The Agency's level of confidence in documents such as the performance work statement or statement of objectives as well as the ability to solve the baseline problem
- The potential risks and benefits of managing the service impact internally or shifting it to a vendor
- The program's readiness to measure the service's impact on its program performance goals/mission, and the readiness of Program staff to participate in the PBA process

Before proceeding to full acquisition of the capital investment (or useful segment) or terminating the investment, the following steps should be taken:[9]

- Design the investment
- Assess benefits, risks, and risk-adjusted life-cycle costs of alternative solutions
- Establish realistic cost, schedule, and performance goals

2) Part I – Summary Information and Justification

The Summary Information and Justification section includes several sections, including Project Overview, Summary of Spending, Acquisition/Contract Strategy, and Performance Information. The remaining sections (Security & Privacy and Enterprise Architecture) need only be completed for IT capital asset investment projects.

3) Part II – Planning, Acquisition, and Performance Information

The Planning, Acquisition, and Performance Information section includes the Alternatives Analysis, Risk Management, and Cost and Schedule Performance sections, all of which must be completed for capital asset investment projects identified as "Planning", "Full Acquisition", or "Mixed Life-Cycle" in Question 6 of the Summary Information and Justification, Project Overview.

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[9] Circular A-11, Section 7, Exhibit 300, Capital Asset Plan and Business Case Summary.

4) Part III – Operations and Maintenance Investments

The Operations and Maintenance Investments section includes the Risk Management and Cost and Schedule Performance sections. Both must be completed for all capital asset investment projects identified as "Operations and Maintenance" in Question 6 of the Summary Information and Justification, Project Overview (Steady State).

5) Multi-Agency Collaboration

The Multi-Agency Collaboration section includes the Multi-Agency Collaboration Oversight, Risk Management, and Cost and Schedule Performance sections. All must be completed for capital asset investment projects identified as "Multi-Agency Collaboration" in Question 6 of the Summary Information and Justification, Project Overview. These projects will include E-Gov initiative, Line of Business (LOB) initiative, or Multi-Agency Collaboration projects.

Related LEED® Credits

The LEED® credits related to OMB's Exhibit 300 are illustrated in Table 6. Definitions for all LEED® abbreviations appear in the Introduction.

Table 6 – LEED® and OMB's Exhibit 300

LEED-NC®	None
LEED-EB: O&M®	None
LEED-ND®	None

TOOLS

OMB Circular A-11, Part 7, Exhibit 300, Capital Asset Plan and Business Case Summary

The Office of Management and Budget (OMB) has prepared Exhibit 300, which is intended to be integrated into the budget decision-making process, to assist with capital asset portfolio management. Completion of this section may be required for major capital investments.

For more information:
www.whitehouse.gov/OMB/circulars/a11/current_year/s300.pdf

Real Property Business Plan

The Real Property Business Plan (RPBP) describes proposed, in-process, and completed projects identified by the Real Property Opportunities (RPO) Report. The RPO Report, first completed in 2005, was a third-party study of real property management opportunities for the Agency.

For more information:

http://www.hq.nasa.gov/office/codej/codejx/Assets/Docs/RPBPConsolidatedVERSION210-05.xls

NASA Business Case Guide for Facilities Projects

The NASA Business Case Guide for Facilities Projects demonstrates that the project supports the Agency's Real Property Asset Management Plan and the associated Real Property Management goals.

For more information:
www.hq.nasa.gov/office/codej/codejx/Assets/Docs/Case_Guide_4-20-06.pdf

Agency IT Investment Portfolio

OMB has prepared Exhibit 53 to assist with IT portfolio management. This section is intended to be integrated into the budget decision-making process and the Federal IT Investment Portfolio.

For more information:
www.whitehouse.gov/OMB/circulars/a11/current_year/s53.pdf

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Integrated Assessment, Operation, and Management

Successful high-performance and sustainable buildings require significant management and maintenance to sustain efficient and environmentally-sensitive operations. Integrated assessment, operation, and management BMPs for existing buildings are found in the *Guiding Principles for Sustainable Existing Buildings*, which is mandated by EO 13423. Implementation of these BMPs requires the efforts of an integrated team to develop and implement policy regarding sustainable operations and maintenance.

Best management practices for incorporating integrated approaches from the *Guiding Principles* include implementation steps for NASA facilities. The BMPs also include discussion of related NASA activities and accomplishments, applicable LEED® requirements, and resources for additional information or assistance.

The Integrated Assessment, Operation, and Management BMPs for existing buildings recommend the following steps:

- Incorporate sustainable operations and maintenance practices within the appropriate **Environmental Management System**.
- Assess existing condition and operational procedures for the building and its major systems, and identify areas for improvement.
- Establish operational performance goals for energy and water consumption, material use and recycling, and indoor environmental quality; ensure that these goals are incorporated throughout the building's remaining life cycle.
- Establish a building management plan to ensure that operating decisions and tenant education are conducted in a manner consistent with integrated, sustainable building operations and maintenance practices.
- Improve building operations and maintenance as needed using occupant feedback on work space satisfaction.

Definition

Environmental Management System

A comprehensive, systematic, planned, and documented collection of an agency's organizational structures and environmental programs, including resources for developing, implementing, and maintaining policies for environmental protection.

BEST MANAGEMENT PRACTICE – ENVIRONMENTAL MANAGEMENT SYSTEM

Incorporate sustainable operations and maintenance practices within the appropriate Environmental Management System.

NASA Requirement

NPR 8500.1B requires using an EMS as a tool to address all environmental aspects of internal NASA operations and activities.

NPR 8553.1B mandates each Center to develop, update, and certify an EMS that satisfies the requirements of EO 13423.

The Environmental Management System (EMS) at NASA is designed to ensure a single, overall Agency approach to management of environmental systems and activities. The focus of the EMS is improving environmental performance and maintaining compliance with applicable environmental legislation, regulations and other requirements.[10] In addition, an EMS provides an orderly, consistent organizational framework in which to allocate resources, assign responsibility, and evaluate practices, procedures, and policies.

As defined by NPR 8553.1B, an EMS is a system that:

- Incorporates people, procedures, and work practices into a formal structure to ensure that the organization's environmental impacts are identified and addressed
- Promotes continuous improvement and provides for periodic evaluations of environmental performance
- Involves all members of the organization, as appropriate
- Involves active senior management support

The requirement that the Agency implement an EMS at all appropriate organizational levels is reinforced by EO 13423, which ensures:

- Use of EMS as the primary approach for managing environmental aspects of internal Agency operations and activities, including energy and transportation functions
- Establishment of Agency objectives and targets to ensure compliance with the Executive Order
- Collection, analysis, and reporting of information to measure performance[11]

[10] NPR 8553.1B, NASA Environmental Management System, NASA.

[11] EO 13423 Strengthening Federal Environmental, Energy, and Transportation Management.

Sustainable practices described in EO 13423 which may be appropriately used in the EMS process include the following:

- Improvement in energy efficiency and reduction in greenhouse gas emissions
- Use of renewable energy
- Reduction in water consumption
- Sustainable acquisition of recycled content, energy-efficient, biobased, and Environmentally Preferable Products and services
- Reduction in use and disposal of toxic and hazardous chemicals and materials
- Waste prevention and recycling programs
- High-performance and sustainable buildings
- Efficient fleet management programs
- Electronics stewardship

The federal commitment to EMS was reaffirmed in EO 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*. Pursuant to this commitment, the Agency established a goal to "sustain environmental management" by:[12]

- Continuing implementation of formal environmental management systems at all appropriate organizational levels
- Ensuring that these systems are able to achieve the level of performance required to attain the goals established in EO 13514

[12] EO 13514 Federal Leadership in Environmental, Energy, and Economic Performance.

Implementing Sustainable O&M Practices into the EMS Process

The steps necessary for implementing sustainable O&M practices into the EMS process are listed in Table 7. These steps are discussed in additional detail in the subsequent narrative.

Table 7 - Integrating Sustainable O&M Practices into the EMS Process

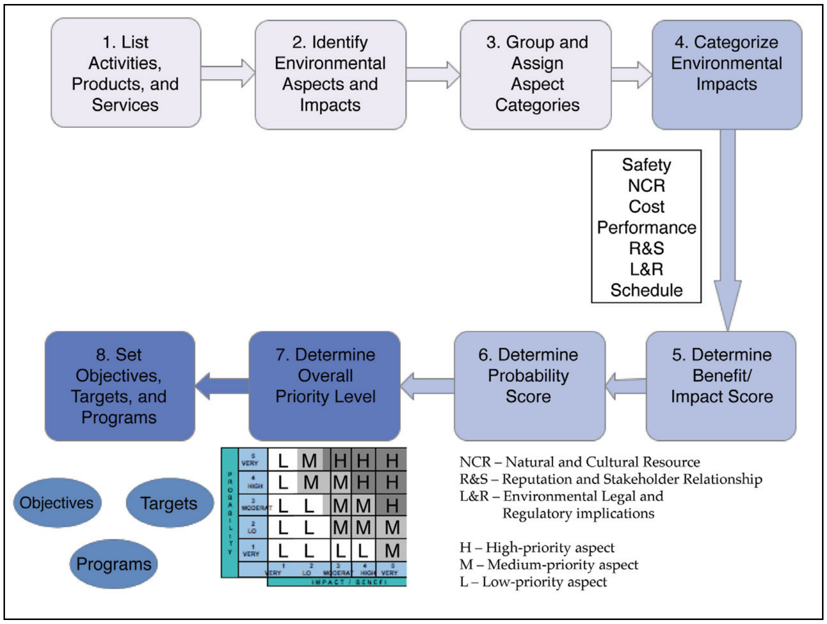
IMPLEMENTATION STEPS	
1)	**Develop an EMS in Accordance with NPR 8553.1B**
□	List activities, products, and services under Center control.
□	Identify environmental aspects and impacts.
□	Group environmental aspects and impacts for manageability, and assign environmental aspect categories.
□	Categorize environmental benefits and impacts.
□	Determine the environmental benefit and impact severity score for each category.
□	Determine the probability score for each aspect category.
□	Determine the overall priority level.
□	Set objectives and targets.
2)	**Coordinate the Building Operating Plan with the Center EMS**
□	Include facility manager and operations staff on EMS team.
3)	**Widen the Scope of the EMS**
□	Increase management of environmental aspects identified as "M" or "L" in the 5x5 Risk Matrix.
□	Implement an EMS in locations or applications currently without one.
□	Implement additional sustainable practices to exceed the goals of the EMS.
4)	**Communication and Training**
□	Train staff on EMS goal setting and maintaining environmental performance.
□	Communicate with building occupants regarding the importance of EMS goals.

1) Develop an EMS in Accordance with NPR 8553.1B

Environmental impacts of each Center's EMS are determined by the process described in NPR 8553.1B. Once this process is integrated into the EMS, the NPR provides guidance on implementation, performance measurement, and management review. The EMS development process also includes guidance on evaluating compliance with legal and other Center requirements.

NASA's EMS process is illustrated in Figure 3.

Figure 3 - NASA EMS Flow Diagram



Source: NPR 8553.1B, Chapter 3, NASA.

2) Coordinate the Building Operating Plan with the Center EMS

The building operating plan should be coordinated with the Center EMS. Many opportunities for implementing sustainable practices exist in the building operating plan's operations and maintenance activities; NPR 8553.1B also provides one of the approaches required for implementing internal Agency environmental policy. Sustainable practices in the building operating plan should align with federal requirements and should be shared and coordinated with the appropriate EMS manager.

3) Widen the Scope of the EMS

The elements of an Agency-appropriate EMS are described in NPR 8500.1B and 8553.1B. In order to include more sustainable practices, the scope of the EMS can be widened in several ways. First, the EMS could increase management of environmental aspects identified as "M" or "L" in the 5x5 Risk Matrix.[13] Since the highest-priority environmental impacts are already managed with an EMS objective and

[13] The 5x5 Risk Matrix process is defined in Chapter 3.1.9 of NPR 8553.1B. Establishing targets and objectives for lower-priority impacts is permitted by Chapter 3.3 of NPR 8553.1B.

target, the mid- and low-level impacts provide additional opportunities.

Secondly, NPR 8553.1B requires implementation of an EMS "when determined to be appropriate by NASA [Headquarters] or its parent Center." Opportunities for establishing sustainable operations and maintenance practices may exist in locations or applications not currently governed by an EMS.

Finally, the EMS process is designed to identify and prioritize the organization's environmental impacts and to set goals and objectives consistent with environmental policy. Establishing goals and objectives which exceed the requirements of EO 13423 and other regulations offers an additional opportunity to establish sustainable operations and maintenance practices.

4) Communication and Training

Communication and training is an essential element of achieving environmental performance. By including facility management staff in the EMS process, the EMS team can both facilitate communication and ensure compliance with the *Guiding Principles*. Compliance also requires ongoing training efforts; accordingly, staff should be trained on the EMS development process and the importance of successful implementation, including setting appropriate and effective goals.

Related LEED® Credits

The LEED® credits related to the EMS process are illustrated in Table 8. Definitions for all LEED® abbreviations appear in the Introduction.

Table 8 – LEED® and Incorporating Sustainable O&M Practices into the EMS Process

LEED-NC®	None
LEED-EB: O&M®	None
LEED-ND®	SLL Prerequisite 2: Imperiled Species and Ecological Communities Conservation
	SLL Prerequisite 3: Wetland and Water Body Conservation
	SLL Prerequisite 5: Floodplain Avoidance
	SLL Credit 7: Site Design for Habitat or Wetland and Water Body Conservation
	SLL Credit 8: Restoration of Habitat or Wetlands and Water Bodies
	SLL Credit 9: Long-Term Conservation Management of Habitat or Wetland and Water Bodies

TOOLS

Environmental Management Division

The Environmental Management Division (EMD) manages the Agency's EMS, following a sequence based on the Plan-Do-Check-Act model.

For more information:
http://environmental.hq.nasa.gov/nasa_ems.html

FEDCenter.gov EMS

The EMS Program Area includes the latest executive orders, guidance, policies, standards, and other resources for the development of an organizational environmental management system. The Program Area also offers lessons learned, trainings, briefings, and presentations.

For more information: www.fedcenter.gov/programs/EMS/

Environmental Protection Agency

The Environmental Protection Agency (EPA) provides resources on specific management practices necessary for the development of a successful EMS. The EPA also offers information on environmental management reviews of EMS programs and identifies ways to improve those programs.

For more information:
http://cfpub.epa.gov/compliance/resources/publications/incentives/ems/

BEST MANAGEMENT PRACTICE – BUILDING ASSESSMENT

Assess existing condition and operational procedures of the building and its major systems, and identify areas for improvement.

An assessment of the condition and operational procedures of a building and its major systems provides critical information for facility managers and Agency staff. The operational procedures of a building and its major systems are documented in several ways, including a sequence of operations, a building operating plan, systems narrative, and preventive maintenance plan. Only trained professional engineers are qualified to assess the condition of these documents and to audit current performance.

The annual Deferred Maintenance (DM) condition assessment at NASA facilities includes an independent, rapid visual assessment of nine different systems within each building. These building systems include structure, roof, exterior, interior finishes, HVAC, electrical, plumbing, conveyance, and program support equipment. The DM model uses existing engineering data and associated algorithms to establish parametric estimates on the costs of remedial maintenance on plant, property, and equipment.

Executive Order 13327, *Federal Real Property Asset Management,* requires federal agencies to catalog real property and to develop methods for improving operational and financial management of the Real Property Inventory (RPI). The DM assessment is one element of NASA's broader real property management efforts.

NASA Requirement

NPR 8831.2E requires periodic condition assessments of Center facilities via a 100 percent inspection or by performing routine inspections scheduled throughout a prescribed five-year cycle.

NPR 8570.1 provides procedural requirements for evaluating and implementing cost effective energy efficiency, renewable energy, and water conservation measures.

Implementing Building System Condition Assessments and Operational Procedure Analysis

The steps necessary for implementing building condition assessments are listed in Table 9. These steps are discussed in additional detail in the subsequent narrative.

Table 9 – Implementing Building Condition Assessments

IMPLEMENTATION STEPS	
1)	**Adminsiter the Deferred Maintenance Assessment**
☐	Conduct the Deferred Maintenance Assessment.
☐	Determine the Facility Condition Index for all facilities.
2)	**Document the Sequence of Operations**
☐	Prepare a sequence of operations for all major building systems.
3)	**Develop the Systems Narrative**
☐	Prepare a systems narrative for the HVAC, domestic hot water, humidifcation and dehumidification, and lighting systems.
4)	**Develop the Preventive Maintenance Plan**
☐	Develop a written description of the preventive maintenance plan.
☐	Record the preventive maintenance schedule.
5)	**Conduct a Walk-through Assessment**
☐	Adminster an energy audit that adheres to ASHRAE Level I Assessment.

1) Administer the Deferred Maintenance Assessment

The DM methodology consists of a parametric estimating model, populated with condition rating data gathered during visual assessments of NASA's facilities and systems. It is designed to provide consistent, auditable DM estimates at the Agency and Center levels, and to provide an assessment of the condition of NASA facilities at the system level. The facility assessments also provide an opportunity for assessors to verify the accuracy of NASA's RPI data. More information about the DM process can be found in the annual NASA-wide Standardized Deferred Maintenance Parametric Estimate Report and in NPR 8831.2E.

2) Document the Sequence of Operations

The sequence of operations describes the optimal operations of the building systems under normal conditions and provides additional detail on each of the operating phases; these phases include warm-up, occupied, and unoccupied. The sequence of operations also provides information on setpoints, controls, and performance monitoring systems.

3) Develop the Systems Narrative

The systems narrative briefly discusses the building's mechanical and electrical systems, identifying system functions and controls by describing the facility's HVAC, domestic hot water, humidification and dehumidification, and lighting systems. Systems, setpoints, and controls throughout the building should be accounted for in the systems narrative. Individual pieces of equipment do not need to be separately listed; instead, the narrative should group similar equipment together into types of systems.

4) Develop the Preventive Maintenance Plan

Preventive maintenance is “planned, scheduled periodic inspection (including safety), adjustment, cleaning, lubrication, parts replacement, and minor repair (no larger than trouble call scope) of equipment and systems.”[14] Preventive maintenance is intended to keep equipment running smoothly and safely and to prevent costly downtime and repairs. The Preventive Maintenance Plan includes a recommended schedule and descriptions of the ongoing maintenance tasks.

5) Conduct a Walk-through Assessment

A walk-through assessment corresponding to an ASHRAE Level I Audit provides a framework for building energy audits. This assessment is based on the requirements of “ASHRAE Procedures for Commercial Building Energy Audits”. At least one year’s worth of utility bills must be collected to develop an estimate of the facility’s energy use, organized by end-use category. Energy consumption data provided in these bills can help assessors to identify opportunities for improvement in energy performance, including possible no-cost and low-cost measures. Additional energy performance analysis provides energy use intensity and cost index figures for comparison with similar building types. A visual survey, during which assessors walk through the facility and meet with staff and occupants, is also required.

[14] NPR 8831.2E, Facilities Maintenance and Operation Management, NASA.

Related LEED® Credits

The LEED® credits related to building condition assessments are illustrated in Table 10. Definitions for all LEED® abbreviations appear in the Introduction.

Table 10 – LEED® and Building Condition Assessments and Operational Procedure Analysis

LEED-NC®	None
LEED-EB: O&M®	EA Prerequisite 1: Energy Efficiency BMP – Planning, Documentation, and Opportunity Assessment
LEED-ND®	None

TOOLS

Computerized Maintenance Management System

A Computerized Maintenance Management System (CMMS) includes software and a database to record, manage, and communicate facility operations issues. The system can assist with managing day-to-day maintenance and operations work and can track progress/status of maintenance activities. Use of the system can increase the effectiveness of maintenance staff and improve the decision-making capability of management staff.

For more information: *www.wbdg.org/om/cmms.php*

ENERGY STAR® Building Upgrade Manual

This manual provides facility managers with a guide to planning and implementing energy-saving upgrades. Topics covered include benchmarking, investment analysis, financing, retro-commissioning, lighting, supplemental load reduction, air distribution systems, and heating and cooling upgrades.

For more information:
www.energystar.gov/index.cfm?c=business.bus_upgrade_manual

Department of Energy - Operations and Maintenance Best Practices Guide

This guide offers suggestions for reducing energy bills by using effective operations and maintenance strategies for systems and equipment.

For more information:
www1.eere.energy.gov/femp/pdfs/omguide_complete.pdf

NASA Requirement

NPR 8500.1B requires incorporation of sustainable practices outlined in EO 13423, and consideration of environmental factors throughout programs' life cycles.

NPR 8570.1 establishes Agency goals for greenhouse gas emissions; energy, water, and petroleum use; renewable energy; energy and water audits; implementing recommendations; using life-cycle cost analysis; applying sustainable design principles; and purchasing ENERGY STAR® products.

NPR 8820.2F requires establishment of a whole-building energy performance target and sets goals for energy, water, construction waste, indoor air quality during construction, ventilation and thermal comfort, moisture control, daylighting, low-emitting materials, biobased content, ozone depleting compounds, and recycled content.

NPD 8831.1E requires use of management techniques, such as RCM and Predictive Testing and Inspection (PT&I), that optimize maintenance activities with respect to risk management and cost.

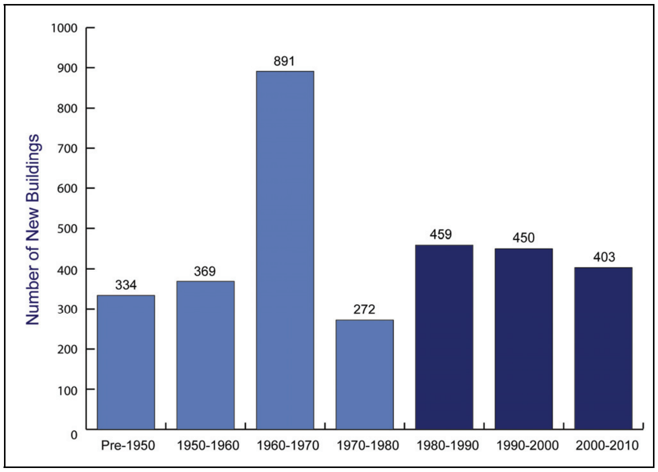
Best Management Practice – Operational Performance Goals

Establish operational performance goals for energy, water, material use and recycling, and indoor environmental quality, and ensure incorporation of these goals throughout the remaining life-cycle of the building.

Integrated and comprehensive operational performance goals consider the design and operation of the facility. Improving sustainability will involve replacement or upgrade of equipment or building materials in some facilities; other buildings may require adjustments in operations and maintenance practices. For some facilities, complete replacement may have a lower life-cycle cost than extensive renovations, and the Agency follows a "Repair by Replacement" program where appropriate.

The Agency operates a significant number of buildings constructed before modern energy and water efficiency standards were established. An estimated 60 percent of actively used buildings in the RPI were constructed before 1980.[15] Numbers of currently active facilities, grouped by first year of operation, are illustrated in Figure 4. Some of these facilities have undergone renovations or process changes, and currently operate efficiently.

Figure 4 - Active NASA buildings, by First Year of Operation



Source: NASA.

[15] Excludes structures and abandoned, excess, mothballed, out-grant, reimbursable, and standby buildings.

A variety of federal regulations and Agency policies govern the introduction of sustainable practices into facility operations and maintenance. These documents offer goals and guidance for incorporating sustainable operations practice throughout a building's remaining life cycle. A facility's operational performance goals, along with Center and Agency goals, form a basis for the maintenance program. According to the WBDG, a comprehensive maintenance program's goals should include:[17]

- Reducing capital repairs
- Reducing unscheduled shutdowns and repairs
- Extending equipment life, thereby extending facility life
- Realizing life-cycle cost savings
- Providing safe, functional systems and facilities that meet the design intent

Reliability-Centered Maintenance (RCM) is a maintenance program used throughout NASA. The RCM philosophy employs both proactive and reactive maintenance techniques "in an integrated manner to increase the probability that a machine or component will function in the required manner over its design life-cycle."[16]

Thousands of public and private organizations around the world employ RCM to improve overall equipment effectiveness while controlling life-cycle costs involved in asset management and facility stewardship. RCM's role has expanded beyond development of maintenance tasks based on **Failure Modes and Effects Analysis** (FMEA) to address:

- Sustainability
- Energy Efficiency
- Maintainability
- Commissioning, Re-/Retro-commissioning
- Age Exploration
- Reliability Analysis

Definition

Reliability-Centered Maintenance

The process used to determine the most effective approach to maintenance, including the mix of preventive, predictive, and reliability-centered maintenance technologies, coupled with equipment calibration, tracking, and computerized maintenance management capabilities all targeting reliability, safety, occupant comfort, and system efficiency.[16]

Definition

Failure Modes and Effects Analysis

Analysis used to determine what parts fail, why they usually fail, and what effect the failure has on the systems in total. This process is an element of reliability-centered maintenance.

[16] NPR 8831.2E, Facilities Maintenance and Operations Management, NASA.

[17] Reliability-Centered Maintenance, WBDG.

Implementing Operational Performance Goals

The steps necessary for implementing operational performance goals are listed in Table 11. These steps are discussed in additional detail in the subsequent narrative.

Table 11 – Implementing Operational Performance Goals

IMPLEMENTATION STEPS	
1)	**Review Existing Goals**
□	Review current goals from Agency policy, federal regulation, Center EMS, and other high-performance buildings.
2)	**Assess Current Performance**
□	Collect and analyze data.
□	Upload data to NETS.
3)	**Determine Approach and Budget**
□	Determine appropriate RCM approach, given conditions and budget.
4)	**Establish Operational Goals**
□	Establish goals for greenhouse gas emissions; energy, water, and petroleum use; renewable energy; energy and water audits; implementing recommendations; utilizing life-cycle cost analysis; applying sustainable design principles; purchasing ENERGY STAR® products; construction waste; indoor air quality during construction; ventilation and thermal comfort; moisture control; daylighting; low-emitting materials; biobased content; ozone depleting compounds; and recycled content.
5)	**Develop Plans**
□	Develop a five-year maintenance plan.
□	Develop the Annual Work Plan.

1) Review Existing Goals

Current facility performance requirements appear in various Agency policies, federal regulations, and other documents. Analysis of existing regulation can help in establishing minimum achievement goals. Operational performance goals of other high-performance buildings may also provide guidance on goal-setting, and Center EMS objectives and targets may provide additional guidance.

2) Assess Current Performance

Operational performance relative to existing goals should be assessed over time. Each Center and Component Facility is currently required by NPR 8570.1 to submit energy efficiency and conservation management information to HQ through the NASA Environmental Tracking System (NETS). Audits, meters, utility bills, and other tracking mechanisms provide much of this data. Monitoring new construction projects and the requirements of those facilities and equipment can help in identifying upcoming changes to energy, water, or material demand.

3) Determine Approach and Budget

The maintenance approach and budget will, in part, guide the goal-setting process for individual facilities. The ultimate goal is to optimize use of scarce workforce, equipment, material, and financial resources to maintain the facilities and equipment needed to safely and efficiently support the Center's mission.

NASA has adopted a streamlined approach compared to the traditionally rigorous RCM process. The Agency's RCM approach is based on the concept that maintenance actions should offer real benefits in terms of improved safety, uninterrupted operational capability, and reduced life-cycle cost. The RCM program includes preventive and reactive maintenance, along with **Predictive Testing and Inspection** (PT&I).[18]

Each facility's maintenance manager will balance the maintenance schedule, requirements, mission criticality, facility condition, customer input, and budget when determining that facility's maintenance approach.

> ***Definition***
>
> ***Predictive Testing and Inspection***
>
> *The use of advanced technology to assess condition of equipment, utilities, and systems. When using Reliability Centered Maintenance, obtaining the PT&I data allows for planning and scheduling preventive maintenance or repairs prior to failure.*

4) Establish Operational Goals

Each facility contributes toward the Agency's organizational goals in different ways. Goals should acknowledge the condition of an individual facility while supporting overall Agency efforts and considering the following:

- NPR 8570.1, which establishes Agency goals for greenhouse gas emissions, energy use, renewable energy, petroleum use, water consumption, energy and water audits, implementing recommendations, using life-cycle cost analysis, applying sustainable design principles, and purchasing ENERGY STAR® products.
- NPR 8820.2F, which requires establishing a whole-building energy performance target, and sets goals for energy, water, construction waste, indoor air quality during construction, ventilation and thermal comfort, moisture control, daylighting, low-emitting materials, biobased content, ozone depleting compounds, and recycled content.

5) Develop Plans

After goals have been established, plans for achieving them should be developed. Priorities for these plans are established by management "based on mission requirements

[18] NPR 8831.2E Facilities Maintenance and Operations Management, NASA.

are important considerations in determining what is to be accomplished and in what order."[19] The Five-Year Maintenance Plan and the Annual Work Plan will assist in this process. The Five-Year Maintenance Plan provides information needed to plan for resource allocation, while the Annual Work Plan guides day-to-day maintenance work. Templates for both of these documents are found in Appendix H of NPR 8831.2E.

Communication is an important element of the processes included in NPR 8831.2E. In developing effective plans that align with Center goals "there must be continual, two-way communication between the facilities maintenance manager and Center staff. Proper direction will ensure that maintenance work is prioritized, planned, and performed in accordance with the Center's mission goals."[19]

Related LEED® Credits

The LEED® credits related to operational performance goals are illustrated in Table 12. Definitions for all LEED® abbreviations appear in the Introduction.

Table 12 – LEED® and Operational Performance Goals

LEED-NC®	LEED-NC® includes a variety of design goals for siting, energy, water, material use, recycling, and indoor environmental quality.
LEED-EB: O&M®	LEED-EB: O&M® includes a variety of performance goals for siting, energy, water, material use, recycling, and indoor environmental quality.
LEED-ND®	LEED-ND® includes a variety of design goals for energy, water, and waste management.

[19] NPR 8831.2E, Facilities Maintenance and Operations Management, NASA.

TOOLS

Reliability Centered Maintenance Guide for Facilities and Collateral Equipment

NASA uses the RCM Guide to develop diverse asset maintenance strategies, varying from “run to failure” to streamlined FMEA, combined with PT&I. NASA believes that the RCM approach can be a valuable tool in the effort to meet the goals of the Energy Policy Act of 2005.

For more information: *www.hq.nasa.gov/office/codej/codejx/Assets/Docs/NASARCMGuide.pdf*

Facility Performance Evaluation

A Facility Performance Evaluation is a wide-ranging process which includes descriptions and evaluations of a facility’s post-occupancy performance. Performance is systematically evaluated, and opportunities for improvement are identified. Re-commissioning and retro-commissioning can be part of this process to adjust facility performance over time.

For more information: *www.wbdg.org/resources/fpe.php*

Rule of Thumb

According to the Federal Energy Management Program (FEMP), the overall O&M program should include:[20]

- *Operations*
- *Maintenance*
- *Engineering*
- *Technology*
- *Administration*

Best Management Practice - Building Management Plan

Incorporate a Building Management Plan to ensure that operating decisions and tenant education are carried out with regard to integrated, sustainable building

A Building Management Plan incorporates instructions and guidelines on all systems, equipment, and spaces into one document. The Building Management Plan, also called a Building Operating Plan or owner's operating requirements, combines system setpoints and operating schedules into a single document to help staff quickly determine designed operating parameters for all mechanical equipment in the facility. Setpoints and schedules should account for seasonal variation.

Developing a Building Management Plan is only a first step. The Plan must be incorporated into facility operations and staff and tenant training programs, and should be incorporated into the Center EMS. The Building Management Plan also covers commissioning, re-commissioning, or retro-commissioning activities, discussed in more detail later in this chapter.

Implementing a Building Management Plan

The steps necessary for implementing a Building Management Plan are listed in Table 13. These steps are discussed in additional detail in the subsequent narrative.

Table 13 – Implementing Building Management Plans

IMPLEMENTATION STEPS	
1)	**Formalize a Building Management Plan**
☐	Develop a building management/operating plan for major mechanical equipment.
☐	Include system-level operating manuals.
2)	**Staff Training**
☐	Incorporate a sustainability training program for Facility Managers.
☐	Develop best practice sharing networks for Facility Managers.
3)	**Integrate Building Management Plan**
☐	Include facility manager and operations staff on EMS team.
☐	Include in commissioning, re-commissioning, or retro-commissioning activities.

[20] FEMP O&M Best Practices – A Guide to Achieving Operational Efficiency, 2004.

1) Formalize a Building Management Plan

Components of the Building Management Plan are developed individually and then combined into a single document. The building operating and maintenance schedule and system-level operating manuals should include documentation of sustainable practices. The Building Management Plan should specify potential methods for meeting operational performance goals, and existing plans for conserving energy or increasing energy efficiency should refer to the goals in the *Guiding Principles*.

2) Staff Training

Once a Building Management Plan has been developed, staff and tenant education should be provided. Tenant training on sustainable practices should be documented in the Building Operating Plan and tenant education programs on emergency response and operations continuity should incorporate goals from the *Guiding Principles*. Tenant education and training can be accomplished through meetings, bulletin boards, e-mail, signs, surveys, or fliers.

Rule of Thumb

Training and education programs should highlight current sustainable building practices so ongoing operations can support facility goals.

Facility Managers and staff should also be trained on the facility's current sustainable building practices. The Agency administers sustainability training approximately every three years for Facility Managers, operations staff, and other interested employees.

Best management practice sharing and Facility Managers' networks are important ways to communicate information on sustainable practices throughout the Agency. The ECIC and Operations and Maintenance Facilities Innovation Team (OMFIT) both offer opportunities for communication and cooperation among Facility Managers. According to NPR 8831.2E, processes and technologies recommended by the ECIC and OMFIT should be implemented in facilities maintenance plans. The ECIC and OMFIT meet monthly via videoconference and twice yearly at face-to-face workshops.

3) Integrate Building Management Plan

The Building Management Plan should be integrated into other processes, including the EMS, commissioning, and re-/retro-commissioning activities. Facility Managers or other operations and maintenance staff should be included in EMS teams. Additionally, standard Building Operating Plans should incorporate the **Reliability Centered Building and Equipment Acceptance** (RCB&EA) process detailed in NPR 8831.2E.

Definition

RCB&EA

The RCB&EA process is NASA's customized version of the commissioning process.

Related LEED® Credits

The LEED® credits related to Building Management Plans are illustrated in Table 14. Definitions for all LEED® abbreviations appear in the Introduction.

Table 14 – LEED® and Building Management Plan

LEED-NC®	None
LEED-EB: O&M®	EA Prerequisite 1: Energy Efficiency BMP – Planning, Documentation, and Opportunity Assessment
LEED-ND®	None

TOOLS

Department of Energy, Operations and Maintenance Best Practices Guide

This guide offers ideas on reducing energy bills through use of effective operations and maintenance strategies for systems and equipment.

For more information:
http://www1.eere.energy.gov/femp/pdfs/omguide_complete.pdf

Federal Facilities Commissioning Guide

The Federal Facilities Commissioning Guide, developed by the Department of Energy's FEMP, offers practical advice on building commissioning, re-/retro-commissioning, and continuous (ongoing) commissioning.

For more information:
http://www1.eere.energy.gov/femp/pdfs/commissioning_fed_facilities.pdf

BEST MANAGEMENT PRACTICE – OCCUPANT FEEDBACK

Augment building operations and maintenance as needed using occupant feedback on work space satisfaction.

Current technologies embedded in many building systems provide facility managers with important data on operational efficiency in their facilities. As discussed in Chapter 2, *Optimize Energy Performance*, energy efficiency rating systems and measurement and verification equipment and systems provide operational information. However, an efficiently operated building is not always a comfortable building for occupants. Building systems may have been designed for a different purpose or number of occupants, or equipment may be outdated or otherwise unable to meet the building's current demands.

The element that connects operational efficiency with comfort is occupant feedback, which can be used to complement or augment existing operating metrics, providing a comprehensive approach. Building occupants offer feedback on issues including facility temperature, humidity, air quality, commuting patterns, smoking, lighting, and daylighting, as well as energy consumption, bathroom fixtures, and custodial staff performance.

Occupant feedback can be gathered through a variety of methods, including e-mail, personal interview, or online survey, but it is generally initiated through the "trouble call" process. Trouble calls (TC) are a subset of repair work, as defined in NPR 8831.2E. These unplanned issues are generally reported by building occupants; they include minor, or "routine," problems and emergency problems. Planned, requested, and executed work must be tracked in the Center's CMMS, a required component of management systems for facilities maintenance as defined by NPR 8831.2E. CMMS provides a structure for controlling work activities, accounting for resources, and monitoring and reporting work execution.

NASA Requirement

NPR 8831.2E requires reporting the planned and actual maintenance effort (parts, labor, and materials) for Repair work and Trouble Calls. These definitions and costs must be used to identify, classify, and analyze trends within facilities maintenance, to prepare Center planning documents such as the Annual Work Plan and five-year plan, and to support any other Agency-wide maintenance functions.

Incorporating Occupant Feedback into Building Operations and Maintenance

The steps necessary for incorporating occupant feedback into building operations and maintenance are listed in Table 15. These steps are discussed in additional detail in the subsequent narrative.

Table 15 – Implementing Occupant Feedback

IMPLEMENTATION STEPS	
1)	**Building Occupant Survey**
☐	Develop the building occupant survey for issues not covered by the CMMS or other existing processes. Surveys should cover temperature, humidity, indoor air quality, commuting patterns, smoking, lighting, daylighting, as well as energy, bathroom fixture, and custodial performance.
2)	**Occupant Survey Process**
☐	Develop a process to administer and collect responses. The occupant responses must be documented.
3)	**Adminster Occupant Surveys**
☐	Administer the surveys.
4)	**Integrate Occupant Survey with CMMS**
☐	Occupant survey and CMMS comparison. Identify gaps, overlap, and opportunities for synergy and integration.
☐	Document the maintenance service requests and the resolutions.
☐	Ensure data compatibility or some other link between surveys and CMMS.

1) Building Occupant Survey

The Center CMMS will track planned, requested, and executed maintenance work; some issues, however, will not be identified through this process. Occupants who feel insufficiently bothered by a particular issue, or who may have given up on the maintenance process are unlikely to report discomfort through the TC process. Seasonal variations in thermal conditions or properly functioning lighting that produces inadequate light levels may also not be reported.

> ***LEED® Focus***
>
> *In order to qualify for LEED-EB: O&M® credits, survey results must be documented and a process for handling dissatisfaction must be in place.*

Other issues which may not be reported include smoking, commuting schedules, and lighting levels. Smoking near doors, windows, or air intakes directly affects indoor air quality. Commuting patterns help facility managers understand the schedules and needs of building occupants and help occupants to arrive and depart safely. An occupant survey may provide information on such unreported issues.

2) Occupant Survey Process

The process used in developing occupant surveys is important to gathering accurate and informative feedback. Survey frequency and follow-up procedures should be developed in advance to maximize the usefulness of occupant feedback. Proper planning ensures a smooth process that generates meaningful data for the facility manager and other facility staff. Planning should include preparations for administering the survey in addition to collecting and analyzing the responses. Additionally, planning should ensure a representative sample of the building occupants is included.

3) Administer Occupant Surveys

Surveys may be administered when an appropriate process has been developed. Common survey techniques include e-mail, phone, in person, or online. The survey should be consistently administered and be available to all regular building occupants, or persons who have permanent workstations or typically spend at least 10 hours per week in the building.

> ***LEED® Focus***
>
> *In order to qualify for LEED-EB: O&M® credits, the survey must gather responses from at least 30 percent of building occupants.*

4) Integrate Occupant Survey with CMMS

As occupant issues and concerns are identified, review existing TC process and CMMS data. Occupant feedback should augment the existing operations and maintenance activities and information. As previously discussed, there are multiple opportunities to identify gaps in the CMMS and TC data. A Center staff member who is familiar with CMMS data should review the data and identify opportunities for integrating occupant feedback into the CMMS system.

Existing CMMS data for TCs includes craft required, work order number, description, building location, actual hours spent on task, date reported, and date completed. An additional field describing service request resolutions may help track maintenance activities.

Related LEED® Credits

The LEED® credits related to building occupant feedback are illustrated in Table 16. Definitions for all LEED® abbreviations appear in the Introduction.

Table 16 – LEED® and Occupant Feedback

LEED-NC®	None
LEED-EB: O&M®	SS Credit 4: Alternative Commuting Transportation
	EA Credit 2.1: Existing Building Commissioning - Investigation and Analysis
	IEQ Credit 2.1: Occupant Comfort - Occupant Survey
LEED-ND®	SLL Credit 3: Locations with Reduced Automobile Dependence
	SLL Credit 5: Housing and Jobs Proximity
	NPD Credit 7: Transit Facilities
	All GIB Credits

TOOLS

Center for the Built Environment

An introduction to the Center for the Built Environment's web-based indoor environmental quality survey is provided on this website.

For more information: *www.cbesurvey.org*

The Usable Buildings Trust

The Usable Buildings Trust encourages better buildings by making more effective use of feedback. An example survey is available included on its website.

For more information:
http://www.usablebuildings.co.uk/fp/index.html

Building Commissioning

Successful high-performance and sustainable buildings require significant management and maintenance. Commissioning and re-/retro-commissioning BMPs are found in the *Guiding Principles for Sustainable New Construction and Major Renovation* and the *Guiding Principles for Sustainable Existing Buildings*. Implementation of these BMPs involves commissioning or re-/retro-commissioning practices tailored to the size and complexity of the building and its system components in order to optimize and verify performance of building components and systems, and to help ensure that design requirements are met.

Best management practices for incorporating integrated approaches from the *Guiding Principles for Sustainable New Construction and Major Renovation* and the *Guiding Principles for Sustainable Existing Buildings* include implementation steps for NASA facilities. The BMPs also include discussion of related NASA activities and accomplishments, applicable LEED® requirements, resources for additional information or assistance.

The BMP regarding sustainable commissioning and re-/retro-commissioning practices for new and existing buildings recommends employing commissioning practices tailored to the size and complexity of the building and its system components in order to verify performance of building components and systems and to help ensure that design requirements are met.

BEST MANAGEMENT PRACTICE – WHOLE BUILDING COMMISSIONING

Employ commissioning practices tailored to the size and complexity of the building and its system components in order to verify performance of building components and systems and help ensure that design requirements are met. These practices should include:

- *Employing an experienced commissioning provider;*
- *Including commissioning requirements in construction documents;*
- *Developing a commissioning plan;*
- *Verifying the installation and performance of systems to be commissioned;*
- *Producing a commissioning report, summary of actions taken, and re-commissioning schedule, and;*
- *Meeting the requirements of Energy Independence and Security Act of 2007, Section 432 and associated FEMP guidance.*

Definition

Building Commissioning

A structured process that documents that all the building subsystems are installed, calibrated, and monitored to manufacturer's specifications and operated efficiently. System installation, calibration, and performance should be compared against design documents or requirements.

Efforts to improve energy efficiency should begin with a review of the facility's building systems. Proper system design, operation, and maintenance can significantly reduce annual energy use. Proper operating procedures should be developed and documented so current and future staff can fully understand how equipment should be operated.

Substantial improvements in energy efficiency can be achieved through fundamental **building commissioning.** Commissioning activities should be completed for energy-related building systems; including heating, ventilating, air conditioning and refrigeration (HVACR), lighting and daylighting controls, hot water systems, and existing renewable energy systems. The commissioning process will be led by an experienced, accredited professional, usually someone independent from the design, construction, or operations management teams. Building commissioning is required for LEED® new construction projects and existing buildings pursuing LEED® certification can earn a significant number of points through the commissioning process.

The term commissioning (Cx) refers to a systematic process for "achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria."[21] In new facilities, commissioning begins during the planning process. It ensures that facility systems are fully functional and that they meet both the design documentation requirements and the operational needs of the owner. The process continues throughout occupancy and operation of the facility.

Re-commissioning (ReCx) and retro-commissioning (RCx) are similar processes, but with some important differences. The ReCx process is intended for buildings that have been previously commissioned. The process may take place as part of an ongoing commissioning process, or it may be initiated due to facility changes or problems. The RCx process is intended for buildings that have never been commissioned.

In addition to enhancing staff knowledge of building systems, the commissioning process will also identify numerous opportunities for improvements in the operation of existing equipment. Managers should carefully consider the costs and benefits of each potential upgrade; many facilities will find no- or low-cost improvements that can contribute substantially to energy efficiency. Retro-commissioning analysis of a NASA facility constructed in 2007 indicated multiple opportunities for operational and equipment improvements.[22]

NASA Requirement

NPD 8820.2C defines commissioning as a quality process emphasizing procedures to ensure that systems are designed, installed, functionally tested, and capable of being operated and maintained to perform in continuity with owner's project requirements.

NPD 8820.2C also requires incorporating building commissioning into the planning and execution of facility projects.

NPR 8820.2F requires total building commissioning of installed items and associated systems as prescribed by the LEED® system. It further requires commissioning of installed equipment, systems, building envelope, and other building elements.

NPR 8831.2E requires a customized portion of commissioning as part of the RCB&EA.

[21] ASHRAE Guideline 0-2005.

[22] Wallops Flight Facility, Building E-109 LEED® EB: O&M Feasibility Study, 2010.

Implementing Whole Building Commissioning

The steps necessary for implementing whole building commissioning are listed in Table 17. These steps are discussed in additional detail in the subsequent narrative.

Table 17 – Implementing Whole Building Commissioning

IMPLEMENTATION STEPS	
1)	**Planning and Investigation Phase**
□	Select the CxA and form project team.
□	The CxA should review the owner's project requirements and basis of design.
□	Develop an initial commissioning plan.
□	Conduct the commissioning plan's investigation and analysis phase.
2)	**Design Phase**
□	Verify the updated owner's project requirements and basis of design.
□	Develop and incorporate commissioning requirements into construction documents.
□	Develop the commissioning schedule with key milestones.
□	Update the commissioning plan.
3)	**Construction Phase**
□	Verify contractor submittals and completeness of construction checklists.
□	Develop performance testing procedures and direct/verify the tests.
□	Verify the installation and performance of systems to be commissioned.
□	Develop the equipment training requirements and system manuals and verify their use.
4)	**Occupancy and Operations Phase**
□	Develop a summary of actions taken and lessons learned.
□	Complete a commissioning report.
□	Update building operating plan and/or systems narrative.
□	Review building operations by the CxA and O&M staff. Develop plan to resolve outstanding issues.
□	Analyze the building's energy use and break it down into end-use categories or conduct an ASHRAE Level II energy analysis.
□	Identify energy-related operating issues and cost-effective capital improvement projects. Develop solutions and the associated cost-benefit.
5)	**Ongoing Commissioning Phase**
□	Develop an ongoing commissioning program that includes planning, performance testing, benchmark measurement, verification, and a corrective process for performance issues. Adjust BAS settings based on observations.
□	Develop a written plan that summarizes the building equipment or system commissioning cycle. Complete at least half of the cycle's work.

1) Planning and Investigation Phase

The planning process begins with selection of a commissioning authority (CxA) and forming a project team. A properly trained, qualified, and available internal staff member may be selected as the CxA. However, if the project is pursuing LEED® certification, the CxA must be independent from the project team and must have experience on at least two commissioning projects. According to the Energy Independence and Security Act of 2007, Section

432, if the facility is less than 50,000 square feet[23] an experienced, independent CxA is not required. When selecting an independent CxA, consider the vendor's LEED® experience, local work history, and staff experience and capability with similar buildings and equipment.

The CxA should review the **owner's project requirements** (OPR) and basis of design (BoD). The CxA should also develop the initial Commissioning Plan, which should be based on project scope and budget. Re-commissioning or retro-commissioning projects should complete the investigation and analysis phase of the Plan.

2) Design Phase

As the facility is designed, the CxA should play a continuing role in reviewing and updating project documents by reviewing the OPR, BoD, and other design documents for consistency as they are updated by the owner and design team. The CxA should attend design reviews and should update the commissioning plan based on design changes. The CxA should also develop a commissioning schedule, including key milestones through facility design, construction, and occupancy. In addition, the CxA should develop commissioning requirements and incorporate them into the construction documents.

3) Construction Phase

During construction, the CxA should continue the process of reviewing construction documents, verifying contractor submittals, and completeness of construction checklists. The CxA should also develop procedures for testing the systems being commissioned and then coordinate and verify those tests. This process should include verifying installation and proper functioning of systems and equipment.

An additional LEED-NC® point can be earned by developing training requirements and system manuals, and verifying that building O&M staff completes the training. Full understanding of the equipment enables staff to achieve efficient and safe operations.

4) Occupancy and Operations Phase

Once the building is occupied, the CxA should prepare a summary of activities and lessons learned. This can be combined with the commissioning plan, major findings, performance testing results, commissioning schedule, and other analyses into a commissioning report. The

Definition

Owner's Project Requirements

The owner's project requirements (OPR) is a dynamic document that provides the explanation of the ideas, concepts, and criteria that are considered very important by the project owner. The OPR is developed during the programming and conceptual design phase and is a primary input for the basis of design.

LEED® Focus

In order to qualify for LEED-NC® points, the CxA should conduct, at a minimum, one commissioning design review prior to the mid-point in construction document development.

This design review must be submitted to the design team and owner and performed concurrently with the architect/engineer of record's review.

The CxA should back-check the review comments in the subsequent design submission to ensure that they are incorporated.

[23] If the building is energy intensive, the cutoff for using an independent CxA is 25,000 square feet.

commissioning report should include the following elements: verification that building systems are operating properly, humidity control measures, and an inspection-driven moisture prevention strategy that addresses roof and foundation maintenance. The commissioning report should also document the facility's performance testing and verification procedures.

An additional LEED-NC® credit can be earned if the CxA and O&M staff conduct a joint review of building operations 8-10 months after facility completion; the review must include a plan for resolving outstanding issues. Additional LEED-EB: O&M® points can be earned through various re-commissioning or retro-commissioning activities, as discussed below.

5) Ongoing Commissioning Phase

Whole-building commissioning continues beyond design, construction, and occupancy to an ongoing or continuous commissioning phase. The ongoing commissioning process offers multiple opportunities to earn LEED-EB: O&M® points; for example, by developing an ongoing commissioning program and a written plan summarizing the commissioning cycle.

The ongoing commissioning program should include planning, operating performance testing, benchmark measurement, verification, and a corrective process for performance issues. Based on observations made during this process, O&M staff may need to adjust Building Automation Systems (BAS) settings for optimal performance. The building equipment and/or system commissioning cycle should not exceed 24 months. This plan should include a building equipment list, frequency of performance measurement for each item, and a process for responding to performance issues. In order to qualify for LEED® points, the CxA or O&M staff should plan to complete at least half of the scope of work detailed in the first commissioning cycle.

Related LEED® Credits

The LEED® credits related to whole building commissioning are illustrated in Table 18. Definitions for all LEED® abbreviations appear in the Introduction.

Table 18 – LEED® and Whole Building Commissioning

LEED-NC®	EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems
	EA Credit 3: Enhanced Commissioning
LEED-EB: O&M®	EA Credit 2.1: Existing Building Commissioning - Investigation and Analysis
	EA Credit 2.2: Existing Building Commissioning - Implementation
	EA Credit 2.3: Existing Building Commissioning - Ongoing Commissioning
LEED-ND®	None

TOOLS

Federal Facilities Commissioning Guide

The Federal Facilities Commissioning Guide offers practical advice on building commissioning, re-commissioning, retro-commissioning, and continuous commissioning. The guide was prepared by the Department of Energy's FEMP.

For more information: *http://www1.eere.energy.gov/femp/pdfs/commissioning_fed_facilities.pdf*

ASHRAE Guidelines

ASHRAE is an international professional organization that seeks to advance HVACR technology, standards, and education.

- Guideline 0-2005 describes a commissioning process that can verify that building systems meet Owners Project Requirements.
- Guideline 1-1996 describes the HVACR-related portions of the commissioning process and the steps to ensure proper system functioning.
- Guideline 4-1993 describes proper operations and maintenance documentation for HVACR design, construction, and commissioning professionals.

For more information: *www.ashrae.org*

Building Commissioning Association

The Building Commissioning Association (BCxA) is an international, non-profit professional organization that provides education, certification, and technical resources for the entire commissioning process. The BCxA has developed a Commissioning Handbook, which includes updated information on all facets of building commissioning; including budgets, facility quality, schedules, and energy efficiency. NASA is a member of the BCxA.

For more information, see:
www.bcxa.org/resources/pubs/index.htm

Cx Assistant Commissioning Tool

The web-based Cx Assistant Commissioning Tool offers project-specific commissioning information, including probable cost, appropriate scope, sample design intent, sample BoD, sample project specifications, and sample HVAC equipment operation sequences.

For more information: *www.ctg-net.com/edr2002/cx/*

Portland Energy Conservation, Inc.

Portland Energy Conservation, Inc. (PECI) provides information, model commissioning guides, training, and resources for commissioning providers and building owners. In addition, they administer the National Conference on Building Commissioning.

For more information: *www.peci.org/resources/index.html*

Professional Development Courses

The University of Wisconsin's Department of Engineering offers a wide variety of continuing education and certification courses for professionals, building owners, and staff. Available courses cover topics such as engineering, design, operations, production, maintenance, management, and planning.

For more information: *http://epdweb.engr.wisc.edu/*

Commissioning for Better Buildings in Oregon

The Oregon Office of Energy provides information, guides, research, case studies, and resources on the commissioning process, including a Commissioning Toolkit.

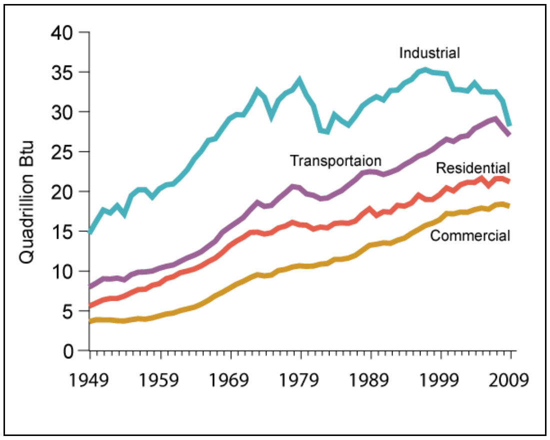
For more information:
www.oregon.gov/ENERGY/CONS/BUS/comm/bldgcx.shtml

CHAPTER 2. OPTIMIZE ENERGY PERFORMANCE

Background

Energy efficiency is critical to the construction and operation of sustainable facilities. Strategic building design, with a focus on energy efficiency, can eliminate the need for certain building systems, reducing capital expenses during construction. Energy-efficient building systems can greatly reduce operation and maintenance (O&M) costs by reducing electricity demand. As identified in Figure 1, total energy consumption in commercial buildings has increased over the last 50 years.

Figure 1 – Energy Consumption by Sector, 1949-2009



Source: Energy Information Administration, Annual Energy Review, 2009.

In addition to reducing construction and operating costs, efficiency and conservation efforts can limit fossil fuel consumption. Consuming these fuels diminishes natural resources, causes pollution, and contributes to **global climate change**.[1] Replacing traditional energy sources with renewable sources can also offer substantial environmental benefits if the energy demand cannot be reduced.

Another element of high performance building systems includes managing emissions from refrigerant systems. Building refrigerant systems should be designed for both energy efficiency and to ensure the elimination of ozone-depleting compounds. By reducing emissions of these damaging chemical compounds a facility can limit its negative impact to the atmosphere.

Chapter Outline

In order to achieve federal policy goals, the Agency should employ a systematic approach to energy investment. Energy performance can be optimized in the design and maintenance of a building through:

- *Energy Efficiency*
- *On-site Renewable Energy*
- *Measurement & Verification*
- *Benchmarking*

Definition

Global Climate Change

Refers to measured increases in the average temperature of the Earth since the mid-20th century, and the projected impacts on the climate and various ecosystems; also called global warming.

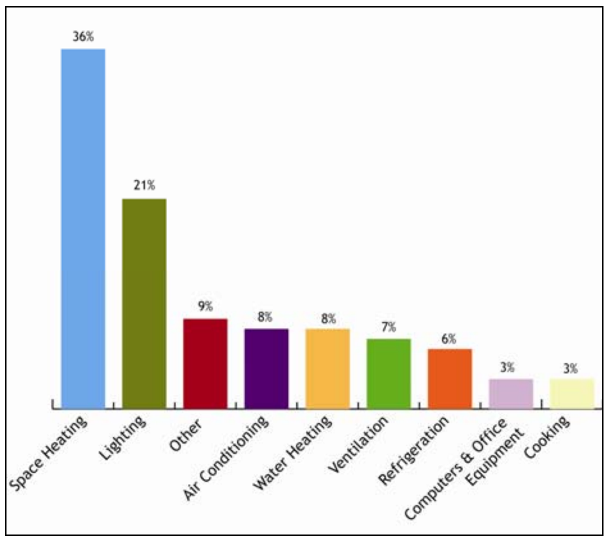
[1] Intergovernmental Panel on Climate Change Fourth Assessment Report, United Nations, 2007.

Energy Efficiency

Improving **energy efficiency** can reduce operating costs, maintain air quality, and reduce the need to expand the electric power distribution system. Energy efficiency can be improved through building design and selection of equipment and materials, as well as through broader efforts to improve operational processes. Existing federal requirements mandate improvements in energy efficiency. These energy efficiency targets help guide goal-setting during facility planning and operations. The commissioning process ensures that a new facility is designed and constructed to optimize energy efficiency and the re-/retro-commissioning process ensures optimal operations in existing buildings. The major energy end-use categories for commercial buildings are identified in Figure 2.

> *Definition*
>
> *Energy Efficiency*
>
> The quantity of energy consumed during operations or to perform an activity. Increasing energy efficiency includes reducing the energy consumption for a given operation or increasing the output from a given amount of energy.

Figure 2 – Energy Use in Commercial Buildings, 2003



Source: *Commercial Building Energy Consumption Survey*, EIA, 2003.

> *Building Focus*
>
> *Flight Projects Center, Jet Propulsion Laboratory*
>
> *The Flight Projects Center uses automated lighting controls to turn off non-essential interior lighting.*

The Best Management Practice (BMP) for improving energy efficiency is derived from the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings*, Agency policy, or the energy industry. Each BMP includes discussion of related NASA activities and accomplishments, relevant Leadership in Energy and Environmental Design (LEED®) credits, and resources for additional information or assistance.

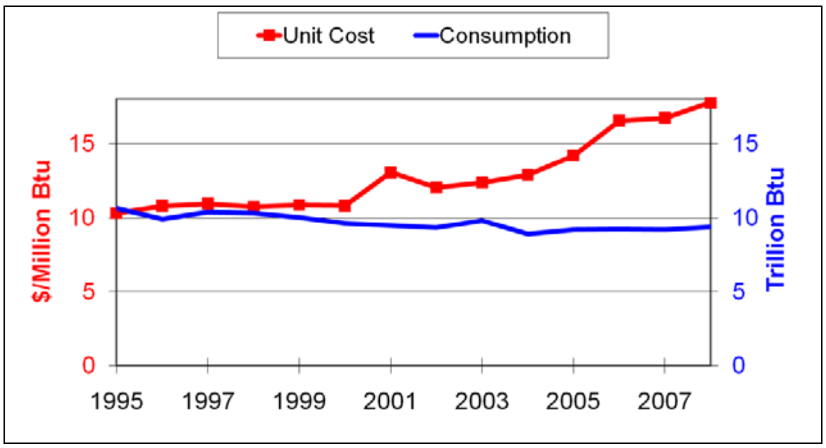
The energy efficiency BMP for new construction, major renovation, or existing buildings requires reducing the designed energy consumption by 30 percent or operating energy consumption by 20 percent.

BEST MANAGEMENT PRACTICE - REDUCE ENERGY CONSUMPTION

Reduce the designed energy consumption by 30 percent or operating energy consumption by 20 percent.

In Fiscal Year (FY) 2005, NASA's facility energy costs were approximately $130 million. Despite conservation efforts that led to a 14 percent reduction in energy consumption at NASA between the years 1995 and 2005, costs per unit rose 38 percent over the same period. Increasing unit costs have eliminated cost savings due to conservation, as illustrated in Figure 3.

Figure 3 – Agency Energy Consumption and Unit Cost, 1995-2005



Source: NASA, Environmental Management Division.

Increased energy costs lead to an increased risk to NASA's mission. This risk can be mitigated through a three-pronged approach: consider energy efficiency and cost in all aspects of facility operations; construct and renovate facilities with the overall life cycle in mind; and make wise purchasing decisions.

Multiple federal regulations mandate cost-effective reductions in energy use or intensity. For example, the Energy Independence and Security Act (EISA) of 2007 established energy reduction goals for federal facilities, relative to a 2003 baseline.[2] EISA 2007 provides for a number of energy conservation provisions and incentives; it also requires energy-efficient procurement practices including purchase of

NASA Requirement

NPR 8820.2F requires project designers to design for the ENERGY STAR target in renovations.

NPR 8820.2F requires project designers to reduce the energy cost budget by 30 percent compared to baseline building performance per ASHRAE 90.1-2004. For major renovations, it requires a reduction of 20 percent from the pre-renovation 2003 baseline.

NPR 8570.1 establishes a goal of 25 percent improvement in facility energy efficiency by FY 2010, relative to FY 1990 levels.

NPR 8570.1 establishes a goal of 35 percent reduction in per-square-foot overall energy use by FY 2010, relative to FY 1985 levels.

2 Federal Energy Management Program.

ENERGY STAR and Federal Energy Management Program (FEMP) designated products; eliminating some synfuel purchases; and eliminating use of incandescent light bulbs.

Implementing Energy Efficiency Improvements

Table 1 lists the steps necessary for implementing energy efficiency improvements. These steps are discussed in additional detail in the subsequent narrative.

Table 1 – Implementing Energy Efficiency Improvements

IMPLEMENTATION STEPS	
1)	**Conduct an Energy Audit**
☐	Determine phase of energy audit needed.
☐	Utilize meters, utility bills, and calculations to determine baseline energy use.
2)	**Establish Energy Efficient Goals**
☐	Use energy audit results as baseline.
☐	Establish goals that support Agency requirements and targets.
3)	**Identify Opportunities for Implementation**
☐	Consider regional and climate differences.
☐	Consider insulation, HVAC systems, water and lighting systems, electrical distribution systems, and other products.
4)	**Estimate the Life-cycle Costs and Benefits**
☐	Determine costs and benefits of the implementation of energy-efficient upgrades.
5)	**Prioritize and Implement Energy-Saving Techniques**
☐	Identify funding resources.
☐	Determine priority of implementation of Plan elements.
6)	**Monitor Energy Savings**
☐	Measure energy savings after energy-efficient methods are implemented.

1) Conduct an Energy Audit

Energy audits provide information on energy use patterns; this information assists facility managers in identifying investment opportunities. An energy audit can help to determine the scope and complexity of building systems and can assist in developing budget priorities. Energy audits are generally performed by professional engineers with experience in energy efficiency.

Energy audits consistent with the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) standards include a preliminary energy-use analysis and three levels of formal energy audit analyses: walk-through, energy survey, and capital-intensive modifications. Overlap may exist, in that a specific task might occur in one or more of the audit’s phases. An audit may be simple or comprehensive in terms of complexity and cost. While comprehensive audits are more expensive, the cost is "justified by the greater energy savings opportunity."[3] A comprehensive audit usually involves a room-by-room inventory of the facility, which allows for room-specific data collection. This data may be used to produce a more specific and understandable Energy Efficiency Implementation Plan for the auditor, owner, and maintenance staff. A comprehensive audit may also reduce chances for duplication of effort by the auditor, as all necessary information will be collected at once.

Preliminary Energy-Use Analysis

A preliminary energy-use analysis indicates if the building is an appropriate candidate for renovation, and what additional level of audit may be necessary. The process includes a study of the facility's historical energy use, analysis of current utility bills to identify potential cost savings opportunities, and benchmarking the facility against similar building types. The benchmarking can be performed by the ENERGY STAR Portfolio Manager, which is discussed in greater detail on page 2-53.

The preliminary energy-use analysis is quick and straightforward, but it is not as comprehensive as the other levels. The overall energy system is not analyzed in depth, so savings opportunities may not be detected. It is also not possible to develop an Energy Efficiency Implementation Plan using only the information gathered during the preliminary analysis.

Level I – Walk-through Analysis

A walk-through analysis includes all of the elements of the preliminary energy-use analysis in addition to a site visit. After the site visit, the auditor may prepare a summary of low-cost and easily implemented energy-efficiency upgrades. The walk-through covers the entire facility, but it does not include an in-depth analysis of building systems. As with a preliminary energy-use analysis, some energy-saving opportunities may not be detected. In addition, it will not be possible to develop an Energy Efficiency Implementation Plan using only the information gathered during this phase. A walk-through analysis may meet the criteria for LEED-EB® Energy and Atmosphere Prerequisite 1 *Energy Efficiency Best Management Practices – Planning, Documentation, and Opportunity Assessment*.

LEED® Focus

Energy audits conforming to ASHRAE's preliminary energy use analysis and Levels I and II meet some requirements in the LEED-EB: O&M® credit system.

[3] Shapiro, Ian, *Energy Audits in Large Commercial Buildings*, ASHRAE Journal, January 2009.

Level II – Energy Survey and Analysis

The energy survey and analysis includes all of the elements of the walk-through analysis, and it includes additional energy calculations and financial analyses. At the completion of this level, the auditor will produce a report projecting return-on-investment for proposed energy conservation measures. This type of audit may meet the criteria for LEED-EB® Energy and Atmosphere Credit 2.1 *Existing Building Commissioning – Investigation and Analysis*.

Level III – Detailed Analysis of Capital-Intensive Modifications

The detailed analysis of capital-intensive modifications includes all of the elements of the energy survey and analysis, in addition to additional investigation of proposed energy conservation measures. The analysis is generally directed by the facility representative and it may include refinement of an existing energy model or additional data collection. After completion of this level, the auditor will produce a report that identifies and justifies large capital expenditures to improve the facility's performance by analyzing energy efficiency data.

Common activities for three levels of energy audits are illustrated in Figure 4.

Figure 4 – Energy Audit Levels and Activities

	Level I **Walk-Through Analysis**	**Level II** **Energy Survey & Analysis**	**Level III** **Detailed Analysis**
Focus of Audit	• Documenting systems and operations • Rough estimate of savings potential • No / low cost measures	• Energy consumption by end use • More rigorous estimate of savings potential • No / low cost and capital measures	• Detailed analysis of subsystems • Investment-grade estimates of savings potential • Capital measures
Inputs	• Utility bills • Site drawings • Site walk-through • Interviews	• Level I items, plus measurement of key environmental parameters	• Level II items, plus measurement of key equipment operational parameters
Outputs	• Checklists • Engineering estimates • Spreadsheet calculations	• More complex spreadsheet calculations • Simple computer energy models	• Complex computer energy models

Source: ASHRAE.

2) Establish Energy Efficiency Goals

Results from energy audits can guide the formation of energy efficiency performance goals by establishing a baseline of energy consumption information. Facility managers can use these results along with a review of utility bills to identify trends and establish goals accordingly. While individual goals may not be appropriate to every facility, all facility goals should align with NASA requirements and targets. For more information on setting performance goals, see Chapter 1 on pages 1-9 and 1-32.

3) Identify Opportunities for Implementation

Once an energy consumption baseline and corresponding goals are established, opportunities for improvement may be identified. These should consider regional climate differences as well as designed or operating energy use. A facility's designed or operating energy efficiency can be improved primarily through changes to insulation, HVAC systems, water heating systems, lighting systems, and electricity distribution design.

Insulation Systems

Insulation affects a building's energy efficiency by helping to manage the interior climate within the **building envelope**. Insulation minimizes unwanted heat loss or gain and helps minimize emissions, life-cycle costs, and the use of natural resources.[4] While insulation is commonly fiberglass, foam, or other materials concealed in walls, it can also include reflective window films, insulating glass units, and window shades on buildings with large areas of **glazing** facing the south and west.

Indoor air quality standards may require outside air ventilation rates that could create need for additional heating or cooling. Accordingly, a facility's air quality goals should be considered when designing new or retrofit insulation systems. In addition, local energy code requirements should be verified.

Current recommended insulation code requirements from ASHRAE are identified in Figure 5. In February 2010, ASHRAE proposed an increase to recommended R-value in Zone 1 to R-20, Zones 2 and 3 to R-25, Zones 4, 5, and 6 to R-30, and Zones 7 and 8 to R-35. These changes are pending ASHRAE board approval.

Definition

Building Envelope

The outer shell of a building, including foundation, walls, roof, doors, and windows that keep the external environment outside of the building.

Building Focus

Collaborative Support Facility, Ames Research Center

The Collaborative Support Facility incorporates a well-insulated aluminum curtain wall with high quality glazing in order to improve building insulation.

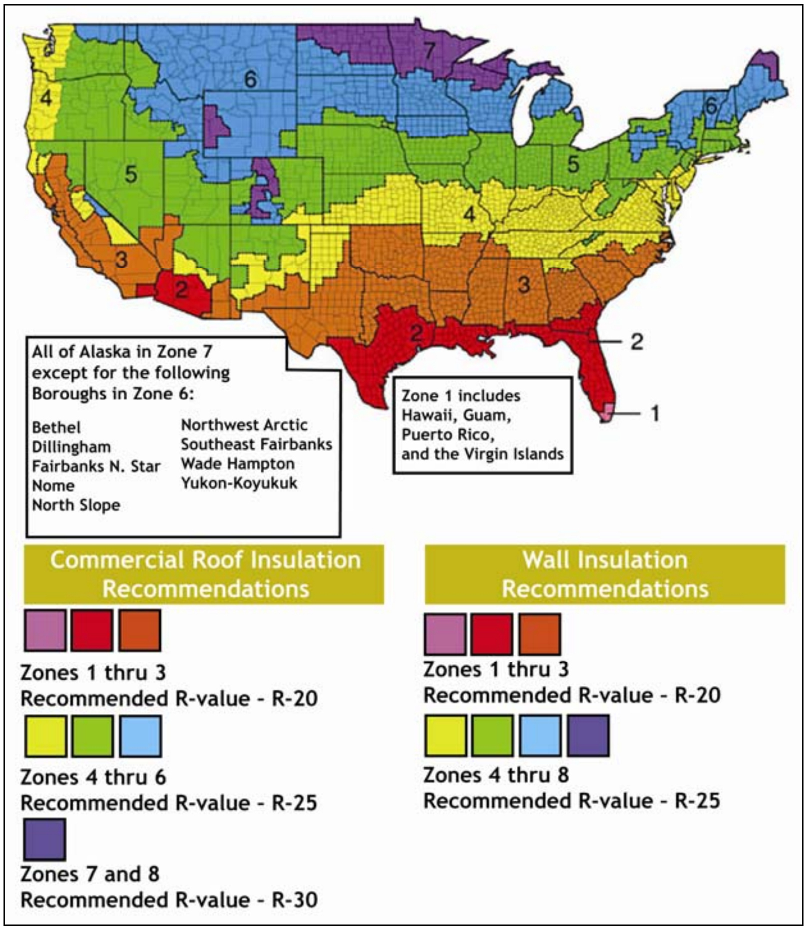
Definition

Glazing

Fitted glass placed into a building's wall, door, or window.

[4] *Mechanical Insulation Design Guide*, Whole Building Design Guide.

Figure 5 – ASHRAE Recommended Insulation Code Requirements



Source: Polyisocyanurate Insulation Manufacturers Association, 2008.

> ***Building Focus***
>
> *Collaborative Support Facility, Ames Research Center*
>
> *The Collaborative Support Facility uses radiant cooling ceiling panels to achieve a uniform temperature without drafts and 40 percent energy cost savings.*

HVAC System

HVAC systems can have a dramatic impact on a facility's total energy use. Indoor air quality standards require the introduction of minimum quantities of outside air into a facility. Heating, cooling, and dehumidifying this outside air demands significant quantities of energy, and energy demand will increase proportionally with increased volume of outside air. ASHRAE, Unified Facilities Criteria (UFC), International Building Code (IBC), and LEED® standards all specify minimum rates for outside air introduction.

Facility managers must determine if inefficient HVAC equipment should be repaired or replaced. When planning major HVAC replacement, managers should consider factors including equipment age, repair history, impact to function from downtime, indoor air quality benefits, energy efficiency improvement, refrigerant requirements, and planned renovations or additions to the facility's systems, roof, or structure.[5] A number of emerging HVAC trends in new building design should also be considered. These trends include decoupling of ventilation systems from space heating and cooling systems, eliminating reheat for comfort cooling applications, minimizing fan energy in HVAC systems, and using moderate temperature water to reduce the required water heating or cooling.

In some cases, HVAC energy efficiency can be improved without repair or replacement to the system. A review of unit controls and setpoints may reveal opportunities for improvements that do not affect occupant comfort. Using the **economizer mode** can conserve energy without compromising indoor air quality. In cold and mild weather, the economizer mode mixes varying quantities of outside air with recirculated air, based on temperature and humidity differences; this allows for improved HVAC efficiency through reduced need for mechanical cooling.

Definition

Economizer Mode

The economizer mode conserves energy consumption by HVAC equipment by utilizing varying amounts of outside air, which is mixed with recirculated air. In some cases conditioning outside air uses less energy than conditioning recirculated air, and the economizer mode uses a computer to maximize these savings.

Lighting Systems

Lighting systems account for more than 20 percent of total energy consumption in commercial facilities, as illustrated in Figure 2. Lighting system design is determined through study of a space's type, size, and intended use; these factors determine the required **luminosity** of a light source. Once the luminosity requirement is determined, the light source and lighting fixtures may be chosen. Generally, a "lighting fixture should not only support the source, but redirect its output into the desired zones and shield it so that it does not become a source of glare."[6]

Definition

Luminosity

A measurement of the brightness of a light source, as it is perceived by the eye at that wavelength.

Reducing the lighting system's share of energy consumption generally requires alteration or replacement of lighting systems; incorporating technologies such as occupancy sensors, lighting tube technology, and light-emitting diode (LED) lighting. Occupancy sensors eliminate wasted illumination in an unused space by automatically turning off lights after a defined period of time without motion or activity. These sensors are relatively easy to install in a new or existing building.

Building Focus

Collaborative Support Facility, Ames Research Center

The Collaborative Support Facility uses an automated lighting control system to dim lights to adjust for ambient conditions and time of day.

[5] Snyder, Loren, *Planning and Coordination Helps HVAC Projects Succeed*, FacilitiesNet, 2010.

[6] *Light in Design – An Application Guide*, IESNA.

LEED® Focus

Daylighting and occupant lighting controls can be implemented to earn points in the LEED-NC® and LEED-EB: O&M® credit systems.

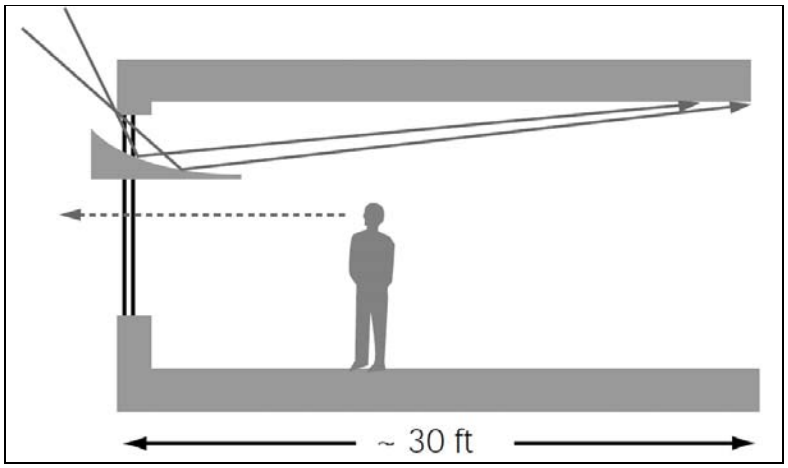
Rule of Thumb

Implementing daylighting can produce overall energy savings of 15 to 40 percent, by minimizing need for artificial lighting, and improving indoor climate control, which can reduce the heating and cooling load.[7]

Other systems or upgrades that can reduce lighting-related energy consumption include lighting tube technology and LED lighting. The Illuminating Engineering Society of North America (IESNA) recommends use of light tubes or fluorescent sources for light distribution over a large area. For narrow light distribution applications, the IESNA recommends low voltage incandescent and LEDs.

Reduced lighting system energy consumption can also be achieved through use of alternate light sources, such as daylight harvesting. Daylight harvesting decreases use of artificial lighting and replaces it with natural daylight to reduce energy consumption and maximize visual comfort.[8] Daylight harvesting with a light shelf is illustrated in Figure 7.

Figure 7 – Daylighting with a Light Shelf



Source: Daylighting with Windows, Lawrence Berkeley National Laboratory.

Figure 6 – Clerestory Windows, Building 265, Johnson Space Center

Source: NASA.

Daylight harvesting systems include a photosensor. Specific techniques for implementing daylighting systems include use of clerestory windows, skylights, light shelves, light tubes, and glass block walls.[9] An example of clerestory windows appears in Figure 6.

Daylighting systems produce several benefits, including reduced energy consumption and improved building occupant comfort and productivity. The California Energy Commission found that "exposure to daylight was consistently linked with a higher level of concentration and better short-term memory

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7 Molinski, Mike, *How Daylighting Works*, FacilitiesNet. 2009.

8 Light Harvesting, Whole Building Design Guide.

9 Daylighting, Whole Building Design Guide.

recall."[10] This increase in productivity can be linked to the natural human attraction and need for daylight.[7]

Daylighting systems can have some disadvantages, including increase in sun glare and increased building temperatures due to solar heat. These issues may be mitigated through use of window treatments, window films, and glazing.

Water Heating System

As illustrated in Figure 2, water heating accounts for eight percent of energy consumption and 13 percent of utility costs in commercial buildings.[11] Most domestic hot water systems use a tank, which stores water heated by electricity, natural gas, or propane. The tank is insulated, to minimize heat loss and energy use.

By reducing demand for hot water, replacing inefficient equipment, and implementing new technologies, facilities can reduce energy costs related to hot water. Per EISA 2007 Section 523, at least 30 percent of hot water demand in new construction projects must be met through solar hot water heating systems. For more information on renewable energy systems, including solar hot water heating, see page 2-29.

Electrical Distribution System

The electrical distribution system carries energy to the consumer from the transmission system. Power lines carry electricity from the production source, and a power network usually includes substations, transformers, wiring, and meters. Although some of this infrastructure is commonly owned and operated by the local utility company, NASA also maintains its own substantial electric distribution systems.

Transformer size can significantly impact long-term energy costs, and proper transformer selection offers an opportunity for reduced consumption and improved costs. A transformer that is 50 percent oversized will consume approximately 50 percent more energy to energize its core.[12] Facility managers should choose energy-efficient transformers with the lowest feasible **K-Factor**.

If possible, facility managers should also consider the local utility company's transformer criteria to ensure selection of the appropriate equipment. Many utility companies consider transformer size in billing calculations; companies that

Definition

K-Factor

The K-Factor signifies the ability of the transformer to handle non-sinusoidal loads without overheating. To get a higher K-Factor, you need a bigger core and insulated windings. Higher K-Factor transformers will demand more power to energize the core. Higher K-Factor transformers are utilized for computer rooms, servers, where non-linear loads will reflect harmonics back on the transformer.

[10] Molinski, Mike, *How Daylighting Can Improve IEQ*, FacilitiesNet. 2009.

[11] Hot Water Systems, Environmental Protection Agency.

[12] American Electricians Handbook, Table 5-45, Tenth Edition.

employ this method bill customers in part based on total capacity of the electrical distribution system. By selecting equipment that is appropriately sized for the facility's needs, managers can reduce operating costs.

> *Rule of Thumb*
>
> *In commercial buildings, computers and other electrical office appliances are responsible for an average of three percent of total facility energy consumption.*[13]

Other Products and Equipment

The HVAC, insulation, water heating, lighting, and electrical distribution systems are not the only areas in which energy consumption can be reduced. Facility managers should analyze the entire facility's energy use to determine which equipment or applications consume the most energy.

Although the energy conservation potential from computers and office equipment in an average building is relatively small, the widespread use of computers throughout the Agency means that replacement of inefficient equipment with ENERGY STAR or other efficient alternatives can lead to meaningful energy savings. In addition, data centers or other facilities with large numbers of computers or other electronic equipment may present large potential energy savings.

Operations adjustments can also lead to reduced energy consumption. The Environmental Protection Agency (EPA) recommends adjusting computer settings to switch-to-sleep, standby, or hibernate mode after 30-60 minutes of inactivity.[14] Monitors can also be set to sleep mode after 5-20 minutes of inactivity to save additional energy. Sleep, standby, or hibernate modes can save energy while not impacting productivity for most computer users.

4) Estimate the Life-cycle Costs and Benefits

To determine the cost-effectiveness of energy efficiency efforts, managers will need to calculate both the cost of products and equipment and the resulting energy cost savings. Energy-efficient products and equipment can vary widely in first-cost and potential long-term savings. No-cost and low-cost changes to equipment and operations may have immediate payback; examples include installation of window films, light dimmers, and utility meters. Major purchases or upgrades, such as replacing an HVAC system or installing a wind turbine, may require a longer payback period.

[13] Commercial Buildings Energy Consumption Survey, Energy Information Administration, 2003.

[14] General Technical Overview of Power Management, ENERGY STAR, EPA.

Potential costs of reducing energy consumption include:

- Purchase and installation of energy- and water-efficient products and equipment
- Impact to occupant productivity during repair and outages
- Ongoing monitoring of energy savings and maintenance

Potential benefits of reducing energy consumption include:

- Lower utility costs
- Reduction in use of fossil fuels

5) Prioritize and Implement Energy-Saving Techniques

Funding may not be immediately available for all energy-saving initiatives; therefore, determining which programs or systems may be most cost-effective is an important first step. The methods which affect the largest number of people may yield the most visible and measurable cost savings. Due to funding limitations, facility managers should think creatively and explore alternative funding. Potential funding mechanisms include:

- Agency appropriations
- The Department of Energy's Energy Efficiency and Renewable Energy Program
- Retained energy savings
- Energy Savings Performance Contracts
- Utility Energy Services Contracts
- O&M performance incentives

6) Monitor Energy Savings

It is critical for facility managers to monitor and measure energy savings after energy-efficient methods are implemented. This data will demonstrate that the facility is complying with Agency policy and federal regulations on reducing energy consumption.

Related LEED® Credits

The LEED® credits related to energy efficiency improvements are illustrated in Table 2. Definitions for all LEED® abbreviations appear in the Introduction.

Table 2 – LEED® and Energy Efficiency

LEED-NC®	EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems
	EA Prerequisite 2: Minimum Energy Performance
	EA Prerequisite 3: Fundamental Refrigerant Management
	EA Credit 1: Optimize Energy and Performance
	EA Credit 2: On-site Renewable Energy
	EA Credit 4: Enhanced Refrigerant Management
	EA Credit 5: Measurement and Verification
	EA Credit 6: Green Power
LEED-EB: O&M®	EA Prerequisite 1: Energy Efficiency BMP - Planning, Documentation, and Opportunity Assessment
	EA Prerequisite 2: Minimum Energy Efficiency Performance
	EA Credit 1: Optimize Energy Efficiency Performance
	EA Credit 2.1: Existing Building Commissioning - Investigation and Analysis
	EA Credit 2.2: Existing Building Commissioning - Implementation
	EA Credit 2.3: Existing Building Commissioning - Ongoing Commissioning
	EA Credit 3.1: Performance Measurement - Building Automation System
	EA Credit 3.2: Performance Measurement - System-Level Metering
	EA Credit 4: On-site and Off-site Renewable Energy
LEED-ND®	GIB Prerequisite 2: Minimum Building Energy Efficiency
	GIB Credit 2: Building Energy Efficiency
	GIB Credit 11: On-site Renewable Energy Sources
	GIB Credit 12: District Heating and Cooling
	GIB Credit 13: Infrastructure Energy Efficiency

TOOLS

American National Standards Institute

The American National Standards Institute (ANSI) oversees "the creation, promulgation and use of thousands of norms and guidelines," which promote the safety of American consumers and protect the environment. ANSI also provides a number of helpful resources including standards and accreditation services, training events, and a library.

For more information: www.ansi.org

HVAC and Energy Standards and Resources

In addition to developing building standards, ASHRAE also promotes advancements in mechanical arts and sciences. Energy-efficiency issues covered on the ASHRAE website include heating, cooling, and indoor air quality.

For more information: www.ashrae.org

Illumination Guide

The "Light in Design – An Application Guide" provides helpful lighting selection guidelines, explanatory diagrams, and application techniques based on room usage.

For more information:
www.ies.org/PDF/Education/LightinDesign.pdf

Federal Energy Management Program - Energy-Efficient Products

The Department of Energy's (DOE) FEMP assists Federal agencies with understanding and complying with energy-efficient product requirements.

For more information:
www1.eere.energy.gov/femp/technologies/procuring_eeproducts.html

Office of Energy Efficiency and Renewable Energy

The Office of Energy Efficiency and Renewable Energy (EERE) supports public-private partnerships to improve energy security, environmental quality, and economic vitality. Programs include the Green Power Network, Solar Energies Technologies, Geothermal Technologies; Biomass, Hydrogen, Fuel Cells, and Infrastructure Technologies; and Wind and Hydropower Technologies.

For more information: www.eere.energy.gov/

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On-Site Renewable Energy

Since 2000, increasing energy costs have emphasized the need for facility managers to consider **alternative energy**, in addition to focusing on reduction of overall energy consumption.[15] The use of alternative power can lead to reductions in long-term energy costs and greenhouse emissions. An example of a renewable energy project appears in Figure 8.

> **Definition**
>
> *Alternative Energy*
>
> *Energy produced from non-petroleum-based sources such as solar, wind, water, biomass, geothermal, or other. Also referred to as renewable energy, green energy, or green power.*

When considering the use of renewable energy, industry experts recommend minimizing a building's energy use by using high-performance systems and components. Once the building site, mass, envelope, and energy using systems are optimized for peak performance, then the use of on-site renewable energy can be considered for maximum impact.

The BMPs for renewable energy sources are derived from the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings*, Agency policy, or the energy industry. Each BMP includes discussion of related NASA activities and accomplishments, relevant LEED® credits, and resources for additional information or assistance. The renewable energy BMPs for new construction, major renovation, or existing buildings require:

- Implement renewable energy generation projects on agency property for agency use, when life-cycle cost effective.
- Meet at least 30 percent of hot water demand through the installation of solar hot water heaters, when life-cycle cost-effective.

Figure 8 - Rooftop Solar Photovoltaic System, Marshall Space Flight Center

Source: NASA.

[15] Electric Power Annual 2007 Summary, Energy Information Administration.

NASA Requirement

NPR 8570.1 requires expanded use of renewable energy for facilities and operational activities by implementing renewable energy projects and by purchasing electricity from clean, efficient, and renewable energy sources.

Definition

Biomass

Plant or other organic matter that is converted into a fuel source, usually to be burned.

Definition

Geothermal

Energy produced by utilizing the consistent temperature of the Earth's crust or groundwater to reduce the energy demand to heat or cool a building.

Best Management Practice – On-Site Renewable Energy

Implement renewable energy generation projects on agency property for agency use, when life-cycle cost effective.

Renewable energy systems use power produced from solar, wind, **biomass**, landfill gas, the ocean (including tidal, wave, current, and thermal), **geothermal**, and municipal solid waste sources.[16] Renewable sources can also include new hydroelectric generation capacity achieved through increased efficiency or through addition of new capacity at an existing hydroelectric plant. The energy derived from these sources delivers electricity, heating, cooling, and other energy. Once the renewable energy infrastructure is paid for by utility savings, there is additional economic benefit to the owner of the renewable energy plant.

Existing federal requirements mandate cost-effective renewable energy generation on agency property for agency use, whenever feasible. Additionally, at least 50 percent of statutorily required renewable energy must come from "new" sources; this includes sources placed into service after January 1, 1999.[17] The federal government as a whole has committed to increasing the percentage of renewable energy consumption compared to overall consumption.[16] These requirements should inform goal-setting during the planning process and during facility operations.

In addition to reducing costs and ensuring compliance with federal requirements, increased use of renewable energy promotes national security through independence from foreign energy sources. In 2008, the United States imported more than 4.7 billion barrels of crude oil and derivatives, and nearly 4 million barrels of liquefied natural gas.[18] Renewable energy sources can combine the energy security benefits of local production with significant environmental benefits. Promotion of renewable energy generation as a means of increasing energy independence is one of the objectives of the EISA 2007.

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[16] Energy Policy Act 2005.

[17] EO 13423 *Strengthening Federal Environmental, Energy, and Transportation Management.*

[18] Total Crude Oil and Natural Gas Imports, Energy Information Administration, 2008.

Identifying cost-effective renewable energy technologies is a complex process. Facility managers should consult the local Center Energy Manager and independent professionals, when appropriate, for recommendations on selection and installation of renewable energy technologies. An Agency-wide "Comprehensive Renewable Energy Survey" is available: facility managers should consult this study for locally appropriate renewable energy technologies. An example of surface-based solar power is illustrated in Figure 9.

Figure 9 – Surface-based Wind and Solar Power, Child Care Center, Johnson Space Center

Source: NASA.

Finally, Centers should consider **net metering** to make renewable energy generation more cost effective. Net metering uses customized utility meters to measure the amount of energy produced in a location versus the amount of energy consumed. If production exceeds consumption, the utility company pays the customer for the excess power at a pre-determined rate. Net metering, while useful, does not guarantee cost effectiveness, and all renewable energy generation projects should be carefully considered.

Building Focus

Kennedy Space Center

Kennedy Space Center has constructed a solar photovoltaic farm that adds one megawatt of energy directly into the power grid.

Definition

Net Metering

A process where individual consumers who use less energy than they generate are credited for the difference in energy by the utility provider. This requires an advanced electricity meter and is usually performed through distributed renewable generation and energy conservation.

Implementing Renewable Energy Sources

Table 3 lists the required steps for implementing renewable energy sources. These steps are discussed in additional detail in the subsequent narrative.

Table 3 – Implementing Renewable Energy

IMPLEMENTATION STEPS	
1)	**Evaluate Existing Energy Use**
□	Conduct an energy audit.
□	Utilize meters, utility bills, and calculations to determine baseline energy use.
2)	**Identify Renewable Energy Opportunities**
□	Consider regional and climate differences.
□	Consider solar, wind, biomass, landfill gas, ocean, geothermal and municipal sources.
3)	**Estimate the Life-cycle Costs and Benefits**
□	Determine costs and benefits of the implementation of renewable energy upgrades.
4)	**Prioritize, Finance, and Install Renewable Energy Generation Projects**
□	Identify funding resources.
□	Determine priority of implementation of Plan elements.
5)	**Maintain and Monitor Installed Systems**
□	Measure energy savings after implementation.
□	Ensure energy savings results meet federal and Agency criteria.

1) Evaluate Existing Energy Use

Rule of Thumb

Energy audits establish an energy use baseline, which is critical in determining cost-effectiveness of potential renewable energy projects.

Energy audits provide information on how energy is being used, and can help to identify and prioritize opportunities for investment. Energy audits also help to determine the scope and complexity of building systems, assist in developing budget predictions, and establish the amount of detail needed to make accurate assessments.

Energy audits consist of four phases: preliminary energy use analysis, walk-through analysis, energy survey and analysis, and detailed analysis of capital-intensive modifications. For more information on building energy audits, see page 2-4.

2) Identify Renewable Energy Opportunities

Renewable energy sources should be implemented comprehensively, accounting for the local climate and the designed facility or existing operations. The Energy Policy Act (EPAct) of 2005 defines renewable energy as power produced from solar, wind, biomass, landfill gas, the ocean (including tidal, wave, current, and thermal), geothermal energy, and municipal solid waste sources.[19] These sources can also include new hydroelectric generation capacity achieved

[19] Energy Policy Act of 2005.

through increased efficiency or by additions of new capacity at an existing hydroelectric plant.

Every project has different requirements, but facility managers may find renewable energy opportunities through photovoltaic panels, solar thermal, wind turbines, and biomass.

Photovoltaic Panels

Solar cells, or photovoltaic panels (PV), are made from a semiconductor material that converts solar radiation directly into electricity. If the PV array produces more power than is immediately needed, a storage system in the form of batteries can save this energy for future use. Alternatively, excess generated power can be sold back to the utility.

Solar cell systems generally require minimal maintenance and they are most useful in areas with abundant sunshine that are located far from conventional power supplies. Cost-effective PV systems may be part of a comprehensive power generation system that enables a remote area to avoid the expense of connecting to traditional sources of power. On their own, however, PV systems usually have the poorest return-on-investment compared to other renewable energy systems.

With the enormous growth of the PV industry, many different technologies and suppliers have emerged. Three technologies that are tested and proven are amorphous silicon (a-Si), multi-crystalline silicon (mc-Si), and mono-crystalline silicon (c-Si). All three have distinct advantages and disadvantages; facility managers should evaluate each of them on a site-specific basis to determine the best solution for a particular facility.

Amorphous Silicon Laminates

Amorphous silicon laminates are commonly used in consumer products such as calculators, outdoor lighting, and radios. Within the last ten years, companies specializing in lightweight laminates have emerged. A new lightweight laminate that can adhere to a metal backing can use 100 times less silicon than traditional crystalline modules. Although amorphous silicon laminates are less costly to manufacture than other PV technologies, they are the least efficient of the three proven PV technologies. Still, amorphous laminates have advantages, including strength, flexibility, durability, low weight, high performance in diffuse, low-light conditions, and stable efficiency at high temperatures.

Multicrystalline Cells

Multicrystalline modules are made from melted and recrystallized silicon, which is cast into a cylindrical shape, and then cut into thin wafers. Multicrystalline cells are less costly to manufacture than monocrystalline cells due to a simpler process, and they are somewhat less efficient.

Monocrystalline Cells

The process for monocrystalline cells is more complicated; it involves growing single crystals into long, cylindrical shapes, which are then sliced into thin wafer cells. Monocrystalline modules are ideal in installations where space and efficiency take precedence over cost, as they are the most efficient of the three PV technologies.

Solar Thermal

Solar hot water heating systems use the sun's energy to heat water. These systems include a collector and a storage tank, and they are available in a variety of designs. The term "solar thermal" is used to differentiate it from electricity derived from solar energy in photovoltaic systems. Solar thermal uses active rather than passive means to obtain thermal energy from the sun. In active collection of solar energy, a heat transfer fluid is pumped between a heat collector and the building's domestic water heating and the heating and ventilation system components. Unlike photovoltaic production, solar thermal will generate the most heat during the time when it is least needed. In fact, the solar array will generate more heat than can be used during the summer months. More information on solar hot water heating can be found on page 2-29.

Wind Power

Wind power is produced by using wind turbine generators, which convert the kinetic energy of wind into useful electrical energy. In locations with optimal wind conditions, wind turbines are a reliable source of constant energy that is not dependent on daylight. To function properly, wind turbines need a wind speed in excess of 10 miles per hour (mph), and they are most effective in areas of high, steady wind. Even a single wind turbine can greatly supplement the power requirements if located in a wind-prone region.

Generally, the most economical wind turbine solutions do not replace all energy sources, but instead complement existing power sources. Popular renewable energy production methods couple wind technology with photovoltaic arrays for economical small-scale renewable electric production. Because these systems may produce more power than immediately needed, storage in the form of batteries is employed to save energy for future use.

Wind power does have disadvantages. Wind farms may not be universally welcomed because of their visual impact and other effects on the environment. Wind power is also non-dispatchable, meaning that for economical operation all available output must be taken when it is available. As long as wind power is used to generate a limited percentage of a facility's power needs, the intermittent nature of the availability of wind should not create supply problems.

Biomass

Biomass stores solar energy in the form of carbon. Plants absorb carbon in the form of carbon dioxide during photosynthesis, which converts carbon dioxide into organic compounds using the sun's energy. Biomass can be managed sustainably, since new growth forests will eventually absorb carbon dioxide from the atmosphere while the previous harvest releases it. While biomass fuel has a less harmful effect on the atmosphere, it also has lower energy densities; this means that a significantly larger quantity of biomass fuel is required to produce the same energy generated by a smaller quantity of fossil fuel.

Both biomass and fossil fuels such as gas, oil, and coal contain carbon in varying amounts. Fossil fuels contain carbon dioxide captured from the atmosphere millions of years ago, while biomass fuels contain carbon dioxide captured recently during the organism's life. Fossil and biomass fuels both return carbon to the atmosphere; however, fossil fuels return carbon sequestered millions of years ago, leading to a more rapid increase in emissions of greenhouse gases. Despite the presence of carbon in both types of fuel, biomass is considered a green energy solution due to the difference in the source of carbon. For more information on impacts to the atmosphere, see Chapter 5, page 5-25.

Wood

Biomass energy can be produced by biomass boilers, which burn various types of fuels, including wood, crop residue, corn, animal byproducts and waste. Wood products, which are the most widely available and usually the least expensive of the biomass fuels, are the most common type of biomass boiler fuel. Available wood fuel products include log wood, wood pellets, wood chips, sawdust, and bark. Before installing a biomass boiler, it is important to consider the advantages and disadvantages for each type of fuel, as they vary in cost, availability, and storage space requirements.

Corn

A number of manufacturers offer corn fuel biomass boilers, as corn is widely available in many parts of the nation, although it is not available year round. The heating potential of corn is high in proportion to its weight and is more consistent than wood, as each species of wood has unique heating properties. Large variations can be found in the heating content of wood, while corn is consistent. The small size of corn makes it easy to handle and it can be used with automatic feeding equipment. There has been a decrease in the use of corn as a biomass boiler fuel due to the ethanol industry's high demand for corn. One drawback to corn fuel is that is can produce "clinkers," which are hard masses of improperly burned fuel that can clog parts of the burner and reduce efficiency.

Animal Waste

Animal waste is sometimes used in biomass boilers in locations where it is produced in quantities greater than is needed for crop fertilization. Currently, there are low cost disposal options for animal waste which makes it less likely that farmers will need to seek alternatives for waste disposal. If disposal costs continue to rise, however, animal waste will be used more frequently for biomass energy.

The United States Green Building Council (USGBC) has defined eligible and ineligible biofuels as illustrated in Figure 10.

Figure 10 - Eligible and Ineligible Biofuels

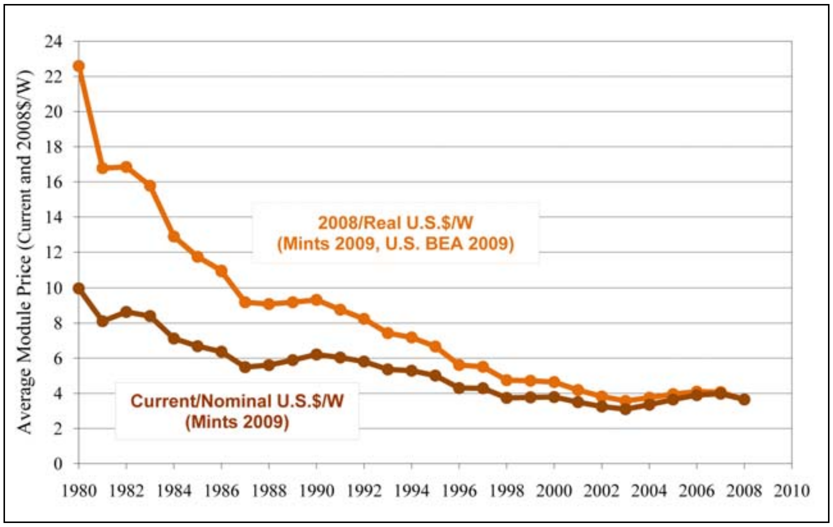
Eligible	Ineligible
• Untreated wood waste, including mill residues • Agricultural crops or waste • Animal waste and other organic waste • Landfill gas	• Combustion of municipal solid waste • Forestry biomass waste other than mill residue • Wood coated with paints, plastics or formica • If more than one percent of the wood fuel is treated for preservation with materials containing halogens, chlorine compounds, halide compounds, chromated copper arsenate or arsenic

Source: USGBC LEED Reference Guide for Green Building Design and Construction; 2009.

3) Estimate the Life-cycle Costs and Benefits

To determine the cost-effectiveness of renewable energy projects, managers will need to carefully analyze energy use, cost, maintenance requirements, and other considerations, including initial equipment cost and resulting energy cost savings. Renewable energy power sources can vary widely in first-cost and potential long-term savings. For example, solar water heaters usually cost less initially than wind turbines or PV systems. Costs of solar renewable energy sources, such as PV cells, have declined since the 1980s, as illustrated in Figure 11.

Figure 11- Global, average PV module prices, all PV technologies, 1980-2008



Source: DOE, Solar Technologies Market Report, 2008.

Wind turbine systems, on the other hand, are more difficult and costly to implement on a large scale due to lack of existing infrastructure. While the construction of transmission lines to support wind turbine energy is increasing, wind turbine farms are not a feasible option without the proper infrastructure already in place.[20] Individual facility systems have lower initial costs and generation potential.

Potential costs of renewable energy projects include:

- Purchase of renewable energy systems
- Installation of renewable energy systems
- Additional planning and design
- Training and education for occupants and staff
- Maintenance of renewable energy systems

[20] Solar Technologies Market Report, DOE, 2008.

Potential benefits of renewable energy projects include:

- Reduction in operation costs
- Lower demand for electricity from the public power grid
- Reduced use of fossil fuels
- Highly visible demonstration of Agency energy-saving efforts

4) Prioritize, Finance, and Install Renewable Energy Generation Projects

Funding may not be immediately available for all cost-effective renewable energy generation projects. Therefore, it is important to determine which projects will be most cost-effective for a particular site. Due to limited funding, facility managers should think creatively and explore alternative funding sources. Potential funding mechanisms include:

- Agency appropriations
- The DOE's Energy Efficiency and Renewable Energy Program
- Retained energy savings
- Energy Savings Performance Contracts
- Utility Energy Services Contracts
- O&M performance incentives

5) Maintain and Monitor Installed Systems

Proper maintenance and monitoring help ensure optimal performance and maximum energy savings from renewable energy systems. Wind turbines, for example, require recurring maintenance on motors and bearings to prevent costly repairs and downtime. It is also important to measure energy performance before and after renewable sources are installed; this can help identify performance issues and demonstrate real and potential savings.

Related LEED® Credits

The LEED® credits related to renewable energy are illustrated in Table 4. Definitions for all LEED® abbreviations appear in the Introduction.

Table 4 – LEED® and Renewable Energy

LEED-NC®	EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems
	EA Prerequisite 2: Minimum Energy Performance
	EA Credit 1: Optimize Energy and Performance
	EA Credit 2: On-site Renewable Energy
	EA Credit 5: Measurement and Verification
	EA Credit 6: Green Power
LEED-EB: O&M®	EA Prerequisite 1: Energy Efficiency BMP - Planning, Documentation, and Opportunity Assessment
	EA Prerequisite 2: Minimum Energy Efficiency Performance
	EA Credit 1: Optimize Energy Efficiency Performance
	EA Credit 2.1: Existing Building Commissioning - Investigation and Analysis
	EA Credit 2.2: Existing Building Commissioning - Implementation
	EA Credit 2.3: Existing Building Commissioning - Ongoing Commissioning
	EA Credit 3.1: Performance Measurement - Building Automation System
	EA Credit 3.2: Performance Measurement - System-Level Metering
	EA Credit 4: On-site and Off-site Renewable Energy
	EA Credit 6: Emissions Reduction Reporting
LEED-ND®	GIB Prerequisite 2: Minimum Building Energy Efficiency
	GIB Credit 2: Building Energy Efficiency
	GIB Credit 9: Heat Island Reduction
	GIB Credit 10: Solar Orientation
	GIB Credit 11: On-site Renewable Energy Sources
	GIB Credit 12: District Heating and Cooling
	GIB Credit 13: Infrastructure Energy Efficiency

TOOLS

National Renewable Energy Laboratory

The National Renewable Energy Laboratory (NREL) supports the DOE's research and development efforts through a variety of programs, including the National Center for Photovoltaics, Advanced Vehicles and Fuels, Biomass, Geothermal, Hydrogen and Fuel Cells, Wind, and Renewable Resource Mapping and Data.

For more information: http://www.nrel.gov

Federal Energy Management Program - Renewable Energy

The FEMP provides technical assistance and resources to help federal agencies evaluate and implement renewable energy technologies. Available tools include a catalog of federal requirements, information on renewable resources and technologies, help with project planning, resource maps and screening tools, information on purchasing renewable power, case studies, training, working groups, and contacts for additional information.

For more information: http://www1.eere.energy.gov/femp/technologies/renewable_energy.html

American Wind Energy Association

The American Wind Energy Association provides basic information on wind energy, including costs and benefits, related legislation and policies, and publication resources.

For more information: www.awea.org

BEST MANAGEMENT PRACTICE - SOLAR HOT WATER HEATING

Meet at least 30 percent of the hot water demand through the installation of solar hot water heaters, when life-cycle cost effective.

Solar hot water heating systems, also called solar thermal systems, use the sun's energy, rather than electricity or natural gas. Solar hot water heating systems can be installed in any climate, and typically are installed on the roof, facing south. An example solar hot water heating system appears in Figure 12.

Figure 12 – Rooftop Solar Hot Water Heating System, Building 20, Johnson Space Center

Source: NASA.

> *NASA Requirement*
>
> *NPR 8570.1 requires expanded use of renewable energy for facilities and operational activities by implementing renewable energy projects and by purchasing electricity from clean, efficient, and renewable energy sources.*

In solar hot water heating systems, the sun's energy is gathered by collectors and it heats water or a non-freezing fluid. Heated water then flows into a well-insulated storage tank or it is used immediately. Indirect systems use a non-freezing fluid to transfer the sun's energy to a heat exchanger in the storage tank, heating the water. Solar water heating systems may also include pumps and controls. Systems with pumps and controls are called active systems, while those without are called passive systems.

In federal facilities, at least 30 percent of total hot water demand must be met by cost-effective solar hot water heating systems.[21] Although solar hot water heating systems

[21] EISA 2007, Section 523.

generally cost more upfront than conventional systems, they can be cost-effective over the facility's life cycle. Total cost savings depend on many factors, including total hot water demand, current system performance, geographic location, and fuel costs.[22] In addition to potential reductions of 50-80 percent in water heating-related energy costs, the facility's budget is also protected from future fuel price increases.[22]

Building Focus

Collaborative Support Facility, Ames Research Center

LEED® Office for Transition, Johnson Space Center

These buildings have installed solar water heating systems.

Implementing Solar Hot Water Heating

Table 5 lists required steps for implementing solar hot water heating. These steps are discussed in additional detail in the subsequent narrative.

Table 5 – Implementing Solar Hot Water Heating

IMPLEMENTATION STEPS	
1)	**Conduct a Hot Water Audit**
□	Determine phase of energy audit needed.
□	Utilize meters, utility bills, and calculations to determine baseline energy use.
2)	**Evaluate Local Solar Resources**
□	Determine if solar hot water heater is cost effective and applicable for the facility.
3)	**Identify Solar Hot Water Heating Opportunities**
□	Research which type of solar hot water heater is most applicable.
4)	**Estimate the Life-cycle Costs and Benefits**
□	Determine costs and benefits of the implementation of solar hot water upgrades.
5)	**Prioritize, Finance and Implement Solar Hot Water Heating Systems**
□	Identify funding resources.
□	Determine priority of implementation of elements.
6)	**Monitor Energy Savings**
□	Measure energy savings after implementation.
□	Ensure energy savings results meet federal and Agency criteria.

1) Conduct a Hot Water Audit

In addition to a building-wide energy audit, a more specific hot-water use audit must be conducted to establish a facility use baseline. The baseline may be established through the water audit or by metering techniques. Supplementary information on water audits and water metering can be found in Chapter 3 on pages 3-8 and 3-12.

2) Evaluate Local Solar Resources

Selection of a solar hot water heating system will depend in part on the intensity of solar energy available in the particular location. Direct and diffuse solar radiation can both

[22] *Economics of a Solar Hot Water Heater*, DOE Energy Efficiency and Renewable Energy.

contribute energy, so facilities do not need to be located in the southwest United States in order to be good candidates for solar hot water heating systems. Generally, unshaded and south-facing locations offer adequate quantities of solar energy. To determine the adequacy of available solar resources, consult a solar system supplier or local utility company for a solar site analysis.

3) Identify Solar Hot Water Heating Opportunities

Once hot-water audit information is collected, the facility manager should determine which type of solar water heater, if any, is most cost-effective and appropriate for the facility. Certified ENERGY STAR solar water heaters can reduce annual water heating bills by 50 percent.[23] Solar hot water heaters offer longer life expectancy and improved water conservation compared with traditional water heating systems.

Solar hot water heating systems include a storage tank and one of three types of solar collector designs: batch collectors, flat-plate collectors, and evacuated tube collectors. Each of the three designs collects thermal energy from the sun and circulates the water in different ways. The efficiency of the collector is related to heat loss across the collector's surface.

Figure 13 – Example Batch Collector System

Source: "Solar Hot Water" ENERGY STAR.

Batch Collectors

Batch collectors, also known as Integrated Collector-Storage (ICS) systems, heat water through a combination of tanks or tubes and an insulated box. Cold water is preheated inside the collector, and then it flows to a conventional backup water heater to ensure that it is sufficiently heated. Once heated, hot water passes through a tempering valve and mixes with cold water, if necessary, to prevent scalding. Batch collectors are not recommended for cold climate regions due to potential pipe freezing. An example batch collector is illustrated in Figure 13.

Flat-plate Collectors

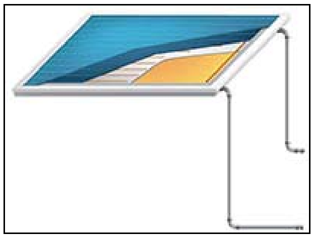
Flat-plate collectors contain a series of parallel copper tubes attached to flat absorber plates. The system is located inside an insulated, weatherproof box, which is covered with tempered glass. A flat-plate collector generally can hold up to 40 gallons of water and can provide approximately one-quarter of the hot water needed by a family of four.[24] Some types of flat-plate collectors are designed without covers or enclosures. These are called "unglazed" systems and they are

[23] "Solar Water Heater," ENERGY STAR.

[24] Water Heater, Solar, ENERGY STAR.

commonly used for solar pool heating. An example flat-plate collector is identified in Figure 14.

Figure 14 – Example Flat-plate Collector



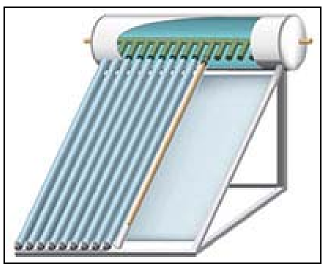
Source: "Solar Hot Water" ENERGY STAR.

Flat-plate collectors offer a favorable price-to-performance ratio and they can be mounted in a variety of ways. Flat-plate collectors can produce fluid temperatures of up to 150 degrees Fahrenheit; this temperature is more than adequate to heat domestic water, but it is considered low for some space heating applications. The efficiency of the flat-plate collector is greatly affected by ambient temperatures, as there are large surface areas that allow heat loss.

Evacuated Tube Collectors

Evacuated tube collectors contain a series of enclosed glass or metal tubes, similar to those found in a thermos. An inner tube holds the fluid while the vacuum between the inside and outside tubes reduces heat loss from the fluid. Generally, this design is the most efficient, and it can be used in overcast conditions and cold climates. However, these systems can cost twice as much per square foot as flat-plate collectors. An example evacuated tube collector appears in Figure 15.

Figure 15 – Example Evacuated Tube Collector



Source: "Solar Hot Water" ENERGY STAR.

Evacuated tube collectors are typically installed as part of a concentrating collector system, where mirrors or other polished surfaces are used to direct the sun's rays to the collectors to enhance their performance. These concentrating collectors can also be used in conjunction with devices that track the movement of the sun either on a single or dual axis to maximize exposure throughout the day.

Definition

Solar Energy Factor

A description of the energy-efficiency of a solar water heating system, determined through calculating the energy delivered to the system divided by the electricity or natural gas energy put into the system.

4) Estimate Life-cycle Costs and Benefits

Determining a solar hot water heater's cost effectiveness requires collecting specific information and performing calculations. Necessary information includes the system's **Solar Energy Factor (SEF)**, the auxiliary tank fuel type, and local energy rates to determine the system's annual operating cost.[25] Each type of auxiliary tank system requires a different calculation technique, depending on whether the tank uses natural gas or electricity. Through another set of calculations, these inputs can determine the payback period, after which the cost of the solar water heater is offset by resulting energy savings. An example calculation table is shown in Table 6.

[25] "Estimating a Solar Water Heather System's Cost," EERE.

Table 6 – Solar Hot Water Heating Calculation

System Models	System Price ($)	SEF (Energy Ratio)	Estimated Annual Operating Cost ($ per year)
System Model A	[Enter $ here]	[Enter SEF here]	[Enter $ per year here]
System Model B (higher SEF)	[Enter $ here]	[Enter SEF here]	[Enter $ per year here]
Difference between Model A and Model B	System Model B ($) - System Model A ($) = Additional Cost of Implementing Model B		System Model B ($ per year) - System Model A ($ per year) = Cost Savings Per Year from Implementing Model B
Payback period	**Additional Cost of Model B ÷ Model B's Cost Savings Per Year = Payback period (years)**		

Source: DOE, Estimating a Solar Hot Water Heater System's Cost, 2010.

Potential costs of solar hot water heating include:

- Purchase and installation of solar hot water heaters, piping, fixtures, or other equipment
- Ongoing maintenance of hot water systems

Potential benefits of solar hot water heating include:

- Reduced energy costs
- Reduced consumption of fossil fuels
- Longer average equipment life expectancy

5) Prioritize, Finance, and Implement Solar Hot Water Heating Systems

Funding for every type of appropriate solar hot water heating system may not be immediately available. Results of water audits can help facility managers to identify the end uses that consume the most hot water and energy.

Potential funding mechanisms include:

- Agency appropriations
- The DOE's Energy Efficiency and Renewable Energy Program
- Retained energy savings
- Energy Savings Performance Contracts
- Utility Energy Services Contracts

6) Monitor Energy Savings

Proper system monitoring ensures efficient operation and reduces the need for required maintenance. In order to ensure and document energy savings, total hot water consumption from solar and conventional systems should be monitored and measured. This data can provide cost justification, as well as additional information necessary to identify system problems and inefficiencies.

Related LEED® Credits

The LEED® credits related to solar hot water heating are illustrated in Table 7. Definitions for all LEED® abbreviations appear in the Introduction.

Table 7 – LEED® and Solar Hot Water Heating

LEED-NC®	EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems
	EA Prerequisite 2: Minimum Energy Performance
	EA Credit 1: Optimize Energy and Performance
	EA Credit 2: On-site Renewable Energy
	EA Credit 5: Measurement and Verification
	EA Credit 6: Green Power
LEED-EB: O&M®	EA Prerequisite 1: Energy Efficiency BMP - Planning, Documentation, and Opportunity Assessment
	EA Prerequisite 2: Minimum Energy Efficiency Performance
	EA Credit 1: Optimize Energy Efficiency Performance
	EA Credit 2.1: Existing Building Commissioning - Investigation and Analysis
	EA Credit 2.2: Existing Building Commissioning - Implementation
	EA Credit 2.3: Existing Building Commissioning - Ongoing Commissioning
	EA Credit 3.2: Performance Measurement - System-Level Metering
	EA Credit 4: On-site and Off-site Renewable Energy
LEED-ND®	GIB Prerequisite 2: Minimum Building Energy Efficiency
	GIB Credit 2: Building Energy Efficiency
	GIB Credit 11: On-site Renewable Energy Sources

TOOLS

ENERGY STAR – Solar Hot Water Heater

The ENERGY STAR program provides resources to help the facility manager select and install energy-efficient products, such as hot water heaters.

For more information:
http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=WSE

Insulating Water Heaters and Pipes

The DOE provides information regarding insulation techniques for hot water systems. Data on cost savings and material pricing is included, as are links to other hot water energy savings resources.

For more information:
www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13070

Solar Site Analysis

The DOE provides information regarding selecting, installing, and maintaining solar hot water heating systems. As part of the system selection process, information regarding evaluating site solar resources and performing a solar site analysis is included.

For more information:
www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=12870

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Measurement and Verification

Once building systems and other facility equipment have been installed and calibrated to proper specifications, they must be periodically checked to ensure optimum efficiency. Ongoing measurement and performance verification combine to give facility managers the information they need to keep systems running smoothly and efficiently. Facility managers should ensure that energy consumption is being monitored, and should develop more detailed information on systems that use the greatest quantities of energy. An example electricity meter appears in Figure 16.

Figure 16 – Example Advanced Electricity Meter

Source: *Metering Best Practices Guide*, FEMP.

The BMP for implementing measurement and verification is derived from the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings*, Agency policy, or the energy industry. The BMP includes discussion of related NASA activities and accomplishments, relevant LEED® credits, and resources for additional information or assistance.

The energy efficiency BMP for new construction, major renovation, or existing buildings requires installing building-level electricity meters in new construction and major renovation projects to track and continuously optimize performance. Per EPAct 2005 Section 103, include equivalent meters for natural gas and steam, where natural gas and steam are used.

Rule of Thumb

Total cost for metering programs comes from three main categories: hardware, labor, and recurring costs. These costs are affected by functionality, communication method, metering infrastructure, and site conditions.

Best Management Practice - Utility Meters

Install building-level electricity meters in new construction and major renovation projects to track and continuously optimize performance. Per EPAct 2005 Section 103, include equivalent meters for natural gas and steam, where natural gas and steam are used.

NASA Requirement

NPR 8831.2E requires utility data management, including metering and analysis of all utilities. Utility data should be used to review billing transactions, usage patterns and levels, and system efficiencies.

NPR 8570.1 requires gathering background information, establishing an Energy Use Index, and assembling other information to identify energy consumption patterns and potential areas for energy conservation opportunities, as part of the planning for an energy efficiency and conservation management program.

Definition

Sub-metering

Sub-metering involves installing secondary meters to measure the consumption of specific end uses or subsystems (e.g. the energy of the lighting system).

Utility meters are a critical source of energy consumption information for facility managers. Meters can be installed at the Center, facility, or system level, or even for a single piece of equipment. Meters are a common way to identify and track electricity, water, or gas savings resulting from conservation or efficiency improvements. The *Guiding Principles* and EPAct 2005 require "building level electricity meters to track and continuously optimize performance."[26] In addition, EISA 2007 requires "equivalent meters for natural gas and steam, where natural gas and steam are used." This section will focus specifically on electricity meters. More information on water meters can be found in Chapter 3 on page 3-12.

Continuous electricity metering is critical to measurement and verification plans, commissioning and re-/retro-commissioning and utility data management. Guidance from the FEMP identifies two important benefits of using meters:[27]

- Reduced operating costs from reduced energy use and increased equipment life
- Optimized building and equipment performance, including improved systems reliability and increased occupant comfort

Meters can help managers to optimize performance by identifying opportunities for energy conservation and efficiency. Facility managers should consider the benefits of optimal building operation versus project costs. Where appropriate, NASA uses wireless automatic meter-reading technology to increase data collection efficiency. Advanced meters can upload data directly into Building Automation Systems (BAS), which allows real-time data analysis and eliminates the need for manual meter readings.

Additional energy consumption information can be obtained by **sub-metering** the building. Sub-metering provides more

[26] *Guiding Principles for High Performance and Sustainable Buildings*, 2008.

[27] *Guidance for Electric Metering in Federal Buildings*, FEMP, 2006.

detailed information that more accurately tracks consumption, and it can reveal unexpected patterns. Additional equipment and administrative costs mean that sub-metering generally costs more to install and operate.

Facilities that produce more energy than they consume can sell the excess power back to the local utility. This process is called net metering and it can provide a new source of revenue for the facility, offsetting some of the upfront project installation costs.

Implementing a Metering System

Table 8 lists the steps required for implementing electricity metering systems. These steps are discussed in detail in the subsequent narrative.

Table 8 – Implementing a Metering System

IMPLEMENTATION STEPS	
1)	**Evaluate the Existing Metering System**
□	Document the type and location of each meter.
2)	**Develop a Metering Plan**
□	Identify major needs and goals of the metering plan.
□	Maintain a written record of preventive maintenance practices relating to the system-level metering.
3)	**Analyze Existing Energy Use by Building System**
□	Prepare an energy use breakdown report.
4)	**Determine the Metering Approach**
□	Identify the facility's metering equipment, data collection, and data storage needs.
□	If facility is part of a District Energy System, identify and follow the appropriate guidance for district energy systems under "Registered Project Tools" page on the USGBC website.
5)	**Estimate Life-cycle Costs and Benefits**
□	Determine the cost of the proposed metering program.
□	Determine the expected/estimated energy savings.
6)	**Prioritize, Finance and Implement the Metering Plan**
□	Identify the buildings where metering is not cost-effective.
□	Include meters for natural gas and steam.
□	Maintain documentation of the system-level metering operation and function.
7)	**Develop Energy-efficiency Plans Based on the Metering Data**
□	Establish procedures to improve system performance by utilizing metering data in monthly and annual reports.
□	Analyze energy reports for trends.

1) Evaluate the Existing Metering System

Before new metering equipment is installed, an inventory of existing systems should be taken. All metering equipment should be documented, whether it is found in the facility design or already installed in the building. In addition to the equipment itself, the frequency of data collection and recording and the type and location of each meter should also be documented.

> *Rule of Thumb*
>
> *Managers should ensure that the meters they select can meet EPAct requirements for hourly data recording intervals and daily data downloads.*

2) Develop a Metering Plan

Facility managers should develop a metering plan that is appropriate to the needs and goals of their facilities. Common performance metrics for meters include accuracy, precision/repeatability, and turndown ratio. Other considerations may include ease of installation, ongoing operations and maintenance, and installation versus capital cost.[28] Metering elements may include data acquisition hardware, electrical sub-meters, natural gas meters, or steam meters. Electricity meter types include mechanical, electro-mechanical, and solid state/digital meters (also called advanced meters). Each type has different data storage and time interval capabilities.

3) Analyze Existing Energy Use by Building System

Prepare an energy-use breakdown report that identifies the energy consumption patterns for major mechanical systems and other end-use applications. Many NASA facilities consume significant amounts of energy in data centers and for process, industrial, and testing uses. Although in some cases there may not be many opportunities for improving energy efficiency, these uses should still generally be included in facility metering plans.

The benefits of metering increase as the scope of the metering plan increases; metering more energy-consuming equipment increases the potential for improving energy efficiency and reducing energy costs. Generally, managers should begin metering the systems that use the most energy and work downward. Managers should also consider metering systems with significant performance variability, even when the energy use is relatively low.

According to NPR 8831.2E, the primary energy-consuming systems commonly found at NASA facilities include:[29]

- Heating and power plants
- Steam distribution systems
- Hot water and chilled water distribution systems
- Electrical distribution systems

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[28] EERE Metering Best Practices Guide, October 2007.

[29] NASA NPR 8831.2E, Facilities Maintenance and Operations Management, Chapter 11.

- Compressed-air distribution systems
- Wind tunnels

4) Determine the Metering Approach

First, develop the metering approach that is best suited to the individual characteristics of each project or facility. The approach will assist managers to determine the metering equipment, data collection, and data storage needs of their facility. The four main metering approaches include one-time/spot, run-time, short-term, and long-term measurement. [30]

One-time/Spot measurement

One-time or spot measurements are taken at a single point in time using a single piece of equipment or system. These measurements are useful at the system and sub-system levels to understand baseline energy use. Data from these measurements allows measurement of performance trends for facility equipment over time. This approach can also identify changes in energy consumption after energy efficiency projects are installed, assuming equipment hours of operation remains constant. Advantages and disadvantages of one-time/spot measurements are listed in Figure 17.

Figure 17 – One-time/Spot Measurement Advantages and Disadvantages

One-Time/Spot Measurements Advantages
- Lowest cost
- Ease of use
- Non-intrusive
- Fast results

One-Time/Spot Measurements Disadvantages
- Low accuracy
- Limited application
- Measures single operating parameter
- Measurement at a single point in time

Note: One-time spot measurements will not be sufficient to comply with the requirements of EPAct Section 103.

Source: *Guidance for Electric Metering in Federal Buildings*, FEMP, 2006.

Run-time measurement

Run-time measurements measure duration of system or equipment run-time rather than energy consumption. For this reason, they are commonly used in conjunction with spot measurements. Run-time measurement is useful at the system or sub-system levels when the critical variable is hours of operation, or when an energy efficiency project has affected the equipment's hours of operation. Measuring the run times of fans and pumps, as well as the performance of heating, cooling, or lighting systems are examples of useful applications for this measurement approach. Most equipment used to make run-time measurements is non-intrusive, and data is generally recorded by the device for future download by an analyst. Advantages and disadvantages of run-time measurements are listed in Figure 18.

Figure 18 – Run-Time Measurement Advantages and Disadvantages

Run-Time Measurements Advantages
- Low cost
- Relatively easy to use
- Non-intrusive
- Useful for constant-load devices

Run-Time Measurements Disadvantages
- Limited application
- Measures single operating parameter
- Requires additional calculations/assumptions
- Requires recover and/or manual data download

Note: Depending on whether data is collected at least hourly and automatically downloaded at least daily, run-time measurements may not meet the definition of advanced metering.

Source: *Guidance for Electric Metering in Federal Buildings*, FEMP, 2006.

Short-term measurement

Short-term measurement combines elements of one-time and run-time measurement into a time-series data record. Energy-use magnitude and duration are generally measured for a period of weeks or months, for up to one year. Short-term measurement is useful at the system, sub-system, and whole

[30] *Guidance for Electric Metering in Federal Buildings*, FEMP, 2006.

building levels for a variety of applications, including verifying performance, initiating trending, and validating energy efficiency improvements. Short-term measurements are generally taken by portable, stand-alone devices capable of multivariate time-series data collection and storage. Most of these devices can measure temperature, pressure, voltage, current flow, and other variables at time intervals ranging from fractions of a second up to hourly or daily recordings. Advantages and disadvantages of short-term measurement are identified in Figure 19.

Figure 19 – Short-term Measurement Advantages and Disadvantages

Short-Term Measurements/Monitoring Advantages

- Mid-level cost
- Can quantify magnitude and duration
- Relatively fast results
- Data can be recovered remotely over data lines

Short-Term Measurements/Monitoring Disadvantages

- Mid-level accuracy
- Limited application
- Seasonal or occupancy variance deficient
- More difficult to install/monitor

Note: Although short-term measurements have their advantages, EPAct Section 103 is directed at permanent, long-term metering installations.

Source: *Guidance for Electric Metering in Federal Buildings*, FEMP, 2006.

Long-term measurement

Long-term measurement also combines elements of one-time and run-time measurement into a time series record, but over a longer period of time. The time period is generally longer than a year and is often permanent, especially at the whole building level. Over time, this form of measurement generates data that allows measurement and analysis of energy consumption trends. Long-term measurement is useful for a variety of applications, including systems that are affected by weather, occupancy, or other operating circumstances. Other applications include reimbursable resource allocation, tenant billing, or measurement of energy savings over time. Long-term measurement equipment is generally installed permanently, and the device records data and transmits information via a network or phone connection. Advantages and disadvantages of long-term measurement are listed in Figure 20.

Figure 20 – Long-term Measurement Advantages and Disadvantages

Long-Term Measurements/Monitoring Advantages

- Highest accuracy
- Can quantify magnitude and duration
- Captures most variance
- Data can be recovered remotely over data lines

Long-Term Measurements/Monitoring Disadvantages

- High cost
- Most difficult to install/monitor
- Time duration for result availability

Note: Long-term monitoring makes use of time-series recording of energy or resource use (but over a longer duration) and meets the requirements of EPAct.

Source: Guidance for Electric Metering in Federal Buildings, FEMP, 2006.

5) Estimate Life-cycle Costs and Benefits

EPAct 2005 requires installation of meters "to the maximum extent practicable." Guidance from FEMP indicates a "practicable meter application is one that can be justified on the basis of its cost-effectiveness."[31] To analyze a metering program's cost- effectiveness, managers will need to calculate both the cost of the program and the resulting energy cost savings. Due to widespread use throughout the residential and commercial building sectors, metering technology and equipment is relatively inexpensive, dependable, and easy to implement, compared to other energy efficiency or renewable energy improvements. Navy cost guidance estimates the cost for continuous metering equipment sufficient to meet LEED-NC® at $1.67 per square foot, or $18 per square meter.[32]

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[31] *Guidance for Electric Metering in Federal Buildings*, FEMP, 2006.

[32] LEED® for New Construction v3.0 Workbook, Naval Facilities Engineering Command.

Estimating energy cost savings resulting from a metering program can be difficult due to limited federal experience with metering. Energy savings also depend in part on the type of metering equipment, and the intensity of the metering program. Facilities with more complex metering systems may have higher costs. Observed energy savings from various types of metering programs are listed in Figure 21. The immediate observed savings may be due to the **Hawthorne Effect** rather than energy savings from the meters.

Figure 21 – Metering Savings Ranges

Action	Observed Savings
Installation of meters	0 to 2% (the "Hawthorne effect")[1]
Bill allocation only	2-1/2 to 5% (improved awareness)
Building tune-up	5 to 15% (improved awareness, and identification of simple O&M improvement)
Continuous Commissioning	15 to 45% (improved awareness, ID simple O&M improvements, project accomplishment, and continuing management attention)

Source: *Guidance for Electric Metering in Federal Buildings*, FEMP, 2006.

6) Prioritize, Finance, and Implement the Metering Plan

It is unlikely that sufficient funding will exist to allow metering of all buildings and/or equipment over the next fiscal year. According to FEMP,[33] managers "should prioritize buildings (and equipment) for metering/sub-metering applications based on the potential to benefit from the metered data." After identifying which elements of the metering plan are most cost effective, managers should address energy consumption, energy costs, and the expected/estimated benefits of each metering objective.

In general, several building types are unlikely to be find metering to be cost effective. These include:

- Low energy intensity buildings, such as unconditioned warehouses, or buildings with low or temporary occupancy
- Small buildings that do not consume a lot of energy[34]
- Leased buildings where reductions in energy costs either provide no benefit, or they provide a benefit which will outlive the lease

Once managers identify the most cost-effective and appropriate metering approach for their facility, sufficient funding will need to be secured. Even equipment with relatively short payback periods will require some funding upfront. A variety of funding mechanisms to assist with purchase and installation of metering equipment are available. Due to funding limitations, facility managers should think creatively and explore alternative funding instruments.

Definition

Hawthorne Effect

The phenomenon where individuals that know they are being measured in some way adjust or improve their normal behaviors merely because they are being measured, not from any particular experimental manipulation.

[33] *Guidance for Electric Metering in Federal Buildings*, FEMP, 2006.

[34] NASA is currently developing a definition for a "small" building. Other organizations use figures in the range of buildings less than 5,000-10,000 square feet.

Potential funding mechanisms include:

- Agency appropriations
- Retained energy savings
- Energy Savings Performance Contracts
- Utility Energy Services Contracts
- Utility company financing
- Bonneville Power Administration
- Public benefits programs and utility demand response programs
- Requirements on new construction and major renovations
- Mandatory tenant sub-metering fees
- O&M performance incentives
- Leased equipment from GSA

7) Develop Energy-Efficiency Plans Based on the Data

According to FEMP, the key to a successful metering program is effective use of the data; mere metering of buildings and/or systems does not save energy by itself.[35] The data collected needs to be analyzed in order to develop priorities and action steps for future energy efficiency projects.

Metering data can be analyzed in a number of ways. For example, data gathered over time can illustrate trends that identify statistically significant changes in building or equipment performance, which can indicate the need for adjustments or replacement. Energy use when the building is not occupied can also be compared to use when the building is occupied. Finally, energy use across different seasons may reveal previously unknown consumption patterns and may indicate a need to alter current building operations.

[35] *Guidance for Electric Metering in Federal Buildings*, FEMP, 2006.

Related LEED® Credits

The LEED® credits related to electricity metering are illustrated in Table 9. Definitions for all LEED® abbreviations appear in the Introduction.

Table 9 – LEED® and Utility Meters

LEED-NC®	EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems
	EA Prerequisite 2: Minimum Energy Performance
	EA Credit 1: Optimize Energy Performance
	EA Credit 2: On-site Renewable Energy
	EA Credit 5: Measurement and Verification
LEED-EB: O&M®	EA Prerequisite 2: Minimum Energy Efficiency Performance
	EA Credit 1: Optimize Energy Efficiency Performance
	EA Credit 3.2: Performance Measurement - System-Level Metering
	EA Credit 4: On-site and Off-site Renewable Energy
	EA Credit 6: Emissions Reduction Reporting
LEED-ND®	GIB Prerequisite 2: Minimum Building Energy Efficiency
	GIB Credit 2: Building Energy Efficiency
	GIB Credit 11: On-site Renewable Energy Sources

TOOLS

DOE Metering Best Practices Guide

The Office of Energy Efficiency and Renewable Energy at the DOE developed this guide in October 2007 to help facilities achieve utility resource efficiency. The guide includes metering approaches, plans, applications, and financial benefits.

For more information:
www1.eere.energy.gov/femp/pdfs/mbpg.pdf

Advanced Utility Metering

The National Renewable Energy Laboratory and FEMP sponsored this report on advanced metering techniques, technologies, system architectures, implementation, and relative costs. Other information includes assistance in specifying, acquiring, using, and expanding systems. Finally the report includes case studies and additional resources.

For more information:
www1.eere.energy.gov/femp/pdfs/33539.pdf

DOE Guidance for Electric Metering in Federal Buildings

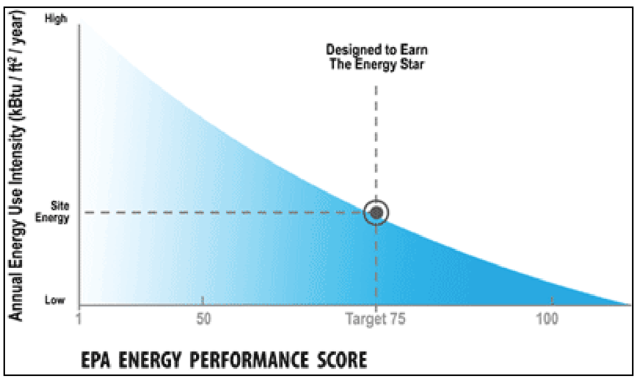
The DOE prepared this guidance document for implementing Section 103 of EPAct 2005 in conjunction with federal facilities managers, national laboratories, universities, advocacy organizations, and representatives from the metering, utility, energy services, and energy efficiency industries.

For more information:
www1.eere.energy.gov/femp/pdfs/adv_metering.pdf

Benchmarking

Designing high-performance and sustainable buildings starts with an integrated, comprehensive approach, as described in Chapter 1. This approach includes establishing whole-building performance targets that take into account the intended use and operation of the facility. Comprehensive and targeted energy goals challenge the design team to investigate innovative, cost-effective solutions that provide energy savings for new construction or retrofit projects. After construction or retrofits are complete, performance data can demonstrate whether or not the building is operating as designed. An illustration of an energy performance score is provided in Figure 22.

Figure 22 – EPA Energy Performance Score



Source: "Target Finder," EPA.

The BMPs for benchmarking facility performance are derived from the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings*, Agency policy, or the energy industry. Each BMP includes discussion of related NASA activities and accomplishments, relevant LEED® credits, and resources for additional information or assistance.

The BMPs for benchmarking new construction, major renovation, or existing buildings energy performance require:

- Establish a whole-building performance target that takes into account the facility's intended use, occupancy, operations, plug loads, and other energy demands.
- Compare actual performance data from the first year of operations with the energy design target, and ensure that the building performance meets or exceeds the design target, or that actual energy use is within 10 percent of the design energy budget.

BEST MANAGEMENT PRACTICE - BUILDING PERFORMANCE TARGET

Establish a whole-building performance target that takes into account the facility's intended use, occupancy, operations, plug loads, and other energy demands.

NASA Requirement

NPR 8820.2F requires project designers to establish a whole-building performance target that takes into account the intended use, occupancy, operations, plug loads, and other energy demands.

NPR 8820.2F requires project designers to design to earn the ENERGY STAR target for renovations.

NPR 8820.2F requires project designers to reduce the energy cost budget by 30 percent compared to baseline building performance per ASHRAE 90.1-2004. For major renovations, it requires designers to reduce the energy cost budget by 20 percent from the pre-renovations 2003 baseline.

NPR 8570.1 sets a goal of improving energy efficiency by 25 percent by FY 2010, relative to FY 1990 levels.

NPR 8570.1 sets a goal of reducing overall energy use per gross square foot by 35 percent by FY 2010, relative to FY 1985 levels.

Whole-building integration analyzes systems, components, and materials; and integrates them to create a high-performance facility. Integrated and comprehensive design goals help ensure that the completed facility will achieve high-performance energy objectives and meet stakeholder needs. As an organization, NASA currently pursues a variety of federal and Agency energy goals. Individual Centers and facilities support the Agency in various ways and may set their own goals that exceed overall requirements.

Facility energy targets identify expected performance goals and incorporate all of the building's expected uses and activities. In addition to the design charrettes discussed in Chapter 1, another tool to help buildings achieve performance targets is building modeling. Modeling can optimize the building design and identify energy-saving investments and improvements to the design. Building modeling can improve energy use, and identify potential solar exposure, daylighting, and air movement.

As the building is designed, models can demonstrate whether the facility meets minimum requirements or more aggressive efficiency targets. Design teams should ensure that the model results are treated as potential results, without the same precision as metered data or energy audits.

Implementing Whole Building Energy Targets

Table 10 lists the steps necessary in implementing whole building energy targets. These steps are discussed in detail in the subsequent narrative.

Table 10 – Implementing Whole Building Energy Targets

IMPLEMENTATION STEPS	
1)	**Gather Energy Information**
□	Determine phase of energy audit needed.
□	Utilize meters, utility bills, and calculations to determine baseline energy use.
2)	**Determine Performance Target Goals**
□	Customize goal selection to individual facility.
□	Ensure goals are cost-effective and follow federal standards.
3)	**Build and Review Energy Model**
□	Review results for accuracy and to determine if data is on track with the facility Energy Model.
4)	**Identify Design Changes for Implementation**
□	Compare Energy Model targets and measured data results to determine discrepancies.
□	If needed, edit Energy Model targets to increase energy performance.

1) Gather Energy Information

A comprehensive and targeted energy performance target requires several inputs. Designers of new construction projects should gather construction design documents, product and equipment specifications, and any other energy-related documents and information. Other inputs may include the building location, envelope specifications, and operating systems and schedules. It is critical to gather input from the design team in order to ensure an integrated design process. For more information on integrated planning and design, see Chapter 1.

Retrofit planners and designers for existing buildings can gather this information through many of the same inputs, as well as through energy audits, electricity meter data, and utility bills. This information will establish baseline energy use, which will help determine feasible conservation goals for the whole-building performance target.

> **Definition**
>
> *Plug Load*
>
> A facility's plug load accounts for all the electrical equipment in the building, and the corresponding energy demand.

2) Determine Performance Target Goals

Once facility managers have gathered energy use information, whole-building performance targets can be determined. These targets should account for the facility's intended use, occupancy, operations, **plug loads**, and other energy demands. Site-specific goals should be cost effective and based on existing federal guidance as well as Center-wide energy-reduction strategies. Goals established will vary significantly for each facility, so it is necessary to customize each goal for the particular building to create a feasible and cost-effective whole building performance target. For more information on setting design and performance goals, see Chapter 1.

New Construction

New construction projects should include designs to reduce energy use by 30 percent compared to the baseline building performance rating. The baseline is determined per the ANSI/ASHRAE/IESNA Standard 90.1-2007, Energy Standard for Buildings (Except Low-Rise Residential). NPR 8820.2F also requires the same level of reduction in the energy cost budget compared to the 2004 version of Standard 90.1, which is less rigorous than the 2007 version.

Major Renovation

Major renovation projects should include plans to reduce energy use by 20 percent below the pre-renovation 2003 energy baseline. Laboratory spaces may use the Laboratories for the 21st Century (Labs21) Laboratory Modeling Guidelines as an alternative performance benchmark.

Existing Building

Existing buildings should measure energy performance through one of three methods. The first option is to use the ENERGY STAR system and receive a rating of 75 or higher, or an equivalent score from the Labs21 Benchmarking Tool. The second is to reduce measured building energy use by 20 percent compared to 2003 building energy use or a year thereafter, with quality energy use data. The third option is to reduce energy use by 20 percent compared to ASHRAE 90.1-2007 baseline building design, if design information is available.

3) Build and Review Energy Model

As building energy targets are developed, some adjustments to the building model or other calculations may be necessary. Model outputs can project whether or not the facility is expected to meet the goal and can focus attention on specific systems or equipment. The model results should be reviewed with reasonable expectations in mind, as missing or faulty data may skew results. The facility manager must carefully review inputs and design load assumptions to ensure that they match the building’s intended occupants, systems, and schedule.

4) Identify Design Changes for Implementation

A careful review of the model or calculation results can predict whether or not the facility's projected energy use will meet or exceed the intended target. If the results do not meet the design team's intent, changes to the design can improve energy performance.

Additionally, potential methods for achieving the building's performance target include insulation and windows, HVAC system, lighting and lighting distribution, and water heating. Renewable energy techniques that can assist with whole-building performance targets include wind and solar. Experts in each of these technologies should be consulted before implementation.

Any changes to the design should be reflected in design documents. Specific energy goals and commitments can be collected and documented in a Statement of Energy Design Intent (SEDI), through Target Finder. The SEDI documents the commitment and execution of energy performance goals throughout the planning, design, and construction process.

> **Rule of Thumb**
>
> *The design team should consider changes to site location, building orientation, building massing, control strategies, glazing optimization, and system upgrades if necessary to improve energy use.*

Related LEED® Credits

The LEED® credits related to whole building performance targets are illustrated in Table 11.

Table 11 – LEED® and Whole Building Performance Targets

LEED-NC®	EA Prerequisite 2: Minimum Energy Performance
	EA Credit 1: Optimize Energy and Performance
LEED-EB: O&M®	EA Prerequisite 2: Minimum Energy Efficiency Performance
	EA Credit 1: Optimize Energy Efficiency Performance
LEED-ND®	GIB Prerequisite 2: Minimum Building Energy Efficiency
	GIB Credit 2: Building Energy Efficiency

TOOLS

Building Information Modeling

Building Information Modeling (BIM) provides a way to generate and maintain project data. The model allows designers to visualize the design, improve consistency, provide real-time design changes, store project information, and analyze all phases of a building's life cycle.

For more information: http://bim.arch.gatech.edu/?id=402

Construction Operations Building Information Exchange

Construction Operations Building Information Exchange (COBie) is a design, construction, and commissioning approach for collecting building information. Documents containing equipment lists, product data sheets, warranties, spare parts lists, preventive maintenance schedules, and other information are captured and recorded in one database.

For more information: www.wbdg.org/resources/cobie.php

Target Finder

Target Finder is a tool from ENERGY STAR that aids the facility design process by providing annual energy use targets for a specified space type. Building designers select the desired ENERGY STAR score or energy reduction target, and Target Finder enables development of a SEDI.

For more information: www.energystar.gov/index.cfm?c=new_bldg_design.bus_target_finder

ASHRAE Performance Rating Method

Appendix G of ASHRAE Standard 90.1-2007 describes a performance rating method for measuring the energy efficiency of buildings which is different from the energy cost budget method. Specifically, this appendix is intended for design teams that need to quantify performance substantially exceeding the requirements of Standard 90.1.

For more information: www.ashrae.org/technology/page/548

National Renewable Energy Program, Energy-10™ Energy Simulation Software

ENERGY-10™ is an award-winning software tool for designing low-energy buildings. ENERGY-10™ integrates daylighting, passive solar heating, and low-energy cooling strategies with energy-efficient shell design and mechanical equipment. The program is applicable to commercial and residential buildings of 10,000 square feet or less.

The ENERGY-10™ software was developed by the National Renewable Energy Laboratory with funding from the Office of Building Technologies, Energy Efficiency and Renewable Energy, DOE. It is distributed by the Sustainable Building Industry Council under license to the Midwest Research Institute.

For more information: www.nrel.gov/buildings/energy10.html

Best Management Practice - Meet or Exceed Design Target

Compare actual performance data from the first year of operations with the energy design target, and ensure that the building performance meets or exceeds the design target or that actual energy use is within 10 percent of the design energy budget.

Design targets establish intended operating performance for each facility. Performance data identifies inefficiencies, potential problems, and any other issues that prevent the facility from operating at designed levels. Data is collected and managed through ENERGY STAR Portfolio Manager, audits, utilities, BAS, or other methods. This data can then be compared with the baseline data of the design target or an existing building.

Ongoing benchmarking assists in detecting energy consumption trends and potential problems. Operating inefficiencies that may be identified through benchmarking include systems improperly installed or inefficiently performing systems. Inefficient operations may be due to operating practices or to the efficiency of the equipment itself. The benchmarking and data comparison process ensures that the Agency is able to monitor energy performance improvement and detect inefficiencies in the overall energy system.

Rule of Thumb

After construction or retrofits are complete, energy use data from building operations provides the foundation for benchmarking performance against the design target and similar building types.

Implementing Facility Performance Comparisons

Table 12 lists the steps required in implementing facility performance comparisons. These steps are discussed in additional detail in the subsequent narrative.

Table 12 – Implementing Facility Performance Comparisons

IMPLEMENTATION STEPS	
1)	**Evaluate Existing Energy Data**
☐	Utilize audits, meters, utility bills, and calculations to determine current energy use.
2)	**Collect or Upload Facility Energy Data**
☐	Register for ENERGY STAR Portfolio Manager.
☐	Input collected data.
3)	**Analyze Facility Energy Data**
☐	Use software to analyze and compare data to previous baseline data.
4)	**Determine the Facility Energy Performance Rating**
☐	Measure if facility performance is within 10 percent of the of the design energy budget for similar buildings.

1) Evaluate the Existing Energy Data

In order to compare actual performance to the design target, the facility manager should gather operating information through an energy audit or a review of utility bills or utility meter data. This data must be collected monthly for at least one year to sufficiently determine energy use trends.

2) Collect or Upload Facility Energy Data

The ENERGY STAR Portfolio Manager is the preferred tool for comparing actual performance data from building operations with the energy design target. In order to use Portfolio Manager and analyze data, the facility manager must register and create an online account. The facility manager or other designated staff member can then enter facility energy data. Data entry can be minimized by importing large facility data sets through an Microsoft Excel template.

Additional data required by the ENERGY STAR Portfolio Manager includes the building space type and characteristics, the monthly energy use and cost, and the utility meter name, type and unit.

3) Analyze Facility Energy Data

> *Rule of Thumb*
>
> *The energy baseline is generally established during the design phase or the initial energy audit.*

If any energy-saving design changes or facility improvements are planned, they should be implemented prior to any analysis of facility energy data. After all energy-saving projects are implemented a facility energy audit or utility meter reading can ensure that these projects were installed correctly and that they are operating efficiently. Results of this audit, combined with one year of facility energy data, are compared against the energy use baseline.

The ENERGY STAR Portfolio Manager includes software that can display the facility energy data. The energy data can be analyzed over a period of time to evaluate such issues as Energy Use, Green House Gas Emissions, Financial Performance, and Water Use.

4) Determine the Facility Energy Performance Rating

Data uploaded to Portfolio Manager determines whether or not facility energy performance is within 10 percent of the design energy budget of similar buildings. Portfolio Manager data can also be used to apply for and earn the ENERGY STAR label. ENERGY STAR compares the facility's energy use to that of similar building types, collected by the DOE's Energy Information Administration (EIA).

The EIA information is gathered every four years from across the country and it enables comparisons based on a percentage rating. For example, if a building receives 50 points, this means it performs better than 50 percent of similar building types nationwide. A building that receives 75 points or more can receive an ENERGY STAR label.

Additional EPA recognitions include “ENERGY STAR Leaders,” which recognizes organization-wide energy improvement, and “ENERGY STAR Partner of the Year,” which focuses on contributions to reducing greenhouse gas emissions through improved energy efficiency.

Related LEED® Credits

The LEED® credits related to design target comparisons are illustrated in Table 13.

Table 13 – LEED® and Design Target Comparison

LEED-NC®	EA Prerequisite 2: Minimum Energy Performance
	EA Credit 1: Optimize Energy and Performance
LEED-EB: O&M®	EA Prerequisite 2: Minimum Energy Efficiency Performance
	EA Credit 1: Optimize Energy Efficiency Performance
LEED-ND®	GIB Prerequisite 2: Minimum Building Energy Efficiency
	GIB Credit 2: Building Energy Efficiency

TOOLS

ENERGY STAR Portfolio Manager Overview

The Portfolio Manager Overview provides background information, definitions, and summaries of each section of Portfolio Manager. The overview also includes links such as the “Benchmarking Starter Kit”, which assists with data collection, as well as information about ENERGY STAR ratings, carbon footprints, and how to obtain other EPA recognitions.

For more information:
www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager

Labs21 Energy Benchmarking Tool

The Labs21 was originally sponsored by the EPA and the DOE. This web-based tool was designed specifically for laboratory spaces; it allows mangers to input a range of facility characteristics and energy data to identify potential opportunities for reducing energy costs. The tool uses comparisons of energy performance between facilities to identify similar spaces.

For more information: *www.labs21century.gov/toolkit/benchmarking.htm*

Building Energy Use and Cost Analysis Software

Building energy use and cost analysis software is available. These include DOE-2 and DOE-2 based products, such as eQUEST, PowerDOE, and COMcheck-Plus.

For more information: *www.doe2.com/*

Chapter 3. Protect and Conserve Water

Background

As building designers and facility managers plan for sustainable buildings, water conservation should be a priority. Conservation helps to limit pressure on increasingly scarce water resources, reduces the amount of energy and chemicals used in wastewater treatment and filtration of **potable water**, and minimizes negative effects on freshwater aquatic habitats.

Potential water use reductions may be identified in a variety of indoor, outdoor, and process applications. Many low-cost water conservation strategies are available. Other conservation approaches, while more costly at the outset, are life-cycle cost-effective due to resulting potable and **non-potable** water and energy savings.

Innovative conservation strategies help capture rainwater and reuse water on-site to limit the demand for treated, potable water. Capturing rainwater can limit demand for indoor and outdoor uses, in addition to maintaining or improving the stormwater runoff of the site.

Efficient water use not only protects the environment and conserves water resources for future generations; it also reduces utility costs. Cost savings come in the form of lower water use fees, lower sewage treatment volumes, and lower capacity charges and limits.

Measurement of Water Use

Reduction in potable water use is a common goal for high-performance and sustainable buildings. The water management approach, program goals, requirements, performance metrics, and building or system inventories are documented in a Water Management Plan or are integrated into a water conservation program, which may include water audits and leak detection assessments. These audits and assessments can detect waste and inefficiency that may not be otherwise apparent.

An understanding of water consumption patterns and volume is necessary to conservation efforts, and metering as a means of water use measurement provides the baseline information necessary to evaluate performance and identify improvement opportunities. The *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings* encourage metering of potable water in new construction and existing facilities.

Chapter Outline

In order to meet federal policy goals, the Agency should employ a systematic approach to sustainability investment. Water conservation goals can be achieved through improvements in:

- *Measurement of Water Use*
- *Indoor Water Use*
- *Outdoor Water Use*
- *Process Water Use*

Definition

Potable Water

Potable water includes water suitable for drinking that meets or exceeds Environmental Protection Agency drinking water standards; it is supplied from wells or municipal water systems.

Definition

Non-Potable Water

Non-Potable water includes water that does not meet EPA drinking water standards; it is not suitable for drinking though it may be appropriate for other uses.

The Best Management Practices (BMP) for incorporating water measurement are derived from the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings,* Agency policy, or the water conservation industry. Each BMP includes discussion of related NASA activities and accomplishments, relevant Leadership in Energy and Environmental Design (LEED®) credits, and resources for additional information or assistance.

The water measurement BMPs for new construction, major renovation, or existing buildings are:

- Prepare and maintain water conservation programs and a Water Management Plan.
- Perform regular water audits and assess the facility's water distribution system for leaks.
- Install water meters to allow for management of water use during occupancy.

Overall withdrawal trends in the United States since 1950, broken into major categories, are illustrated in Figure 1.

Figure 1 - Total Water Withdrawal Trends

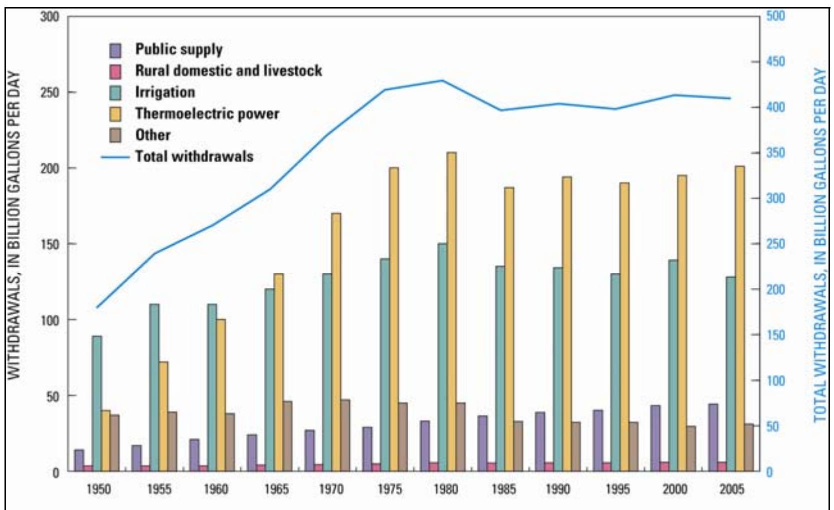


Figure 14. Trends in total water withdrawals by water-use category, 1950–2005.

Source: Estimated Use of Water in the United States, United States Geological Survey, 2005.

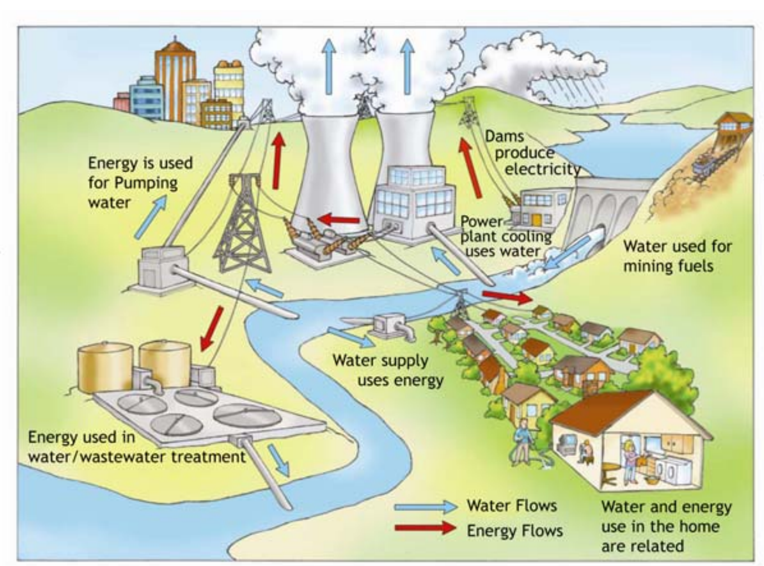
BEST MANAGEMENT PRACTICE – WATER MANAGEMENT PLANNING

Prepare and maintain water conservation programs and a Water Management Plan.

Successful water conservation programs begin with development of a comprehensive Water Management Plan. Plans should include relevant utility information, metering or measurement plans, historic and predicted water use trends, emergency response plans, assessments of improvement opportunities, and strategies for implementing potential improvements. Centers should work to develop management strategies that are cost-effective, implementable, and enforceable.

A Water Management Plan should be integrated with the Center Master Plan (CMP) and Environmental Management System (EMS). By incorporating water management planning into construction plans and facility management documents, planners and facility managers can ensure that water conservation becomes a priority. Integrated planning can also reinforce the relationship between water conservation and energy savings, as illustrated in Figure 2.

Figure 2 – Relationships Between Water and Energy



Energy Demands on Water Resources, Department of Energy, 2006.

Employees should also be educated on water management efforts. New operation procedures, retrofits, and replacements are most effective when employees,

NASA Requirement

NPR 8570.1 requires establishing a facility energy efficiency and water conservation plan and integrating it with existing Center planning documents, in addition to establishing education and awareness activities to draw attention to water conservation issues.

NPR 8580.1 requires that water-efficient practices, particularly those associated with landscaping, be included in the Center's Environmental Resources Document.

NPR 8810.1 requires that Centers establish a narrative and graphic presentation of water conservation methods as part of the Center Master Plan.

contractors, and the public are aware of new technology or methods and how to use them properly.

Implementing a Water Conservation Program

Table 1 lists the steps necessary for implementing a water conservation program. These steps are discussed in detail in the subsequent narrative.

Table 1 – Implementing a Water Conservation Program

IMPLEMENTATION STEPS	
1)	**Gather Facility Information**
□	Collect information about the facility including users, layout, operating, and maintenance schedule.
□	Determine the type and amount of water being used.
2)	**Consult Regulations and Regional Context**
□	Determine local regulations about water conservation and usage.
3)	**Establish Conservation Goals**
□	Develop facility goals that are cost-effective.
4)	**Select Techniques for Implementation**
□	Choose feasible and applicable strategies.
□	Ensure the collection of accurate water measurements.
5)	**Estimate the Life-cycle Costs and Benefits**
□	Determine costs and benefits of Water Management Plan.
6)	**Develop a Water Management Plan**
□	Document the Water Management Plan and prioritize repairs.
□	Relay information to building occupants.
7)	**Coordinate the Plan With EMS**
□	Ensure Water Management Plan is consistent with EMS.
8)	**Monitor the Water Management Plan**
□	Continue collection of water data and properly install fixtures.

1) Gather Facility Information

Facility information should be gathered before any decisions regarding water conservation strategies are made. Necessary information includes floor plan and layout, operating, maintenance and janitorial schedules; information on occupants (including employees and visitors), and information on water use patterns. Total water use for the building, individual equipment, and building fixtures must be determined.

Accurate water-use measurement allows managers to understand consumption patterns and to detect and remedy possible water system deficiencies. Consumption measurements can be obtained through water and sewer bills, water meters, or water audits. Qualified staff can conduct a basic water audit using published tools and fixture-use assumptions, or water-efficiency professionals may be hired to complete a more thorough evaluation. For more information on water audits and meters, see pages 3-8 and 3-12, respectively.

2) Consult Regulations and Regional Context

A successful water-efficiency program must take local regulations and regional climate differences into account. Locations such as the Jet Propulsion Laboratory in Pasadena, California or the Johnson Space Center in Houston, Texas, for example, will have different requirements than the Glenn Research Center in Cleveland, Ohio.

3) Establish Conservation Goals

Establishing water-related design and performance goals is an important part of Front-End Planning, as described in NPR 8820.2F. Water management planning helps the facility manager to determine current water consumption levels and associated costs; this information assists with effective water management decision-making.

Site-specific goals should be cost-effective and aligned with Center-wide and federal guidance. Goals will vary significantly for each facility, so it will be necessary to customize goals to ensure feasible and cost-effective water conservation plans. For more information on setting design and performance goals, see Chapter 1.

4) Select Techniques for Implementation

Once facility information has been collected and goals have been established, managers should choose and implement feasible techniques and strategies designed for the desired environmental impact. Determining each technique's total conservation potential helps managers to prioritize action steps.

5) Estimate the Life-cycle Costs and Benefits

An estimate of costs and benefits is essential to ensuring success in water conservation efforts. Life-cycle cost is an important consideration in determining appropriate action steps and economic feasibility.

Potential costs of a Water Conservation Plan include:

- Fixtures and equipment
- Water purchased from utilities
- Pumping energy
- Water pretreatment, heating, and cooling
- Chemical treatments
- Sewer costs

Benefits of a Water Conservation Plan include:

- Reduced utility costs
- Preservation of local water resources

> *Rule of Thumb*
>
> *Water Management Plans contain clear information about a facility's water use and disposal patterns.*

6) Develop a Water Management Plan

Once all elements of the Water Management Plan have been developed, each element should be incorporated into a written document. The Facility Manager should document priorities, which are developed based on water use, occupant needs, and life-cycle costs. Because increased water use increases energy use and related costs, facilities with the largest number of people or the highest levels of water use should be prioritized. The first available funding sources should be allocated to the highest-priority facilities.

The Facility Manager should also communicate the Plan and work schedule to building occupants including employees, contractors, and maintenance staff. Effective communication techniques may include signs and newsletters.

7) Coordinate the Plan with the Environmental Management System

As described in Executive Order (EO) 13423, the Center EMS is the primary management approach for addressing environmental issues. The Agency uses the EMS as a single, overall approach to managing environmental activities; in addition to ensuring EO 13423 compliance, this approach allows for efficient, prioritized execution. Accordingly, the Water Management Plan's policy statements, goals, measurements, and other supporting information should align with the EMS. Water use data collected through metering or other Plan approaches should provide guidance to the EMS. For more information on developing an EMS, see Chapter 1.

8) Monitor the Water Management Plan

Effective Water Management Plans require ongoing monitoring to measure overall impact and to ensure that water savings are achieved. As water conservation efforts begin, it is important to verify with contractors that all fixtures are installed properly. After installation is complete, confirm water consumption reductions with utility provider to ensure that fixtures are operating properly and that the system is not leaking. The facility manager, or Center water or energy manager, is responsible for continued reductions in water usage rates, and for ongoing communication with operations and maintenance (O&M) staff. Any problems identified by users should be addressed immediately.

Related LEED® Credits

The LEED® credits related to water conservation programs are illustrated in Table 2. Definitions for all LEED® abbreviations appear in the Introduction.

Table 2 – LEED® and Water Conservation Programs

LEED-NC®	WE Prerequisite 1: Water Use Reduction
	WE Credit 1: Water Efficient Landscaping
	WE Credit 2: Innovative Wastewater Technologies
	WE Credit 3: Water Use Reduction
LEED-EB: O&M®	WE Prerequisite 1: Minimum Indoor Plumbing Fixture and Fitting Efficiency
	WE Credit 1: Water Performance Measurement
	WE Credit 2: Additional Indoor Plumbing Fixture and Fitting Efficiency
	WE Credit 3: Water Efficient Landscaping
	WE Credit 4: Cooling Tower Water Management
LEED-ND®	GIB Prerequisite 3: Minimum Building Water Efficiency
	GIB Credit 3: Building Water Efficiency
	GIB Credit 4: Water Efficient Landscaping
	GIB Credit 8: Stormwater Management
	GIB Credit 14: Wastewater Management

TOOLS

WaterWiser Water-Efficiency Clearinghouse

The American Water Works Association’s WaterWiser Water-Efficiency Clearinghouse offers a guide to education programs, a database of existing efforts across the United States, case studies, and links to educational resources.

For more information:
www.awwa.org/Resources/Waterwiser.cfm

Greening Federal Facilities

The “Greening Federal Facilities” guide includes a variety of useful resources for federal facilities managers, including a step-by-step guide to writing a successful water management plan.

For more information:
www1.eere.energy.gov/femp/pdfs/29267-0.pdf

Best Management Practice - Water Audit and Leak Detection

Perform regular water audits and assess the facility's water distribution system for leaks.

NASA Requirement

NPR 8570.1 establishes a goal of conducting water audits for all NASA facilities.

Routine water distribution system maintenance is an essential component of a water conservation program. Before making alterations to fixtures and fittings or implementing new water conservation practices, it is important to repair leaks and other system malfunctions. With a properly maintained system, it is possible to establish a baseline for future water-saving goals.

A distribution system audit, leak detection, and repair program can help facilities to reduce water loss and make better use of limited water resources. Regular water distribution system audits have substantial benefits, including:

- Reduction in water loss resulting from leaks.
- Reduction in operating costs through reduced utility charges for water, reduced costs for energy use related to water delivery, and reduced chemical water treatment costs.
- Increased understanding of the distribution system, which helps maintenance staff respond more quickly to emergencies such as water main breaks.
- Reduced risk of property damage and improved safeguards on human health and safety.
- Improved data, which can validate the need for reductions in water consumption, and provide justification for water management programs.

Implementing Water Audits and Leak Detection Assessment

Table 3 lists the steps necessary for implementing regular water audits and leak detection assessments. These steps are discussed in additional detail in the subsequent narrative.

Table 3 – Implementing Water Audits and Leak Detection Assessment

IMPLEMENTATION STEPS	
1)	**Complete a Prescreening System Audit**
□	Collect information about water usage through an audit.
□	Identify the users of the building.
2)	**Perform a Full-scale System Audit**
□	Follow AWWA directions for auditing.
3)	**Estimate the Life-cycle Costs and Benefits**
□	Determine current costs of water metering system.
□	Identify potential benefits of implementation.
4)	**Prioritize and Repair Leaks and/or Replace Pipes**
□	Ensure financing spent first on most severe projects.

1) Complete a Prescreening System Audit

Routine water system maintenance begins with a prescreening system audit to determine if a full-scale system audit is necessary. In order to complete the prescreening audit, the following should be collected every two years:[1]

- Determine authorized uses
- Determine other system verifiable uses
- Determine total supply into the system

The full-scale system audit is necessary if the total authorized uses plus other verifiable uses, divided by the total supply is less than 0.9. Alternatively, the prescreening audit can be performed after a previous audit is complete if increases to the minimum system flow are detected. These increases can be assumed to be leak-related and should be fully audited. If no leak is detected, a full-scale audit is not necessary.

2) Perform a Full-Scale System Audit

The American Water Works Association's (AWWA) "Water Audit and Leak Detection Guidebook, Number M36" provides step-by-step directions for conducting a full-scale system audit, should it be necessary. Per NPR 8570.1, when necessary facilities should complete full-scale system audits of the distribution system using a methodology consistent with the AWWA's Guidebook. Additionally, pipes should be replaced or repaired when leaks are found. Center or other

Rule of Thumb

Water leaks that are deemed low-priority should be re-audited every two years.

Rule of Thumb

The minimum system flow is generally the flow rate at around 3 or 4 a.m.

[1] NPR 8570.1, Energy Efficiency and Water Conservation, NASA.

NASA engineers, in addition to other government agency staff and industry professionals should be consulted for more details.

3) Estimate the Life-Cycle Costs and Benefits

Fixing and replacing pipes can be more cost-effective than some other water conservation efforts, such as replacing the fixtures in an entire facility.

Potential costs of leak detection and water audits include:

- Equipment purchases
- Installation-related labor
- Impact to occupant productivity during repair and outages

Potential benefits of leak detection and water audits include:

- Ongoing utility savings
- Reduced environmental impact

4) Prioritize Leak Repairs and Pipe Replacement

Some leak repairs may not be cost-effective. The facility manager should ensure that Agency funding is spent on repair of the most severe leaks, or of leaks that may become worse without repair. Generally, a large leak or water waste will be the top repair priority.

Related LEED® Credits

The LEED® credits related to water audits are illustrated in Table 4. Definitions for all LEED® abbreviations appear in the Introduction.

Table 4 – LEED® and Water Audits

LEED-NC®	WE Prerequisite 1: Water Use Reduction
	WE Credit 3: Water Use Reduction
LEED-EB: O&M®	WE Prerequisite 1: Minimum Indoor Plumbing Fixture and Fitting Efficiency
	WE Credit 1: Water Performance Measurement
	WE Credit 3: Water Efficient Landscaping
LEED-ND®	None

TOOLS

Water Audit Software

The AWWA provides free online water audit software. The software includes a spreadsheet with five worksheets where users can enter measured or estimated water use values, and then perform calculations on a variety of performance indicators.

For more information: www.awwa.org/Resources/WaterLossControl.cfm?ItemNumber=48511&navItemNumber=48158

Water Audit Checklist

The New Mexico Office of the State Engineer developed "A Water Conservation Guide for Commercial, Institutional and Industrial Users," which provides a step-by-step checklist for conducting a water audit. It also provides other water conservation and planning techniques.

For more information: www.ose.state.nm.us/water-info/conservation/pdf-manuals/cii-users-guide.pdf

Leak Detection and Audits

The Federal Energy Management Program (FEMP) developed best practices for distribution system audits, leak detection, and repair programs designed to help federal facilities reduce water loss and to improve the use of limited water supplies.

For more information: www1.eere.energy.gov/femp/program/waterefficiency_bmp3.html

BEST MANAGEMENT PRACTICE - WATER METERING

Install water meters to allow for the management of water use during occupancy. Building sites with significant indoor and outdoor water use are especially important.

NASA Requirement

NPR 8831.2E requires utility data management, including metering of all utilities.

NPR 8820.2F requires Facility Managers to gather and develop sufficient information to define a facility project.

Definition

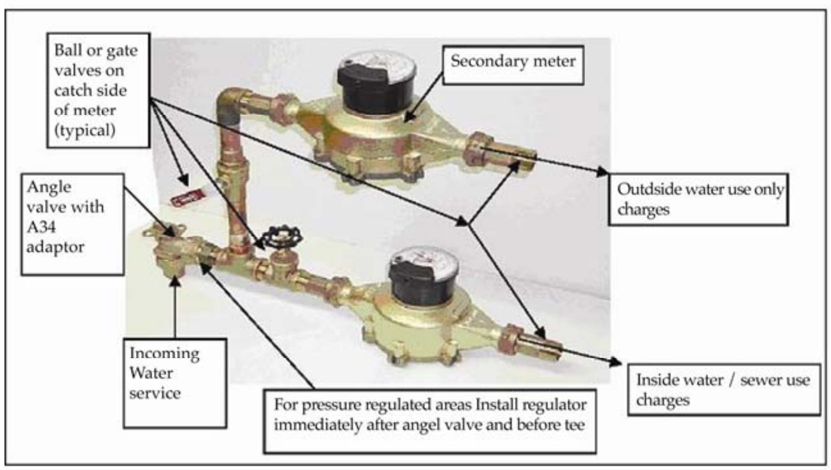
Sub-metering

Sub-metering involves installing secondary meters to measure the consumption of specific end uses or subsystems (e.g. the water of the irrigation system). Sub-metering provides more detailed information that more accurately tracks consumption and can reveal unexpected patterns. Sub-metering may also be used to measure use of specialized systems, such as reclaimed greywater or rainwater.

Water metering allows facility managers to measure their facility's water efficiency performance throughout the facility's life. Accurate water measurement allows managers to understand consumption patterns and to detect possible water system deficiencies. Water metering is also an element of Front End Planning, as described in NPR 8820.2F.

Facility managers can measure water usage through meters in two different ways: whole-building metering and sub-metering. Some facilities employ whole-building potable water metering, which measures overall water consumption rates. For facilities with several specialized water uses, **sub-metering** may be more effective in tracking and identifying specific system or equipment problems. An example of water sub-metering appears in Figure 3.

Figure 3 – Water Sub-Metering



Source: Secondary Meter Installation Guide, Bloomfield Township, MI.

Meter installation helps identify performance problems and allows opportunities for energy-efficiency projects, according to NPR 8831.2E. The FEMP also encourages data management as an important component of water conservation planning. Data obtained from water meters can be incorporated into facility management through the use of Building Automation Systems (BAS), in which a computer can monitor and record water use.

Implementing a Water Metering System

Table 5 lists the steps necessary for implementing a water metering system. These steps are discussed in additional detail in the subsequent narrative.

Table 5 – Implementing Water Metering Systems

IMPLEMENTATION STEPS	
1)	**Evaluate the Existing Facility Conditions**
□	Identify type and location of water meters, facility piping, and current system applications.
□	Conduct the commissioning plan's water-related analysis phase.
2)	**Analyze Existing Water Use by Building System**
□	Obtain water bills from the last two years.
3)	**Develop the Water Metering Plan**
□	Document conditions of water system and establish relevant goals.
4)	**Estimate the Life-cycle Costs and Benefits**
□	Determine costs and benefits of implementing water metering system.
5)	**Prioritize the Metering Plan**
□	Determine priority of implementing Plan elements.
6)	**Finance and Implement the Metering Plan**
□	Decide upon funding sources for implementation.
7)	**Develop Water-Efficiency Plan and Water Conservation 5-Year Plan**
□	Measure data over a one year time period and maintain meter conditions.
□	Analyze recorded data and develop action steps.

1) Evaluate the Existing Facility Conditions

The first step in implementing a metering program is evaluation of existing water meters and systems. Types of meters, pipes, and applications should be recorded. The location and type of each existing water meter and sub-meter should be identified, and information about the piping system, including sizes, types, condition, flow rates, and ranges of flow, should be documented.

Once the water system hardware is inventoried, the water system's current application should be addressed. Identifying how the water is used will assist managers to identify the most efficient metering approach.

2) Analyze Existing Water Use by Building System

After the existing equipment is inventoried, an analysis of facility water usage can begin. Existing water usage can be measured by reviewing water bills or by conducting a water use inventory, as recommended by NPR 8570.1. A metering or other measurement plan ensures that a baseline for comparative measurement is documented. Managers must collect sufficient quantities of data in order to make informed decisions. A review of water and sewer bills from the previous two years will enable managers to "identify inaccuracies and determine that [the facility manager] is using the appropriate rate structure."[2]

> **Rule of Thumb**
>
> *Developing the appropriate metering approach includes assessing the following:*
>
> - *Current design of the building and water system*
> - *Budget*
> - *Accuracy requirements*
> - *Minimum, maximum, and range of flow*
> - *Type of water used (e.g. potable, process, high-temperature water, chilled water)*

> **Rule of Thumb**
>
> *Sub-metering is recommended for the following systems:*
>
> - *Indoor plumbing fixtures and fittings*
> - *Irrigation*
> - *Cooling towers*
> - *Domestic hot water*
> - *Other process water*

In addition to reviewing water bills, managers may decide to install a water meter. Water meter types include positive displacement meters, differential pressure meters, and velocity meters.

Positive Displacement

Positive displacement meters operate by the fluid physically displacing the measuring mechanism. These meters are generally found at "service entrances to buildings and homes. These meters are most often used on pipe sizes up to 3 inches and have accuracy in the range of 0.5 to 1.0 percent."[3] Several types of positive displacement meters exist, including nutating-disk, oval-gear, piston, and rotary-vane meters.

Differential Pressure

Differential pressure meters operate by measuring the velocity-pressure relationship of the flowing fluid. This type of meter is generally used in "specialty potable water applications where size, space and/or accuracy dictate their use."[3] For applications with pipe sizes ranging from 0.25 to 4 inches and requiring accuracy of 0.25 to 2 percent, facility managers should consider an orifice meter or a Venturi meter.[3]

Velocity Meter

Velocity meters operate by measuring the velocity of the fluid flow. These meters tend to have higher accuracy and better turndown ratios than positive displacement or differential pressure meters. Each type of velocity meter is suited to different types of applications. The turbine meter is typically used for "larger industrial metering functions" and when connection sizes range from 2 to 20 inches, with an accuracy range of 0.5 to 1.0 percent.[3]

Another type of velocity meter, the ultrasonic meter, can be used on connection sizes of 20 inches or larger with accuracy ranges from 1 to 5 percent. Ultrasonic meters are also the least intrusive since they can be mounted on the "outside of the piping and can be used as both temporary and permanent metering."[3]

3) Develop the Water Metering Plan

Facility managers should develop a Water Metering Plan that addresses their specific needs, goals, facility conditions and

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[2] NPR 8570.1, Energy Efficiency and Water Conservation, NASA.

[3] *Metering Best Practices Guide*, Department of Energy, 2007.

existing use in a written Plan. The final Plan should include the following elements:

- Existing water meters
- Final design of the water metering system
- Current potable water consumption
- Desired achievements for the metering system
- Consideration of regional water conditions and regulations, as encouraged by NPR 8570.1
- Method of data analysis
- Consideration of seasonal variations in water usage

4) Estimate the Life-cycle Costs and Benefits

The Energy Policy Act (EPAct) of 2005 requires installation of meters “to the maximum extent practicable.” Guidance from FEMP suggests that a “practicable meter application is one that can be justified on the basis of its cost-effectiveness.” Significant time and effort must be devoted to tracking water use if a metering program is to be effective, but investment can provide significant savings in water bills and O&M costs.

Estimating potential energy cost savings can be difficult due to limited federal experience with water metering; additionally, savings will depend in part on what equipment selection and the intensity of the metering program. An important cost-benefit consideration is that installation during initial construction tends to be less costly than post-occupancy meter installation.

Potential costs of the water metering system and related data management include:

- Purchased equipment
- Costs associated with continual data measurements
- Impact to occupant productivity during repair and outages

Potential benefits of the water meter system and related data management include:

- Reductions in water usage
- Improved detection of leaks
- Ability to analyze the performance of systems and equipment
- Ability to identify opportunities to increase water efficiency

5) Prioritize the Metering Plan

It is unlikely that sufficient resources will be available to fund metering programs for all Agency buildings and/or equipment during the next fiscal year. According to FEMP, managers should identify if there is a need to prioritize buildings based on cost, phasing, location, total water use, or other criteria.[4] Generally, managers should start metering the systems that use the most water as this approach offers the greatest potential for increasing efficiency and reducing water costs.

6) Finance and Implement the Metering Plan

Once managers identify the metering approach that is most appropriate and cost-effective for their facility, sufficient funding will be needed. Even equipment with relatively short payback periods will require some upfront funding. A variety of funding mechanisms exist to assist with costs associated with purchase and installation of metering equipment. Due to funding limitations, facility managers should think creatively and explore alternative funding instruments when necessary.

Definition

Energy Savings Performance Contracts

Energy Savings Performance Contracts (ESPC) are a method of financing and implementing a capital improvement project by using utility cost savings to recover project costs. This type of contract is provided by private energy service companies.

Potential funding mechanisms include:

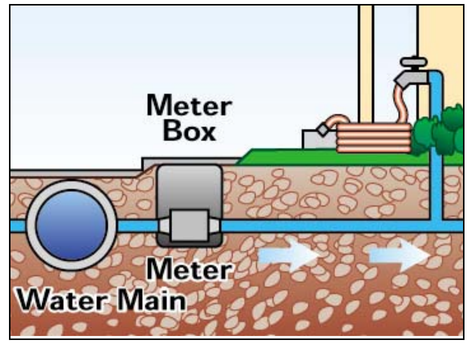
- Agency appropriations
- Retained energy savings
- **Energy Savings Performance Contracts**
- Utility Energy Services Contracts
- Utility company financing
- Public benefits programs and utility demand response programs
- Requirements on new construction and major renovations
- Mandatory tenant sub-metering fees
- O&M performance incentives
- Government Services Administration (GSA) equipment leases

Installation and maintenance of water meters can have an impact on functionality. Water meters can be installed in pits below ground or at ground level. If meters are not installed during construction, installing a section of horizontal piping in an accessible location will make future retrofits less costly and complicated. Facility managers should ensure that

[4] *Metering Best Practices Guide*, FEMP, 2007.

outdoor meter locations balance access, safety, and security concerns. An example of a water meter appears in Figure 4.

Figure 4 – Example Meter Location



Source: Saving Water Partnership.

7) Develop Water-Efficiency Plan and Water Conservation 5-Year Plan

After the water metering plan is implemented, the data can be analyzed and used to promote water conservation. According to FEMP, the key to a successful metering program is the quality of the data collected and the productive application of the data; mere metering does not save water by itself.[5] Metering plans should also include ongoing meter maintenance and calibration.

To produce accurate analyses, data must be measured over a period of time. At least one year's worth of recorded data is needed to identify trends and account for seasonal variation; additionally, at least one year's worth of monthly reporting summaries are required for LEED credit consideration. Data should then be analyzed to develop priorities and action steps for future energy efficiency projects, such as the Water-Efficiency Plan or the Water Conservation 5-Year Plan, as outlined in NPR 8570.1.

Related LEED® Credits

The LEED® credits related to water metering systems are illustrated in Table 6. Definitions for all LEED® abbreviations appear in the Introduction.

Table 6 – LEED® and Water Metering Systems

LEED-NC®	WE Prerequisite 1: Water Use Reduction
	WE Credit 1: Water Efficient Landscaping
	WE Credit 2: Innovative Wastewater Technologies
	WE Credit 3: Water Use Reduction
LEED-EB: O&M®	WE Credit 1: Water Performance Measurement
	WE Credit 3: Water Efficient Landscaping
	WE Credit 4: Cooling Tower Water Management
LEED-ND®	GIB Credit 3: Building Water Efficiency
	GIB Credit 4: Water Efficient Landscaping

[5] *Metering Best Practices Guide,* FEMP, 2007.

TOOLS

DOE Metering Best Practices Guide

The Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy developed this guide in October 2007 to assist facilities with efforts to achieve water resource efficiency. The guide also includes metering approaches, plans, applications, and financial benefits.

For more information:
www1.eere.energy.gov/femp/pdfs/mbpg.pdf

Whole Building Design Guidelines - Water Conservation

A program of the National Institute of Building Sciences, the Whole Building Design Guide (WBDG) focuses on a number of building design topics. The Water Conservation section covers DOE's FEMP guidelines; it also discusses other benefits of water conservation, including cost-effectiveness. The guide offers links to successful water conservation case studies and pertinent codes and standards.

For more information:
www.wbdg.org/resources/water_conservation.php

Indoor Water

Changes in occupant behavior and modifications to fixtures and fittings can lead to significant reductions of potable water use. The reduction in potable water use creates life-cycle economic savings for the Agency's operations and maintenance budget, helps to sustain or improve the quality of surrounding aquatic ecosystems, and reduces the need to expand municipal water sources. Total domestic indoor withdrawals of potable water are illustrated in Figure 5.

Figure 5 - Total Domestic Withdrawals

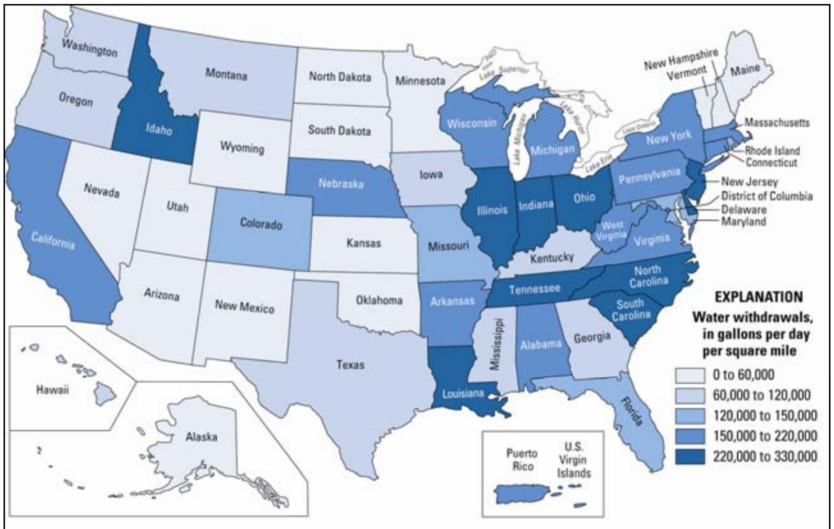


Figure 4. Intensity of freshwater withdrawals, 2005.

Source: Estimated Use of Water in the United States, USGS, 2005.

The BMPs for reducing potable water from indoor applications in the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings* include implementation steps for NASA facilities. Each BMP also includes discussion of related NASA activities and accomplishments, applicable LEED® requirements, resources for additional information or assistance.

The indoor water BMPs for new construction, major renovation, or existing buildings are:

- Employ strategies that in aggregate use a minimum of 20 percent less potable water than the building's calculated indoor water baseline.
- Use of harvested rainwater, treated wastewater, and air conditioner condensate should also be considered and used where feasible for non-potable and potable uses where allowed.

BEST MANAGEMENT PRACTICE - POTABLE REDUCTION

Employ strategies that in aggregate use a minimum of 20 percent less potable water than the indoor water baseline calculated for the building.

NASA Requirement

NPR 8570.1 requires Centers to address water conservation through implementation of a Water Conservation Plan and enact BMPs that are life-cycle cost-effective.

NPR 8820.2F requires that project designers reduce potable water consumption of indoor plumbing fixtures by at least 20 percent from the baseline calculated using EPAct 1992 standards.

The federal government uses approximately 250 billion gallons of water every year, enough water for 10 million people.[6] This level of consumption results in significant environmental and economic impacts, as the water must be heated and treated. The energy required to supply and treat water and wastewater accounts for approximately four percent of yearly power generation in the United States.[7] Construction of the required infrastructure also consumes scarce financial resources.

When planning reductions in water use, facility managers should continuously monitor overall water system pressure. In some cases, problems can arise from significantly reducing the total usage and system pressure.

Efforts at reducing consumption of potable water should coordinate with efforts to incorporate alternative sources of water, and to reduce consumption of outdoor and process water. For more information on alternative water sources, see page 3-28; for information on outdoor water, see page 3-35; and for information on process water, see page 3-49.

[6] FEMP Water Efficiency Program.

[7] "Energy Demands on Water Resources," DOE, 2006.

Implementing Indoor Potable Water Use Reductions

Table 7 lists the steps necessary for implementing indoor potable water use reductions. These steps are discussed in additional detail in the subsequent narrative.

Table 7 – Implementing Indoor Potable Water Use Reductions

IMPLEMENTATION STEPS	
1)	**Caclulate the Potable Baseline**
□	Use calculations, water audits or water meters to establish baseline.
□	Ensure the building meets the facilty age-appropriate reduction goals.
2)	**Identify Fixture and Fitting Upgrades**
□	Determine which fixtures would most benefit from replacement and use water-efficient devices when upgrading design or facility.
3)	**Estimate the Life-cycle Costs and Benefits**
□	Determine costs and benefits of implementating water-efficient upgrades.
4)	**Prioritize, Finance and Incorporate Upgrades**
□	Identify funding resources.
□	Determine priority of implementation of Plan elements.
□	Follow construction specifications on installation.
5)	**Develop a Plan for Future Upgrades and Changes**
□	Determine life-expectancy of new fixtures and include in Plan.

1) Calculate the Potable Baseline

Determining targets for total reductions in potable water use begins with establishing a baseline of current consumption. The baseline can be calculated or measured through a variety of techniques, including design analysis, water audits, and water meters. Once a baseline is set, targets for potable water use reductions can be established.

The potable water use baseline in new construction projects is established by assuming all fixtures and fittings in the facility meet the EPAct 1992, Uniform Plumbing Code 2006 (UPC), and the International Plumbing Codes 2006 (IPC) performance requirements.

The potable water use baseline for existing buildings can be established through one of two methods. The first method uses calculations based on the fixture requirements identified in Table 8, adjusted for the age of the facility. Buildings constructed in 1994 or later should use 120 percent of the fixture requirements, and buildings constructed before 1994 should use 160 percent of those requirements. The second method uses measured potable water consumption in 2003 or any later year for which quality data is available. This data generally comes from the utility provider or water meters.

The standards for facility water fixtures are listed in Table 8.

Table 8 - Fixture Requirements for Commercial Buildings

Commercial Fixtures, Fittings, and Appliances	Current Baseline		
	UPC and IPC Standard	EPA WaterSense Standard	Unit
Water Closets	1.6	1.28	gpf
Urinals	1	0.5^	gpf
Showerheads*	2.5	1.5-2.0^	gpm
Public Lavatory (restroom) Faucets and Aerators**	0.5	N/A	gpm
Private Lavatory Faucets and Aerators**	2.2	N/A	gpm
Kitchen and Janitor Sink Faucets	2.2	N/A	gpm

*When measured at a flowing water pressure of 80 pounds per square inch

**When measured at a flowing water pressure of 60 pounds per square inch

^Anticipated

gpf = Gallons per flush

gpm = Gallons per minute

Source: LEED® Reference Guide.

2) Identify Fixture and Fitting Upgrades

Once a baseline of potable water use is established, opportunities for fixture and fitting upgrades can be identified. At a minimum, fixtures should meet the requirements listed in Table 8. The analysis phase of a Water Management Plan may identify performance issues and other opportunities for water use reduction. For more information on Water Management Plans, see page 3-3.

Installing low or ultra-low water-efficient fixtures or other water saving devices can also reduce water consumption. Water-efficient devices can be identified by searching for the WaterSense label or FEMP certification. WaterSense-labeled products should be specified in construction or renovation planning documents. Opportunities for improving fixture and fitting performance commonly include upgrading faucets, urinals, water closets (toilets), and showers.

> *Building Focus*
>
> *Life Support Facility, Kennedy Space Center*
>
> *The Life Support Facility has reduced potable water usage by 45 percent through the installation of waterless urinals, dual-flush water closets, and low-flow lavatories and showers.*

Faucets

Federal facilities generally have three types of faucets: bathroom faucets, kitchen faucets, and industrial/workroom faucets. Each type of faucet has different flow rates and operational requirements. Older faucets typically have flow rates of three to five gallons per minute (gpm); these waste tremendous quantities of water. An inefficient faucet can be improved through use of an aerator, which limits the total flow of water by spreading the stream into droplets. Installing aerators tends to be less expensive than replacing the fixture. An older, inefficient faucet with a new aerator appears in Figure 6.

Figure 6 – Example Faucet and Aerator Building 1267A, Langley Research Center

Source: NASA.

The fixture requirements listed in Table 8 limit faucet flow rates to no more than 2.2 gpm. Industrial bathroom faucets are restricted to 0.5 gpm or less, and metered-valve institutional bathroom faucets are limited to a 0.25 gallon per cycle discharge. Low-flow faucets may have electronic sensors, though sensors may not be appropriate for custodial, kitchen, and industrial sinks.

Urinals

The fixture requirements listed in Table 8 limit urinals to no more than 1.0 gallons per flush (gpf). Modifications such as infrared or ultrasound sensors can help prevent water waste. **Blowout urinals** can be modified to function only when the building is occupied. High-efficiency urinals (HEU) are available in a variety of water-use profiles ranging from 0.5 gpf down to 0.125 gpf. In some cases, ultra-low flow urinals may need to be flushed repeatedly, which negates some of their efficiency benefits.

Definition

Blowout Urinal

Blowout urinals include models that flush automatically at given intervals and can be equipped with sensors to limit flushing frequency or shut off the urinal after operating hours.

Waterless urinals present another significant opportunity for water savings; these are generally available at little or no cost premium. These urinals have a regular waste connection but no water supply which provides upfront savings due to reduced plumbing connections. A mineral oil seal trap cartridge blocks sewer gas from below while allowing waste to pass into the building's waste system. This type of urinal is appropriate for most new buildings other than small, mostly unoccupied, or remotely located facilities. Due to their frequent use, urinals account for a major portion of a facility's water consumption. Potential water cost savings can pay back installation costs for waterless urinals in only a few years, depending on current water use.

Building Focus

Marshall Space Flight Center facilities project designs do not include waterless urinals due to custodial and maintenance concerns. Low-flow urinals are specified instead.

Disadvantages of waterless urinals must be considered in evaluating costs and benefits. The traps must be replaced regularly, at significant cost; the trap may also be unique to the manufacturer, meaning it must be sole-sourced. Maintenance of the oil trap cartridges requires additional

Figure 7 – Example Male Urinal Building 1267A, Langley Research Center

Source: NASA.

Definition

Dual-Flush Toilet

Dual-flush toilets include models with two different flush settings, usually 0.8 gpf for liquid removal and 1.6 gpf for full flush solid removal.

Definition

Composting Toilet

A composting toilet is a waterless toilet that conveys waste to a bin where it is allowed to decompose into organic compost and usable soil.

training and education, as well as specific tools. Disposal requirements for the traps may also increase ongoing maintenance costs. Retrofitting waterless urinals can be a very costly job or can result in the new urinals being mounted extremely high, necessitating a raised floor or platform. Finally, some building occupants perceive waterless urinals as unpleasant. An example of a conventional urinal appears in Figure 7.

Water Closets

The fixture requirements listed in Table 8 limit water closets, or toilets to no more than 1.6 gpf. Water closets can account for almost one-third of a typical building's water consumption, so replacing old equipment with new, ultra-low-flow (ULF) or high-efficiency toilet (HET) models can contribute greatly to overall water savings. Modifications such as **dual-flush toilet** adaptors and refill diverters can also enhance water savings. **Composting toilets**, which require no water, may be used in limited applications; for example, at remote sites where their high initial cost can be justified by scarce or non-existent public water resources in those locations.

The benefits of low-flow models should be compared to their costs. Models with "jet tank" flush mechanisms, which feature a compressed air boost in the toilet tank, are generally more costly and require more maintenance, though they consume less water per flush. Additionally, proximity sensors that operate the flush mechanism can cause repeated unnecessary flushes when improperly calibrated; these can also break down and render the toilet useless. Proximity sensors can consume more than manual flush models while also increasing maintenance costs. The usefulness of proximity sensors for urinals does not necessarily indicate that sensors will work effectively in water closets.

Showers

The EPAct 1992 and the UPC/IPC 2006 fixture requirements for residential showerheads limit consumption to no more than 2.5 gpm at 80 pounds-per-square-inch (psi). Conventional showerheads are rated to use 3.0-7.0 gpm. High-efficiency replacement showerheads are a low-cost method for improving water-efficiency. Purchasing specifications for replacement showerheads may require flow rates of 2.2 gpm or less.

3) Estimate the Life-Cycle Costs and Benefits

Although some water-efficient plumbing fixtures cost more upfront than regular fixtures, they can offer significant water and energy savings over time. Life-cycle cost-effective reductions in water consumption intensity are required by EO 13423 and EO 13514.

Water savings estimates depend in part on equipment selection. An important cost-benefit consideration is that installation of water-efficient fixtures and equipment during initial construction tends to be less costly than post-occupancy installation.

Potential costs of water-efficient fixtures include:

- Purchase of water-efficient plumbing fixtures
- Installation of water-efficient plumbing fixtures
- Impact to occupant productivity during repair and outages
- Increased maintenance

Potential benefits of water conservation include:

- Reduction in water utility costs
- Reduction in energy cost from hot water heating
- Preservation of local water sources

4) Prioritize, Finance, and Incorporate Upgrades

Once managers identify the most appropriate and cost-effective fixture and equipment elements for their facility, funding will be needed. Even equipment with relatively short payback periods will require some upfront funding. A variety of funding mechanisms to assist with costs associated with purchase and installation of water-efficient equipment. Due to funding limitations, facility managers should think creatively and explore alternative funding.

Potential funding mechanisms include:

- Agency appropriations
- Retained energy savings
- Energy Savings Performance Contracts
- Utility Energy Services Contracts
- Utility company financing
- Public benefits programs and utility demand response programs
- Mandatory tenant sub-metering fees
- O&M performance incentives

5) Develop a plan for future upgrades and changes

Once the new fixtures are installed, the facility manager should determine their anticipated life expectancy. This process should include product warranty information and operating performance data. Manufacturer information, leak detection, water audits, and water meter data can all help to determine if the fixtures are operating properly. A documented evaluation and monitoring process for indoor water fixtures should be incorporated into the facility or Center Water Management Plan. For more information on Water Management Plans, see page 3-3.

Related LEED® Credits

The LEED® credits related to indoor potable water use reductions are illustrated in Table 9. Definitions for all LEED® abbreviations appear in the Introduction.

Table 9 – LEED® and Indoor Potable Water Reductions

LEED-NC®	WE Prerequisite 1: Water Use Reduction
	WE Credit 1: Water Efficient Landscaping
	WE Credit 2: Innovative Wastewater Technologies
	WE Credit 3: Water Use Reduction
LEED-EB: O&M®	WE Prerequisite 1: Minimum Indoor Plumbing Fixture and Fitting Efficiency
	WE Credit 1: Water Performance Measurement
	WE Credit 2: Additional Indoor Plumbing Fixture and Fitting Efficiency
	WE Credit 3: Water Efficient Landscaping
	WE Credit 4: Cooling Tower Water Management
LEED-ND®	GIB Prerequisite 3: Minimum Building Water Efficiency
	GIB Credit 3: Building Water Efficiency
	GIB Credit 4: Water Efficient Landscaping
	GIB Credit 14: Wastewater Management

TOOLS

WaterSense Products

WaterSense is an Environmental Protection Agency (EPA) partnership program that provides independent labeling and certification for water-efficient products. Labeled products must meet efficiency performance specifications. WaterSense also encourages innovation and provides education on best practices.

For more information:
www.epa.gov/watersense/products/index.html

> ***Rule of Thumb***
>
> *WaterSense products are labeled with the EPA's logo.*
>
> EPA WaterSense

FEMP Purchasing Specifications

FEMP provides purchasing specifications for commonly purchased energy-efficient products. These specifications include the requirements that products must meet in order to earn FEMP designation as energy-efficient products. Designated products include faucets, urinals, toilets, and showerheads.

For more information:
www1.eere.energy.gov/femp/technologies/eep_purchasingspecs.html

Faucet and Showerhead BMPs

FEMP has collected best practices and informational resources on water-efficient faucet and showerheads installation Product specifications and links to technical assistance and product lists are included.

For more information:
www1.eere.energy.gov/femp/program/waterefficiency_bmp7.html

Toilet and Urinal BMPs

The FEMP has also collected best practices and informational resources on water-efficient toilet and urinal installation. Product specifications and links to technical assistance and product lists are included.

For more information:
www1.eere.energy.gov/femp/program/waterefficiency_bmp6.html

BEST MANAGEMENT PRACTICE - ALTERNATIVE SOURCES

The use of harvested rainwater, treated wastewater, and air-conditioner condensate should also be considered and used where feasible for non-potable and potable uses where allowed.

Non-potable water can have many uses in a facility's overall facilities management process. Non-potable water may be used for irrigation, as process water in building systems, and as flush water in toilets and urinals. By using non-potable water collected on-site, facilities can reduce utility bills and lessen the environmental impact of water use. Alternative water sources include **reclaimed water**, **greywater**, and rainwater.

Efforts to incorporate alternative sources of water into a facility should complement and coordinate with efforts to reduce potable water consumption. For more information on reducing potable water consumption, see page 3-19.

Implementing Use of Alternative Water Sources

Table 10 lists the steps necessary for implementing use of alternative water sources. These steps are discussed in additional detail in the subsequent narrative.

Table 10 – Implementing Alternative Water Sources

	IMPLEMENTATION STEPS
1)	**Determine Current Potable and Non-potable Water Use**
□	Examine which fixtures use potable/non-potable water.
□	Determine potable/non-potable water usage of each application.
2)	**Evaluate Alternative Water Sources**
□	Research alternative water sources and determine appropriate water sources for facility goals.
3)	**Incorporate Alternative Source Planning**
□	Review existing plans and coordinate alternative source strategies.
□	Relay information to building occupants.
4)	**Estimate the Life-cycle Costs and Benefits**
□	Determine costs and benefits of implementing alternative water sources.
5)	**Prioritize, Finance and Incorporate Alternative Source Systems**
□	Identify funding resources.
□	Determine priority of implementing Plan elements.
□	Follow construction specifications on installation.
6)	**Monitor and Maintain the Installed System**
□	Determine maintenance requirements, funding, and responsibilities.

NASA Requirement

NPR 8570.1 requires Centers to meet 4 of 10 water-efficiency BMPs developed by the FEMP, which include recommendations for water reuse and recycling.

NPR 8820.2F requires that landscape designers consider recycled or reused water for irrigation to reduce outdoor potable water consumption.

Definition

Reclaimed Water

Reclaimed water includes water that has been treated to remove solids and other impurities and is captured for reuse. Without additional treatment, reclaimed water is generally not safe to drink.

Definition

Greywater

Greywater is untreated domestic wastewater from showers, sinks, washing machines, and fountains that can be reused on site for non-potable uses such as irrigation and flushing toilets and urinals.

1) Determine Current Potable and Non-potable Water Use

Information collected during water management planning, especially through water metering and sub-metering, can establish the scale and application for use of alternative water sources. Before alternative sources are considered, total facility potable and non-potable water use should be determined. In addition, regional requirements, existing landscaping contracts, and other water-consuming processes should be evaluated.

> **Rule of Thumb**
>
> *Facilities that consume large quantities of potable water and that have sub-metering installed may be good candidates for implementing use of alternative water sources.*

2) Evaluate Alternative Water Sources

Once current water consumption has been established, facility managers should evaluate various alternative water sources to determine the most appropriate strategy for their facility. Alternative water sources include reclaimed or recycled water, greywater, and harvested rainwater. For a detailed analysis and additional information, consult experts including staff engineers, independent water consultants, or qualified agency staff.

> **LEED® Focus**
>
> *Utilizing alternative water sources is one of the strategies to reduce potable water consumption included in the LEED-NC® and LEED-EB: O&M® credit systems.*

<u>Reclaimed or Recycled Water</u>

Reclaimed or recycled water can be used for a variety of non-potable uses. In some cases, it is even technically possible to use reclaimed water as a potable water source.[8] Generally, reclaimed water does not pose a threat to human health; however, it is most appropriate for non-potable uses including landscape irrigation, decorative water features, cooling towers, process uses, lavatory flushing, and fire protection.[9]

Reclaimed water planning should identify all potential sources as well as all potential uses and users.[10] Piping, meters, and valves for reclaimed water systems require a visible identification system, such as color-coded tags. The reclaimed water system should be maintained at a lower pressure to prevent backflow, and it should not connect directly to the potable water system. Piping for reclaimed water systems is generally installed lower in elevation and physically separate from the potable water system.

> **Rule of Thumb**
>
> *Reclaimed water or greywater programs are especially relevant in areas with chronic water concerns, such as California, Florida, and Texas.*

<u>Greywater</u>

Greywater includes water claimed from showers, bathtubs, bathroom sinks, washing machines, and drinking fountains. It may also include condensation pan water from refrigeration equipment and air conditioners. Greywater is minimally

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8 *Greening Federal Facilities*, DOE, 2001.

9 NPR 8570.1, Energy Efficiency and Water Conservation, NASA.

10 *Guidelines for Water Reuse*, EPA, 2004.

contaminated as compared with **blackwater**, which is usually defined as untreated water from urinals and water closets. Water from kitchen sinks is often excluded from greywater sources because it contains oil, grease, and food scraps which can burden the treatment and disposal process. Common uses for greywater include irrigation and toilet and urinal flushing.

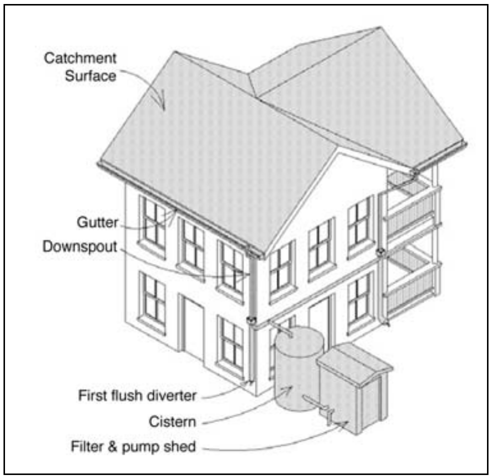
> *Definition*
>
> *Blackwater*
>
> *Blackwater is untreated wastewater that contains potential toxins, such as water from toilets and urinals. This water source must be treated before it can be reused.*

Greywater systems may be most useful in administrative buildings with many lavatories and little or no industrial or shower consumption. Greywater systems may be appropriate in facilities where large quantities of potable water are consumed through the lavatory flushing system or in the landscape irrigation system.

Greywater is collected through a modified plumbing system that diverts greywater away from other building wastewater sources, filters it to remove large particles, and pools it in a central location for reuse. Greywater should not be stored for extended periods of time because it is not heavily treated. A connection with the sewer line should be provided for overflow, and extensive planning, design, and maintenance is required. The required pumping systems will also consume energy.

According to NPR 8570.1, Appendix V, untreated filtered water may be appropriate for uses such as vehicle washing and landscape irrigation, as well as decorative water features, cooling towers, process uses, lavatory flushing, and fire protection. NPR 8570.1 does not recommend use of untreated water from showers and clothes washers for landscape irrigation due to capital costs and health and safety concerns.

Figure 8 - Typical Rainwater Harvesting Elements



Source: Texas Manual on Rainwater Harvesting, Texas Water Development Board, 2005.

Harvested Rainwater

Harvested rainwater is another potential alternative water source. Rainwater is usually collected from building roofs or other catchment areas through a gutter system that leads through a filter or leaf screen to a storage cistern. The elements of a typical rainwater harvesting system are pictured in Figure 8. Generally, rainwater is used in cooling towers or for landscape irrigation. In some locations where potable water supplies are severely limited, rainwater may be treated and purified for potable uses.

A rainwater system should be designed to safely handle any storm size. Considerations should include appropriately sizing the cistern based on the local climate, and use of a passive, gravity-based system to send excess stormwater into the storm drain. The local climate will also inform winterization and spring restart requirements.

Rainwater harvesting is most productive in areas where aquifer-based water supplies are limited or ecologically fragile; where pumped groundwater is polluted or excessively mineralized, requiring heavy treatment; or where stormwater runoff is a major concern.[11] If the building's roof area is large enough relative to the landscape irrigation area, then rainwater harvesting can significantly reduce irrigation water usage. Rainwater collection systems also require regular maintenance.

> *Rule of Thumb*
>
> *Roofs with total area under 5,000 square feet (SF), or with numerous sections and roof drains, are generally poor candidates for rainwater collection.*

3) Incorporate Alternative Source Planning

According to NPR 8570.1, Water Management Plans and Water Conservation 5-year Plans should include at least four of the DOE's water-efficiency best practices. These best practices include water reuse and recycling. Operational practices should be implemented, and opportunities for retrofit or replacement should be reviewed every two years. Retrofit and replacement options should be implemented, where life-cycle cost-effective.

Communication with building occupants and staff is critical for the long-term success of alternative water systems. Effectively training the maintenance staff on proper operations also helps to ensure that water is safely handled.

> *Building Focus*
>
> *Propellants North Administrative and Maintenance Facility, Kennedy Space Center*
>
> *The Propellants North building uses rainwater harvesting.*

4) Estimate the Life-Cycle Costs and Benefits

Although most alternative sources of water require installation of separate piping systems, they can lead to significant water and energy savings over time. Life-cycle cost-effective reductions in water consumption intensity are required by EO 13423 and 13514, and according to NPR 8570.1, "although treatment and distribution of [alternative water sources] can be expensive, it is usually cost-effective when compared to the costs to develop additional potable water supplies." Detailed estimates on water savings depend in part on the type of system. Incorporating non-potable water systems into new facility design is generally the most cost-effective strategy.[12]

Municipalities may offer reclaimed water at a significantly reduced rate compared with potable water rates. Facilities located on campuses with their own wastewater treatment plants can save even more through use of on-site reclaimed or recycled water. A package storage and treatment system with a warranty may also be cost-effective.

> *Building Focus*
>
> *Moffett Field, Ames Research Center*
>
> *A combination of reclaimed water use, a Native Garden Initiative, and an educational outreach program decreased Center-wide potable water consumption by 80 million gallons and saved $404,000 in FY 2009. This project also won a Federal Energy and Water Management Award in 2010.*

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[11] *Greening Federal Facilities*, DOE, 2001.

[12] NPR 8570.1, Energy Efficiency and Water Conservation, NASA.

Data on water consumption and application (e.g. lavatory, cooling tower, fire protection, fountains) is important to determining life-cycle cost-effectiveness. Additionally, local climate, especially the yearly average rainfall, is a critical factor in determining life-cycle cost-effectiveness of rainwater as a non-potable water source. Total costs for rainwater systems vary widely, based largely on cistern size. In general, a rainwater system costs $1.00/gallon for storage systems under 10,000 gallons, and $0.50/gallon for larger systems.[13]

Potential costs of alternative water sources include:

- Purchase of alternative water piping, meters, and valves
- Installation of alternative water piping, meters, and valves
- Rainwater cistern
- Training and education for building occupants and staff
- Operations manuals for building staff
- Impact to occupant productivity during repair and outages
- Ongoing maintenance and testing of pumps, tanks, and filters

Potential benefits of utilizing alternative water sources include:

- Reduction in water utility costs
- Preservation of local water resources
- Decreased discharge to sensitive water bodies
- Improved stormwater runoff

5) Prioritize, Finance, and Install Alternative Source Systems

Once managers identify the alternative water source systems that are most appropriate and cost-effective for their facility, funding will be needed. Even systems with relatively short payback periods may require some upfront funding, and a variety of funding mechanisms to assist with costs associated with purchasing and installing piping, storage capacity, and other hardware are available. Due to funding limitations, facility managers should think creatively and explore

[13] *Greening Federal Facilities,* DOE, 2001.

alternative funding instruments. When installing alternative water source systems, the facility manager must ensure that construction specifications and other guidance documents are followed.

Potential funding mechanisms include:

- Agency appropriations
- Retained energy savings
- Energy Savings Performance Contracts
- Utility Energy Services Contracts
- Utility company financing
- Public benefits programs and utility demand response programs
- Mandatory tenant sub-metering fees
- O&M performance incentives

6) Monitor and Maintain the Installed System

Long-term efficiency and effectiveness of an alternative water source will depend on proper system operations and maintenance. System maintenance should be explicitly assigned and funded, due to the health risk from bacteria and other contaminants. In addition, the risk of flooding and system failure requires ongoing maintenance.

Related LEED® Credits

The LEED® credits related to alternative water use sources are illustrated in Table 11. Definitions for all LEED® abbreviations appear in the Introduction.

Table 11 – LEED® and Alternative Water Sources

LEED-NC®	WE Prerequisite 1: Water Use Reduction
	WE Credit 1: Water Efficient Landscaping
	WE Credit 2: Innovative Wastewater Technologies
	WE Credit 3: Water Use Reduction
LEED-EB: O&M®	WE Prerequisite 1: Minimum Indoor Plumbing Fixture and Fitting Efficiency
	WE Credit 1: Water Performance Measurement
	WE Credit 3: Water Efficient Landscaping
	WE Credit 4: Cooling Tower Water Management
LEED-ND®	GIB Credit 4: Water Efficient Landscaping

TOOLS

FEMP Alternative Water Sources

The FEMP has collected best practices and informational resources on alternative water sources. Links to technical assistance are included.

For more information:
www1.eere.energy.gov/femp/program/waterefficiency_bmp14.html

Water Reuse

The EPA has published guidelines and research relating to water reuse in general and reclaimed water systems in particular. The guide outlines regulatory guidelines on reclaimed water, and contains case studies on communities, industries, and facilities where reclaimed water has been used successfully.

For more information:
www.epa.gov/nrmrl/pubs/625r04108/625r04108.pdf

Greywater System Guide

The California Department of Water Resources has developed a guide to using greywater in landscaping; the guide also includes information on design and installation of greywater systems.

For more information:
www.owue.water.ca.gov/docs/greywater_guide_book.pdf

Rainwater Harvesting

The Texas Water Development Board has published a manual on rainwater harvesting equipment components, sizing, costs, and incentives. The guide also outlines a series of BMPs for installation of and use of rainwater harvesting systems.

For more information:
www.twdb.state.tx.us/publications/reports/RainwaterHarvestingManual_3rdedition.pdf

Outdoor Water

Water management practices are not restricted to applications inside buildings. Sustainable site design can reduce demands on water supplies as well as reduce the polluted discharges resulting from rainfall. Every strategy to reduce irrigation water consumption or improve stormwater management may not be appropriate for all sites. While some sustainable landscaping or stormwater management techniques may have a substantial initial cost, the reduction in potable water use and stormwater runoff creates life-cycle economic savings for the Agency's operations and maintenance budget, maintains or improves the quality of surrounding aquatic ecosystems and provides social benefits by reducing the need to expand municipal water sources. An example of water-efficient landscaping is pictured in Figure 9.

Figure 9 - Water-efficient Landscaping, Building E-109, Wallops Flight Facility

Source: NASA.

The BMPs for reducing potable water from irrigation and improving stormwater management in the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings* include implementation steps for NASA facilities. Each BMP also includes related NASA activities and accomplishments, applicable LEED® requirements, and tools that provide additional information or assistance.

The outdoor water BMPs for new construction, major renovation, or existing buildings include:

- Use water-efficient landscape and irrigation strategies to reduce outdoor potable water consumption by a minimum of 50 percent over that consumed by conventional means.
- Employ planning, design, construction, and maintenance strategies that reduce stormwater runoff and discharges of polluted water offsite. To the maximum extent technically feasible, maintain or restore the predevelopment hydrology of the site with regard to temperature, rate, volume, and duration of flow.

Building Focus

Building E-109, Wallops Flight Facility

The landscaping at Building E-109 uses zero potable water. The interior courtyard combines plants, trees, rocks, benches, sidewalks, and mulch to create a water-efficient site, including the courtyard pictured in Figure 9.

BEST MANAGEMENT PRACTICE - IRRIGATION

Use water efficient landscape and irrigation strategies to reduce outdoor potable water consumption by a minimum of 50 percent over that consumed by conventional means.

NASA Requirement

NPR 8570.1 requires Centers to meet 4 of 10 water-efficiency BMPs developed by the FEMP, which include recommendations for water-efficient irrigation.

NPR 8580.1 requires discussion of landscape management practices, including water efficient landscaping practices, as part of the Environmental Resources Document.

NPR 8820.2F requires that project designers reduce outdoor potable water consumption by 50 percent by using water-efficient irrigation and other strategies.

Building Focus

Collaborative Support Facility, Ames Research Center

The Collaborative Support Facility's landscaping design includes plants that are drought-resistant and native to California.

Landscape irrigation practices consume large quantities of potable water across the United States; irrigation can account for 40 percent of a typical commercial building's water consumption.[14] Achieving optimal irrigation system performance requires considering efficiency throughout the entire process. For example, proper system installation and management limits water lost to evaporation and wind. In addition, an efficient irrigation schedule accounts for water availability, seasonal change, weather, soil, plant type, and land grading. An example of water-efficient landscaping is pictured in Figure 10.

Figure 10 – Water-efficient Landscaping, Kennedy Space Center

Source: NASA.

Contractors are commonly part of installing and maintaining site landscaping. When developing a landscaping plan, consult contractors experienced with water efficient practices and management.

In addition to utilizing water-efficient equipment, management, and experienced contractors, the water-efficiency of site landscaping can be improved through installing native plant species. Native plants are indigenous to an area, are not invasive, and require little or no irrigation in

[14] *Greening Federal Facilities,* DOE, 2001.

addition to average rainfall totals. These types of plants are common in **Xeriscaping**.

Implementing Water-Efficient Irrigation Strategies

Table 12 lists the steps necessary for implementing water-efficient landscape irrigation strategies. These steps are discussed in additional detail in the subsequent narrative.

Table 12 – Implementing Water-Efficient Irrigation

IMPLEMENTATION STEPS	
1)	**Calculate the Irrigation Baseline**
□	Use calculations, water audits, or water meters to establish baseline.
2)	**Perform an Audit of Current Irrigation System**
□	Select a qualified auditor.
□	Identify changes to landscaping and system, and identify new technologies.
3)	**Identify Irrigation Contractors and Strategies**
□	Select a certified contractor from a WaterSense-labeled program.
□	Identify strategies appropriate to the site.
4)	**Incorporate Irrigation into Planning**
□	Review existing plans and coordinate irrigation strategies.
□	Relay information to building occupants.
5)	**Estimate the Life-cycle Costs and Benefits**
□	Determine costs and benefits of implementing water-efficient landscaping.
6)	**Prioritize, Finance, and Install Irrigation Systems**
□	Identify funding resources.
□	Determine priority of implementing Plan elements.
□	Follow construction specifications on installation.
7)	**Monitor and Maintain the Installed System**
□	Determine maintenance requirements, funding, and responsibilities.

Definition

Xeriscaping

Defined by LEED® as a landscaping method that makes routine irrigation unnecessary. It uses drought-adaptable and low-water plants as well as soil amendments such as compost and mulches to reduce evaporation.

1) Calculate the Irrigation Baseline

Determining total reductions in irrigation water use begins with establishing a baseline of current design or operational consumption. The irrigation water use baseline can be established through a variety of techniques including design analysis and water consumption data. Once a baseline is established, irrigation water reductions can be determined.

The irrigation water baseline in new construction projects is established by assuming the site consumes water based on conventional plant species and plant densities that are typical for the region. Sites that are designed to utilize significant amounts of irrigation water use should install a water sub-meter to measure consumption.

The irrigation water baseline for existing buildings can be established through one of three methods. The first method calculates a baseline based on the consumption from conventional plant species and plant densities. The second

Building Focus

Astronaut Quarantine Facility, Johnson Space Center

The Astronaut Quarantine Facility's site utilizes native grasses and trees to limit the required irrigation.

method to determine an irrigation water use baseline for existing buildings is to use measured irrigation water consumption in 2003 or a year thereafter with quality water data. This data generally comes from the utility provider or water meters. The final method to establish a baseline is to not use any potable irrigation water.

2) Perform an Audit of Current Irrigation System

Water audits of the current irrigation system should be conducted in order to ensure the current system is operating efficiently. Water audits provide an in-depth assessment of system performance. The audit should identify issues resulting from changes to the landscaping or system infrastructure, as well as opportunities to employ new technologies. Plants should only receive water when scheduled; overwatering or underwatering can be detected by an audit.

Rule of Thumb

On average, irrigation systems should undergo an audit every three to four years by a qualified auditor.

3) Identify Irrigation Contractors and Strategies

Water-efficient landscaping plans that achieve significant reductions in potable water use can be developed and implemented by certified contractors. Facility managers should identify contractors who are certified through a WaterSense-labeled program. This program will ensure the contractor is familiar with water-efficient practices and management.

Building Focus

Collaborative Support Facility, Ames Research Center

100 percent of designed irrigation at the Collaborative Support Facility is to be provided through the use of treated groundwater.

In conjunction with landscaping consultants and contractors, facility managers should identify water-efficient strategies. These strategies include irrigation scheduling, water reuse, water recycling, and the use of harvested rainwater. Other strategies encouraged by the FEMP include water-demand-based irrigation controls, drip or micro-irrigation, as well as rain, frost, and wind sensors which turn the irrigation system on and off depending on weather conditions. For more information on water reuse, water recycling, and utilizing harvested rainwater, see the alternative source section on page 3-28.

Rule of Thumb

Communication with building occupants and staff is critical for the long-term success of water-efficient landscaping. In addition, effectively training and educating the maintenance staff on proper operations helps ensure potable water is used only when necessary.

4) Incorporate Irrigation Into Planning

Information collected during the water audit should complement the existing Water Management Plan and water conservation program. According to NPR 8570.1, Water Management Plans and Water Conservation 5-year Plans should include at least four of the DOE's water-efficiency best practices. The water-efficiency best practices include water-efficient landscaping. Developing these Plans should include a routine inspection and maintenance program to review the landscaping contracts, schedules, and overall performance.

5) Estimate the Life-Cycle Costs and Benefits

Although installing or removing irrigation water systems require significant costs, they can achieve significant water and energy savings over time. Life-cycle cost-effective reductions in water consumption intensity are required by EO 13423 and 13514.

In cases where alternative sources of water are appropriate as replacements for potable irrigation water, alternative sources are "usually cost-effective when compared to the costs to develop additional potable water supplies."[15] Detailed estimates of water savings depends in part on what type of system is installed. Furthermore, an important cost-benefit aspect to consider is that including non-potable water into the design of new facilities is generally the most cost-effective strategy.[15]

> **Rule of Thumb**
>
> *The local climate, especially the yearly average rainfall, is a critical component when determining life-cycle cost-effectiveness of incorporating rainwater as a non-potable water source.*

In addition, the total cost of a rainwater system varies widely, primarily due to the uneven cost of the cistern. In general, a rainwater system costs $1.00/gallon for storage systems less than 10,000 gallons, and $0.50/gallon for larger systems.[16]

Potential costs of reducing potable irrigation include:

- Purchase and installation of alternative water piping, meters, and valves
- Removal of existing irrigation systems
- Additional planning and design
- Rainwater cistern or other storage equipment
- Training and education for building occupants and staff
- Operations manuals for building staff

Potential benefits of reducing potable irrigation include:

- Reduction in water utility costs
- Preservation of local water sources
- Decreased discharge to sensitive water bodies
- Improved stormwater runoff

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[15] NPR 8570.1, Energy Efficiency and Water Conservation, NASA.

[16] *Greening Federal Facilities,* DOE, 2001.

6) Prioritize, Finance, and Install Irrigation Systems

Once managers identify the irrigation systems and/or landscaping that are appropriate and cost-effective for their facility, sufficient funding is needed. Systems with relatively short payback periods may require some upfront funding; a variety of mechanisms exist to assist with purchasing and installing piping, storage capacity, and other hardware. Due to funding realities, facility managers should think creatively and explore alternative funding instruments. When installing landscaping and irrigation systems, the facility manager must ensure that construction specifications and other guidance documents are followed.

Potential funding mechanisms include:

- Agency appropriations
- Retained energy savings
- Energy Savings Performance Contracts
- Utility Energy Services Contracts
- WaterSense Rebates from the EPA
- Utility company financing
- Public benefits programs and utility demand response programs
- Mandatory tenant sub-metering fees
- O&M performance incentives

7) Monitor and Maintain the Installed System

Long-term efficiency and effectiveness of water-efficient landscaping will depend on proper system operations and maintenance, unless no potable irrigation is used. If any potable water is used for irrigation, another water audit should be performed after installation or at least every three to four years, per FEMP guidance.

Related LEED® Credits

The LEED® credits related to water-efficient landscaping are illustrated in Table 13. Definitions for all LEED® abbreviations appear in the Introduction.

Table 13 – LEED® and Water-efficient Landscape Irrigation

LEED-NC®	WE Credit 1: Water Efficient Landscaping
LEED-EB: O&M®	WE Credit 1: Water Performance Measurement
	WE Credit 3: Water Efficient Landscaping
LEED-ND®	GIB Credit 4: Water Efficient Landscaping

TOOLS

FEMP Landscaping

The FEMP has collected best practices and informational resources on water-efficient landscaping. Operations and installation best practices and links to technical assistance are included.

For more information:
www1.eere.energy.gov/femp/program/waterefficiency_bmp4.html

FEMP Irrigation

The FEMP has collected best practices and informational resources on water-efficient irrigation. Operations and installation best practices and links to technical assistance are included.

For more information:
www1.eere.energy.gov/femp/program/waterefficiency_bmp5.html

BEST MANAGEMENT PRACTICE - STORMWATER

Employ planning, design, construction, and maintenance strategies that reduce storm water runoff and discharges of polluted water offsite. To the maximum extent technically feasible, maintain or restore the predevelopment hydrology of the site with regard to temperature, rate, volume, and duration of flow.

NASA Requirement

NPR 8570.1 requires Centers take water supply, wastewater, stormwater issues and water efficiency BMPs into account at the earliest stages of planning and design for renovation and new construction.

NPR 8580.1 requires Centers to consider stormwater permits, stormwater runoff, and chemical and physical qualities of stormwater; to adjust for increases in stormwater runoff and identify how stormwater can/should be controlled.

Stormwater includes rainwater, snowmelt, or other water that enters the stormwater system. The amount of **impervious surface** such as roads, parking lots, sidewalks, and buildings directly relates to the amount of stormwater runoff. Stormwater runoff can have negative consequences on the surrounding environment including the erosion of streambeds and the introduction of chemicals and pollutants into the local water system. The relationship between impervious cover and stormwater runoff is highlighted in Figure 11.

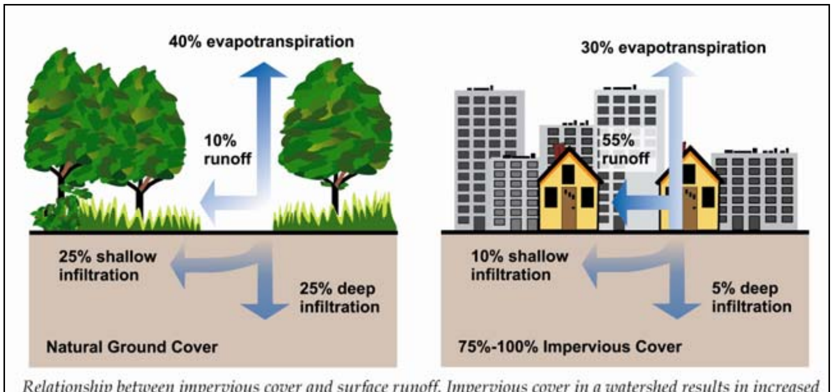
Stormwater can be mitigated through a variety of site planning, design, construction, and maintenance strategies. Existing stormwater management controls across the United States are commonly insufficient, but improved site design and management approaches have been shown to reduce runoff volume, peak flows, and to remove pollutants.[17]

Definition

Impervious Surface

An impervious surface includes any surface that does not allow stormwater or other water sources to infiltrate into the ground.

Figure 11 - Impervious Cover and Stormwater Runoff



Relationship between impervious cover and surface runoff. Impervious cover in a watershed results in increased surface runoff. As little as 10 percent impervious cover in a watershed can result in stream degradation.

Source: Protecting Water Quality From Urban Runoff, EPA, 2003.

[17] *Urban Stormwater Management in the United States*, National Academy of Sciences, 2008.

In addition, the Energy Independence and Security Act (EISA) of 2007 recommends that any federal facility with a footprint greater than 5,000 square feet must plan for redevelopment hydrology. Each facility must "maintain or restore stormwater runoff to the maximum extent technically feasible" and ensure that receiving waters are not negatively affected by stormwater flow.[18]

Implementing Stormwater Reduction Techniques

Table 14 lists steps necessary for implementing stormwater and off-site discharge reduction techniques. These steps are discussed in detail in the subsequent narrative.

Table 14 – Implementing Stormwater Reduction Techniques

	IMPLEMENTATION STEPS
1)	**Perform a Stormwater Analysis**
□	Establish the baseline stormwater flow and pollutant discharges.
□	Complete an Environmental Resources Document.
2)	**Identify Structural Changes**
□	Incorporate green infrastructure and low-impact development techniques into site design and landscaping changes.
3)	**Identify Non-Structural Changes**
□	Determine appropriate site design and landscaping changes.
4)	**Incorporate Stormwater Management into Facility Planning**
□	Identify existing stormwater permits and regional regulation variations, if any.
5)	**Estimate the Life-cycle Costs and Benefits**
□	Determine costs and benefits of implementing water-efficient landscaping.
6)	**Prioritize, Finance, and Install Stormwater Management Techniques**
□	Identify funding resources.
□	Determine priority of implementing Plan elements.
□	Follow construction specifications on installation.
7)	**Implement Ongoing Maintenance of Stormwater Management Techniques**
□	Ensure proper maintenance and operations.

1) Perform a Stormwater Analysis

Stormwater analysis determines the current baseline total of stormwater runoff in one location. This process includes evaluating average precipitation, soil analysis, the proposed or existing design of the building and site, peak flow calculations, and examining historical patterns of stormwater flow. The roof design, site design, stormwater ponds, and other stormwater management features must all be documented. This process should also predict or quantify the vehicular and landscape pollutants that reach the runoff stream. The pollutants may include oil, gasoline, heavy

Rule of Thumb

Existing stormwater problems may not be immediately apparent without direct observation during rain events.

[18] Energy Independence and Security Act, 2007.

metals, detergents, cleaners, fertilizers, pesticides, or herbicides.

A description of existing water resources, quality, and pollution is part of an Environmental Resources Document (ERD) as described by NPR 8580.1. This should include a description of the nature of existing techniques for water pollution control and the status of any water pollution permits.

Definition

Green Infrastructure/Low-Impact Development

Provides a framework for implementing stormwater management practices. This framework includes a comprehensive planning strategy that protects natural resources, manages erosion and sediment controls, and minimizes site imperviousness.

LEED® Focus

Reducing stormwater runoff is one of the sustainable site strategies included in the LEED-NC® and the LEED-EB: O&M® credit systems.

2) Identify Structural Changes

Site design strategies directly impact the amount of stormwater runoff. Techniques and practices from the **Green Infrastructure/Low-Impact Development** (GI/LID) framework should be included from the beginning of the planning process. Specific strategies may include narrower street design, green roofs, and permeable pavement; together these techniques provide the potential to reduce runoff dramatically. New construction sites should be disturbed as little as possible during construction, and soil compacted as little as possible. In addition, minimizing the total amount of impervious surfaces, or separating impervious surfaces with turf, gravel, or vegetation can minimize stormwater runoff. Providing an opportunity for stormwater to infiltrate into the ground as close as possible to where the precipitation falls is generally the most effective strategy.[19]

Stormwater at existing facilities can be mitigated through many of the same strategies as new construction sites. Facility managers should plan to incorporate stormwater mitigation strategies when the site landscape is redesigned or replanted, site is re-graded, utilities are excavated, buildings are reroofed, streets or sidewalks are modified, and paved areas are replaced, resurfaced, or enlarged.[19]

3) Identify Non-Structural Changes

Non-structural techniques can mitigate stormwater runoff from facilities. These techniques include rainwater harvesting, submerged gravel wetlands, and landscape infiltration. Non-structural changes can be used in new construction or existing building projects, and are generally considered less intrusive than site design management techniques. For more information on rainwater harvesting, see page 3-30.

[19] *Greening Federal Facilities*, DOE, 2001.

4) Incorporate Stormwater Management into Facility Planning

Stormwater Management Plans are a common way to document the processes, goals, and requirements for facilities and Centers. As described in NPR 8580.1, Center planning may include water pollution control techniques, as well as any National Pollution Discharge Elimination System (NPDES) permits. The NPDES program governs discharges from municipal separate storm sewer systems, construction activities, and industrial operations.

Similar to potable water supplies, stormwater runoff has regional variations. Each facility manager must become familiar with local and regional resources and codes, and contact with local authorities is encouraged.

5) Estimate the Life-Cycle Costs and Benefits

Installation of some stormwater management strategies can require significant capital expenditures. Structural and non-structural changes can impact site runoff, as well as the discharges of polluted water offsite. Ignoring stormwater runoff can cause problems in local vegetation, loss of natural drainage patterns, increased volume of runoff, and increased pollution contaminants. In addition, allowing stormwater runoff to continue without intervention can be more expensive than early and comprehensive mitigation.

Potential costs of stormwater management include:

- Analysis of current stormwater runoff
- Purchase of stormwater management infrastructure
- Installation and renovation costs

Potential benefits of stormwater management include:

- Preservation of local water systems
- Potential for water recycling
- Erosion reduction

6) Prioritize, Finance, and Implement Stormwater Management Techniques

Once the costs and benefits of each stormwater management strategy are determined, the facility manager needs to secure financing and prioritize the individual projects. Stormwater management priorities generally include sources producing the largest amount of runoff and that have the highest impact on people or the local water systems. Agency funding will not exist for all projects in the next fiscal year, so the facility manager must determine which projects will be the most cost-effective. In addition, stormwater permit actions are among the activities normally funded from sources other than Construction of Facilities (CoF) accounts.[20]

Potential funding sources include:

- Clean Water State Revolving Fund
- Permit fees
- Stormwater utility fees

7) Implement Ongoing Maintenance of Stormwater Management Techniques

The facility manager must ensure the implemented stormwater management techniques are properly maintained. Structural and non-structural strategies require ongoing care and maintenance. Integrating staff feedback into the Stormwater Management Plan process can assist Centers identify and correct problems.

Related LEED® Credits

The LEED® credits related to reducing stormwater runoff are illustrated in Table 15. Definitions for all LEED® abbreviations appear in the Introduction.

Table 15 – LEED® and Stormwater Reduction Techniques

LEED-NC®	WE Credit 1: Water Efficient Landscaping
	WE Credit 2: Innovative Wastewater Technologies
	WE Credit 3: Water Use Reduction
LEED-EB: O&M®	WE Credit 4: Cooling Tower Water Management
LEED-ND®	GIB Credit 4: Water Efficient Landscaping
	GIB Credit 8: Stormwater Management

TOOLS

Stormwater Runoff Guidance

The "Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act Installation" is a guidance document that discusses implementation; it also offers a number of successful case studies.

For more information:
www.epa.gov/oaintrnt/documents/epa_swm_guidance.pdf

[20] NPR 8820.2F *Appendix D*, NASA, 2008.

EPA National Pollutant Discharge Elimination System

The EPA National Pollutant Discharge Elimination System's Stormwater Program includes technical and regulatory information relating to stormwater and water pollution discharge.

For more information:
http://cfpub.epa.gov/npdes/home.cfm?program_id=6

Green Infrastructure/Low-Impact Development

The Green Infrastructure/Low-Impact Development program by the EPA is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible.

For more information:
http://water.epa.gov/polwaste/green/

Federal Facilities Program Managers

The EPA offers assistance for compliance and enforcement at federal facilities is available by regional program managers.

For more information:
www.epa.gov/compliance/contact/fedfac-regional.html

National Menu of Stormwater Best Practices

This resource covers public education, public involvement, illicit discharge, detection and elimination; and construction, post-construction, and pollution prevention.

For more information:
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm

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Process Water

Process water includes water used to make a product or affect a procedure or action. Implementing changes to building system equipment or to industrial operations and process can achieve reductions in potable water use. These processes include boilers and steam systems, as well as air-conditioning systems and cooling towers. Life-cycle cost-effective adjustments and upgrades that reduce potable water use can maintain or improve the quality of surrounding aquatic ecosystems and provide social benefits by reducing the need to expand municipal water sources. An example cooling tower is identified in Figure 12.

Figure 12 - Cooling Tower, Building 1238B, Langley Research Center

Source: NASA.

The BMP for reducing potable water from process applications in the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings* include implementation steps for NASA facilities. The BMP also includes related NASA activities and accomplishments, applicable LEED® requirements, and tools that provide additional information or assistance.

The process water BMP for new construction, major renovation, or existing buildings requires deploying life-cycle cost-effective water conservation measures when potable water is used to improve a building's energy efficiency.

BEST MANAGEMENT PRACTICE - PROCESS WATER

When potable water is used to improve a building's energy efficiency, deploy life-cycle cost effective water conservation measures.

NASA Requirement

NPR 8570.1 requires Centers to meet 4 of 10 water-efficiency BMPs developed by the FEMP, which include recommendations for water-efficient boilers and steam systems.

Potable water is used in a number of facility process uses, such as boilers, steam generators, cooling towers, and air-conditioning systems. Treated water is important to sustainable operations, and conditioning water properly can even extend equipment life.[21] In cases where potable water is used, water conservation measures should be implemented to reduce the total environmental and economic impact.

Water-efficient boiler, steam system, cooling tower, and air-conditioning system operations are encouraged by NPR 8570.1 and the associated FEMP guidance. Reducing the potable water consumption from these process applications can be accomplished through two main techniques; including adjusting or upgrading the equipment to consume less water and changing the process in order to not use any potable water.

LEED® Focus

Cooling tower water management is one of the water-efficient strategies included in the LEED-NC® and the LEED-EB: O&M® credit systems.

[21] *Energy Efficiency Handbook*, Council of Industrial Boiler Owners, 1997.

Implementing Reductions in Potable Water Consumption from Process Uses

Table 16 lists the steps necessary for implementing a plan to reduce water use from process applications. These steps are discussed in additional detail in the subsequent narrative.

Table 16 – Implementing Process Water Use Reductions

IMPLEMENTATION STEPS	
1)	**Determine Current Potable Water Use**
□	Utilize meters, audits, or other data sources.
2)	**Identify Appropriate Equipment and Process Adjustments**
□	Determine appropriate equipment and process changes.
3)	**Incorporate Process Uses in Planning**
□	Edit Water Management Plan and Water Conservation 5-year Plan.
4)	**Estimate the Life-cycle Costs and Benefits**
□	Determine costs and benefits of water-efficient landscaping.
5)	**Prioritize, Finance, and Implement Process Water Improvements**
□	Identify funding resources.
□	Determine priority of implementing Plan elements.
□	Follow construction specifications on installation.
6)	**Develop a Plan for Future Upgrades or Replacements**
□	Identify a system implementation schedule.
□	Incorporate ongoing maintenance into the Water Management Plan.

1) Determine Current Potable Water Use

Information collected during water management planning, especially through water metering and sub-metering, informs the scale and application of process water. Facilities without boilers or cooling towers should still determine potable water use through the steam and air-conditioning systems. Leaks in these systems may lead to large reductions in system efficiency. This can be especially true for steam, which may be produced in another location and piped into the facility.

2) Identify Appropriate Equipment and Process Adjustments

Once current potable water consumption has been established, facility managers should evaluate the various process applications. For a detailed analysis and additional information, consult experts such as staff engineers, consultants, and other agency staff. Process water applications that consume potable water include boilers and steam systems, as well as cooling towers and air-conditioning systems.

Definition

Blowdown

Blowdown is the periodic or continuous removal of water from a boiler to remove accumulated dissolved solids and/or sludge.

NASA Requirement

NPD 8710.5D describes the policies to design, acquire, fabricate, inspect, test, install, repair and alter, operate, and maintain all ground-based pressure vessels and pressurized systems in accordance with the applicable codes, standards, guides, and regulations as detailed in STD 8719.17, NASA Requirements for Ground-Based Pressure Vessels and Pressurized Systems. STD 8719.17 requires annual tests of the accuracy of the pressure set points in steam systems.

Boilers and Steam Systems

Boilers and steam generators are commonly used in large heating systems, industrial kitchens, or facilities where large amounts of process steam are used. This equipment consumes varying amounts of water depending on the size of the system, the amount of steam used, and the amount of condensate returned. With new construction, it is possible to specify an energy- and water-efficient boiler or use alternative heating technology for the facility. In existing facilities, sustainability goals may be harder to achieve. Older, less efficient systems often require significant water input from the domestic water line because condensate is either not captured effectively or not captured at all. Older boilers also have less efficient **blowdown** systems that require greater water input to reduce contamination accumulation.

Improving the efficiency of boilers and steam systems may be possible through modifications to existing boiler systems; however, total replacement of the boiler system with a newer, more efficient system is preferable. By upgrading an existing boiler system or installing a new boiler system, facilities can ensure savings from both water-use reduction and energy efficiency. All boiler systems should be periodically examined for maintenance problems and tuned to maintain a high level of water efficiency. Where possible, the conversion of an old steam heating system to one based on hot water can save energy and water.

Air-Conditioning Systems

Air-conditioning systems use water in the production of cool air. Single-pass systems, in which water is circulated once through a piece of equipment and then disposed, are the most water-inefficient cooling systems. They continually require a fresh water supply to maintain effectiveness. To maximize water savings, single-pass cooling equipment should either be modified to recirculate water or eliminated altogether.

Many air-conditioning and refrigerated systems can be based on an air-cooled design. This eliminates essentially all water consumption for cooling, but the overall system is often less energy-efficient than a water-cooled system. The relative costs and benefits of water-cooled versus air-cooled systems should be considered in new construction or retrofit mechanical installations. In areas where water conservation is a high priority, the water consumption and disposal issues with cooling towers should be cited as a factor in HVAC design decisions, and should be included early in the planning process.

For large-scale mechanical retrofit projects in existing buildings, consideration should be given to replacing an existing cooling tower with an air-cooled system which uses no water, if life-cycle cost-effective. Recent technological improvements in air-cooled systems have reduced the historic energy penalty for these systems relative to cooling towers.

Cooling Towers

Cooling towers utilizing recirculating water to regulate temperature are more efficient than single-pass cooling equipment and are standard in most facilities. In some jurisdictions, single-pass systems are no longer acceptable by building codes and standards. Cooling towers are used with chillers, air-conditioning equipment, and other process equipment. While cooling towers consume less water than single-pass systems, they still require significant water inputs. Proper cooling tower maintenance can conserve significant amounts of water. Controlling biotic growth on wet cooling towers is important for successful cooling-tower management. Uncontrolled growth of microorganisms in cooling tower water can cause serious problems such as the risk of Legionnaire's Disease, as well as blocked cooling water passages, accelerated corrosion, and reduced heat-exchanger efficiency.

Cooling tower water consumption is a function of evaporation, drift, blowdown, and any basin leaks or overflows. Evaporation is used by cooling towers to transfer heat from the system to the environment. Because evaporation is required for cooling tower functionality, little can be done to reduce the water demand due to evaporation. Drift loss occurs when water is carried from the tower as mist or small droplets. Drift loss is small but can be controlled readily with baffles and drift eliminators. As in boilers and steam systems, blowdown is used to control buildup of dissolved solids within the cooling tower. Careful monitoring and controlling the quantity of blowdown provides the most significant opportunity to conserve water in cooling tower operations. Repairing leaks and controlling overflows also contribute to water efficiency. Modern technologies such as automatic basin cleaning and filtration systems can reduce the need for blowdown.

Building Focus

At Goddard Space Flight Center, a well was drilled adjacent to the cooling tower. Groundwater supplements the total supply for the system, reducing the demand on potable water supplies.

3) Incorporate Process Uses in Planning

According to NPR 8570.1, Water Management Plans and Water Conservation 5-year Plans should include at least four of the DOE's water-efficiency best practices. The water-efficiency best practices include operations of boiler and steam systems, single-pass cooling equipment, cooling towers, and other water-intensive processes. Developing these Plans includes a routine inspection program to review the applications for leaks, corrosion, or other problems.

Operational practices and opportunities for retrofit or replacement should be reviewed every two years. The retrofit and replacement options should be implemented, where life-cycle cost-effective. Communication with building occupants and staff throughout this process is critical for the long-term success of alternative water systems. In addition, effectively training and educating the maintenance staff on proper operations helps ensure water is safely handled.

4) Estimate the Life-Cycle Costs and Benefits

Most process water applications require installation of separate piping systems; upgrading, replacing, or monitoring those systems can achieve significant water and energy savings over time. Life-cycle cost-effective reductions in water consumption intensity are required by EO 13423 and EO 13514. Detailed cost-benefit calculations depend on the type of systems installed or the water conservation measures taken.

Potential costs of water-efficient process uses include:

- Analysis of current potable water consumption
- Purchase of process water efficiency upgrades or replacements
- Installation and renovation costs
- Impact to occupant productivity during repair and outages

Potential benefits of water-efficient process uses include:

- Reduction in water utility costs
- Preservation of local water sources

5) Prioritize, Finance, and Implement Process Water Improvements

Once managers identify the upgrades or replacements to process water applications that are appropriate and cost-effective for their facility, sufficient funding is needed for implementation. Systems with relatively short payback periods will likely require some upfront funding, and a variety of mechanisms exist to assist with purchasing and installing piping, meters, and other hardware. Due to funding realities, facility managers should think creatively and explore alternative funding instruments. When installing process water upgrades or replacements, the facility manager must ensure that construction specifications and other guidance documents are followed.

Potential funding mechanisms include:

- Agency appropriations
- Retained energy savings
- Energy Savings Performance Contracts
- Utility Energy Services Contracts
- Utility company financing
- Public benefits programs and utility demand response programs
- Mandatory tenant sub-metering fees
- O&M performance incentives

6) Develop a Plan for Future Upgrades or Replacements

Any upgrades or replacements that are not implemented should be incorporated into the facility planning process. Facility managers should incorporate all planned or scheduled process water improvements, as well as collect staff feedback and equipment performance data. Additionally, managers should collect leak detection, water audits, or water meter data. A documented process for evaluating and monitoring process water applications should be incorporated into the facility or Center Water Management Plan. For more information on Water Management Plans, see page 3-3.

Related LEED® Credits

The LEED® credits related to reducing potable water use from process applications are illustrated in Table 17. Definitions for all LEED® abbreviations appear in the Introduction.

Table 17 – LEED® and Process Water

LEED-NC®	None
LEED-EB: O&M®	WE Credit 1: Water Performance Measurement
LEED-ND®	GIB Credit 14: Wastewater Management

TOOLS

Boiler System Replacement Guidance

The American Council for an Energy-Efficient Economy (ACEEE) provides a useful consumer guide on how to determine when to replace an existing boiler, how to calculate return-on-investment, and how to select new systems.

For more information:
www.aceee.org/consumerguide/heating.htm

FEMP Boilers and Steam System

The FEMP has collected best practices and informational resources on water-efficient boilers and steam systems. Operations and installation best practices and links to technical assistance are included.

For more information:
www1.eere.energy.gov/femp/program/waterefficiency_bmp8.html

Steam System Best Practices

The Council of Industrial Boiler Owners (CIBO) has developed an Energy Efficiency Handbook. This Handbook includes a variety of equipment and operations best practices.

For more information:
www1.eere.energy.gov/industry/bestpractices/pdfs/steamhandbook.pdf

Process Cooling

Process Cooling, a supplement to *Process Heating* magazine, follows developments in cooling technologies and equipment. The supplement is focused specifically on cooling equipment, materials, and supplies. It also provides information how to troubleshoot systems and how to specify new equipment.

For more information: www.process-cooling.com

FEMP Cooling Tower Management

The FEMP has collected best practices and informational resources on cooling tower management. Operations and installation best practices and links to technical assistance are included.

For more information:
http://www1.eere.energy.gov/femp/program/waterefficiency_bmp10.html

CHAPTER 4. ENHANCE INDOOR ENVIRONMENTAL QUALITY

Background

The presence of bacteria, chemical pollutants, and other allergens in buildings can create substantial health risks and lead to indoor environments that may be more polluted than outside air, even in large cities.[1] Many Americans spend as much as 90 percent of an average day indoors, leading to significant exposure to poor-quality indoor air. This exposure's effects on building occupants' health may be immediate or gradual. In either case, improvements to indoor environmental quality (IEQ) may offer substantial reduction in these health risks. Meanwhile, a growing body of research demonstrates a connection between employee productivity and the quality of the indoor environment. By improving IEQ, facility managers can enhance employee productivity and reduce energy costs.[2]

Health hazards resulting from exposure to poor-quality indoor air may be minor or severe, depending in part on the concentration of pollutants and the health of the individuals exposed. These hazards may be caused by the building materials, the activities inside the building, poor ventilation or material choice, or by its occupants, through carbon dioxide or secondhand smoke. Health impacts "among building occupants may be reduced through improvements in [heating, ventilating, and air-conditioning] system design and maintenance and by maintaining outside air intakes distant from potential pollutant sources."[3]

Poor IEQ may be caused by a number of factors other than poor air quality. Indoor pollutants, thermal forces, outdoor pollutants near the building, pollution transported through ventilation systems, poor filtration or lack of filtration, and indoor climate quality may all have a negative effect on IEQ.

Chapter Outline

To ensure compliance with federal policy, the Agency should employ a systematic approach to indoor environmental quality enhancement, focusing on:

- *Ventilation and Thermal Comfort*
- *Moisture Control*
- *Daylighting*
- *Low-emitting Materials*
- *Protection of Indoor Air Quality During Construction*
- *Environmental Tobacco Smoke Control*
- *Indoor Pest Control*

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1 *The Inside Story: A Guide to Indoor Air Quality*, EPA, Office of Air and Radiation.

2 Browning, Bill and Joseph Romm. *Greening the Building and the Bottom Line.* Rocky Mountain Institute, 1994.

3 Sieber, W.K., et al, "HVAC Characteristics and Occupant Health" ASHRAE Journal, 2002.

Ventilation and Thermal Comfort

High-performance and sustainable buildings provide occupants with a well-ventilated and comfortable indoor environment. The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) and the American National Standards Institute (ANSI) maintain continuously updated standards for ventilation and thermal comfort. These include Standard 62.1, *Ventilation for Acceptable Indoor Air Quality;* and Standard 55, *Thermal Environmental Conditions for Human Occupancy*.

A sufficient quantity of outdoor air may be provided by either mechanical or natural ventilation. Increased ventilation reduces concentrations of carbon dioxide and pollutants, and can mitigate occupant health impacts.

Thermal comfort is another important component of IEQ. Thermal comfort refers to the state of mind that expresses satisfaction with the surrounding environment.[4] As with lighting and ventilation, thermal comfort concerns must be weighed against energy efficiency goals.

The Best Management Practices (BMP) for ventilation and thermal comfort are derived from the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings* and Agency policy. Each BMP includes discussion of related NASA activities and accomplishments, relevant Leadership in Energy and Environmental Design (LEED®) credits, and resources that offer additional information or assistance.

The ventilation and thermal comfort BMPs for new construction, major renovation, or existing buildings require the following:

- Meet ASHRAE Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality.
- Meet ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy, including continuous humidity control within established ranges per climate zone.

Building Focus

Johnson Space Center, LEED® Office for Transition

The LEED® Office for Transition's air handling units and energy recovery ventilator use ultra-violet light to kill or inactivate microorganisms in the building's airstream.

[4] ASHRAE Standard 55, Thermal Environmental Conditions for Human Occupancy.

BEST MANAGEMENT PRACTICE - VENTILATION

Meet ASHRAE Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality.

In a poorly ventilated building, pollutants can accumulate to levels that lead to health risks and comfort issues.[5] Adequate ventilation, with outdoor air replacing indoor air at an exchange rate high enough to reduce concentration of indoor pollutants, is essential to efforts to minimize these risks. Through extensive research and experience, ANSI and ASHRAE have developed standards and guidelines for building designers and facility managers.

The ANSI/ASHRAE standard for ventilation is updated every three years, and specifies "minimum ventilation rates and indoor air quality that will be acceptable to human occupants and are intended to minimize the potential for adverse health effects."[6] HVAC system design professionals perform ventilation design calculations per ANSI/ASHRAE Standards. These calculations should determine the designed ventilation rates for each **climate zone**, compared to the minimum rates in the Ventilation Rate Procedure.

Standard 62.1 was updated in 2010, incorporating new minimum filtration, air cleaning, and ventilation system operation requirements, as well as a procedure for natural ventilation. Additionally, the standard revised indoor air quality procedures, demand-controlled ventilation system design requirements, intake and exhaust separation requirements, and ventilation rates and occupancy categories.

NASA Requirement

NPR 8820.2F requires compliance with ASHRAE Standard 62.1-2004, which is the 2004 edition of this standard.

Definition

Climate Zone

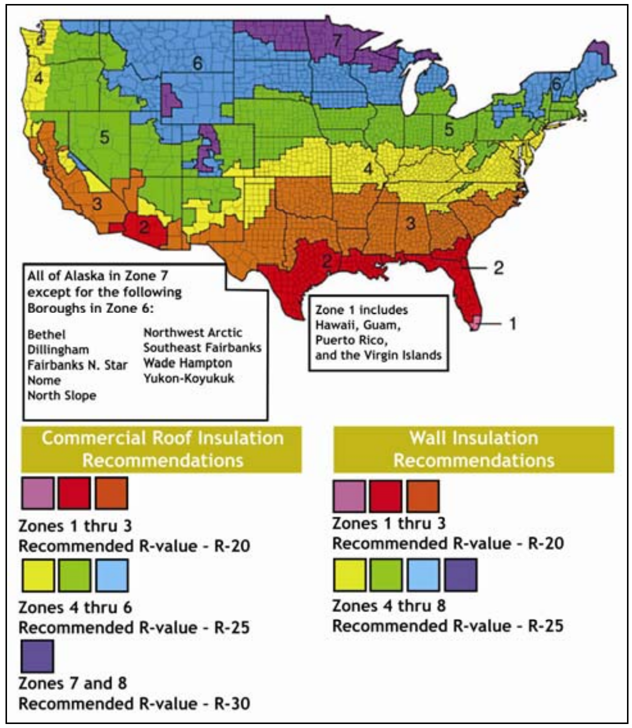
Developed by the International Energy Conservation Code, climate zones use county boundaries to delineate zones of similar average temperatures and relative humidity. The climate zones have been adopted by ENERGY STAR, ASHRAE, and other organizations.

[5] *The Inside Story: A Guide to Indoor Air Quality*. EPA, Office of Air and Radiation.

[6] ANSI/ASHRAE Standard 62.1 *Ventilation for Acceptable Indoor Air Quality*.

Energy Conservation Climate zones for the United States are illustrated in Figure 1.

Figure 1 – Energy Conservation Code Climate Zones



Source: Department of Energy.

Implementing a Ventilation Program

Table 1 illustrates the steps required to implement a ventilation program. These steps are discussed in detail in the subsequent narrative.

Table 1 - Implementing Ventilation Techniques

IMPLEMENTATION STEPS	
1)	**Identify Appropriate Ventilation Methods**
□	Determine which ventilation system is most appropriate for the facility.
□	Use regional guidelines for ventilation.
2)	**Perform Design Calculations**
□	Consult experienced ventilation professionals.
□	Minimize space cooling loads.
□	Manage occupant comfort expectations.
□	Determine which ventilation system design is most appropriate for the facility.
3)	**Implement Ventilation System Controls**
□	Implement ventilation controls that are most appropriate for the facility.
□	Account for climate and occupancy changes.
4)	**Commission the Ventilation System**
□	Place commissioning agent on design team.
□	Extend contract for commissioning agent into post-occupancy period.

1) Identify Ventilation Methods

Outdoor air can enter a building through mechanical (active) ventilation, natural (passive) ventilation, a mixture of mechanical and natural ventilation, or infiltration. Designers should compare natural ventilation methods to mechanical ventilation methods, and may select a mixed-mode system that incorporates both mechanical and natural ventilation.

In many climates, small design changes can render natural ventilation a viable alternative, especially when combined with other heating, cooling, or lighting design changes. Overall, these changes can generate significant energy cost savings.

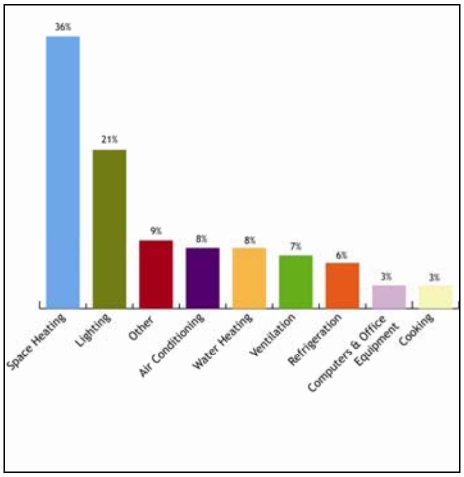
> **Rule of Thumb**
>
> *Efficient mechanical ventilation equipment, in conjunction with whole building design, can help facilities to achieve annual energy cost savings of 30 percent, with a simple payback of five years or less.*[7]

2) Design Ventilation System

High-performance ventilation systems require detailed design and analysis by experienced professionals, who should be consulted before any construction or renovation project is undertaken. An integrated approach to building ventilation includes use of architectural elements and consideration of energy goals, IEQ, safety, and other factors.

Limiting direct solar and internal heat gains through design can make natural ventilation or a reduction in the size of mechanical ventilation equipment feasible. Ideally, space cooling loads will be limited to approximately 12 British thermal units (Btu) per square foot, which translates to 1,000 square feet per ton of traditional mechanical cooling. Reducing mechanical heating, cooling, conditioning, or ventilating can significantly reduce energy consumption. Techniques such as night cooling can also reduce the temperature of the building's mass, which can reduce the cooling load during the warmer daylight hours. The average percentage of total energy consumption, by end-use, is illustrated in Figure 2.

Figure 2 – Energy Use in Commercial Buildings, 2003



Source: Commercial Building Energy Consumption Survey, Energy Information Administration, 2003.

In addition to minimizing space cooling loads, designers should also manage occupant comfort expectations. Although natural ventilation is affected by outside air conditions and naturally-ventilated buildings may experience greater variability of indoor temperature than is typical in conditioned facilities, building occupants may not be any less comfortable as a result. When designed properly, natural ventilation can produce air exchange rates from 0.5 to 5 air changes per hour (ACH). An ACH value of 1.0 equates to the entire volume of air in a workspace being exchanged once per hour.

[7] Graham, Carl. "High-Performance HVAC" Whole Building Design Guide, 2009.

Definition

Air-handling Unit

A device used to circulate or condition air throughout a facility. Consists of a blower, heating or cooling elements, filter chambers and damper that connect to ductwork.

Mechanical Ventilation

Designing high-performance mechanical ventilation systems requires an integrated approach that balances air quality, energy efficiency, operations and maintenance (O&M), safety, and other life-cycle concerns. Mechanical ventilation accounts for seven percent of total energy use in commercial buildings.[8]

Mechanical, or forced, ventilation exchanges and circulates air within a building using mechanical equipment such as fans or **air-handling units** (AHU). Fans mounted on the ceiling circulate air around a single room, while others, such as those installed in bathrooms, may exhaust to the outdoors. Air handling systems use fans and ducting to filter, condition, and exchange outside air into the building. Ventilation system types include constant air volume, variable air volume, low-flow air diffusers, fan-powered variable air volume, and raised floor air distribution. An example AHU is illustrated in Figure 3.

Figure 3 - Building 1221B, Langley Research Center

Source: NASA.

The AHU is part of the overall HVAC system. An AHU usually includes a fan, air ducts, heating or cooling elements, humidifier, air filters, and heat exchanger, as well as noise and airflow controls. A unit that conditions only outside air and not recirculated air is called a makeup air unit (MAU). The terms package unit (PU) and rooftop unit (RTU) refer to air handlers installed outside, usually on a roof.

[8] *Commercial Buildings Energy Consumption Survey*, Energy Information Administration, 2003.

Fundamentals of energy-efficient HVAC design are listed in Figure 4.

Figure 4 – Fundamentals of energy-efficient HVAC design

Consider all aspects of the building simultaneously
Energy-efficient, climate responsive construction requires a whole building perspective that integrates architectural and engineering concerns early in the design process. An energy efficient building envelope, coupled with a state-of-the-art lighting system, and efficient, properly sized HVAC equipment will cost less to purchase and operate than building systems that are selected in isolation from each other.
Decide on design goals as early as possible
A building that meets minimum energy code requirements will often have a different HVAC system than a building that uses 40 percent less energy. The differences may include component size as well as basic system type.
"Right size" HVAC systems to ensure efficient operation
Greatly oversized equipment operates less efficiently and costs more than properly sized equipment. Installation and operating costs are increased by assuming simultaneous worst-case scenarios and applying the highest safety factors for sizing for all load components, such as occupancy, lighting, shading devices, and weather.
Consider part-load performance when selecting equipment
Most heating and cooling equipment only operate at their rated, peak efficiency when fully loaded and operating at maximum output. The conditions for maximum output generally occur a very small percentage of each day, meaning many HVAC systems are oversized and do not operate at full load.
Shift or shave electric loads during peak demand periods
Many electric utilities offer lower rates during off-peak periods that typically occur at night. Whenever possible, design systems to take advantage of this rate structure.
Plan for expansion, but don't size for it
Plan equipment and space so that future expansion is possible, but don't provide the capacity immediately, as the capacity may never be utilized or the equipment may be obsolete by the time it is needed.
Commission the HVAC system
Comprehensive commissioning of the HVAC system tests equipment under all operating conditions, reveals performance problems, and ensures the system is operating as designed. The commissioning program will also ensure operations and maintenance personnel are properly trained in all system functions.
Establish an operations and maintenance program
Proper performance and energy-efficient operation of HVAC systems can only be ensured through a operations and maintenance program that details the levels of maintenance.

Source: Graham, Carl. “High-Performance HVAC” Whole Building Design Guide, 2009.

Natural Ventilation

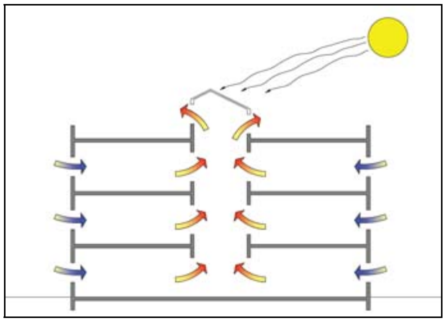
Natural ventilation has become an increasingly attractive method for providing acceptable IEQ and maintaining a healthy, comfortable, and productive indoor climate while reducing energy use and cost.[9] Natural, or passive, ventilation exchanges air and regulates temperature by using openings in

[9] Natural Ventilation, Whole Building Design Guide.

Rule of Thumb

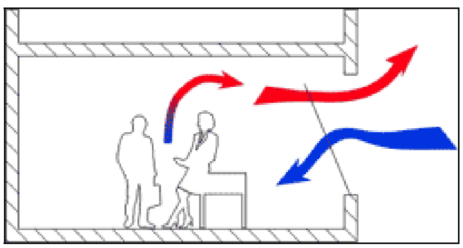
The size, type, and placement of openings in the building are critical to determining the total amount of natural ventilation.

Figure 5 – Example Stack Effect



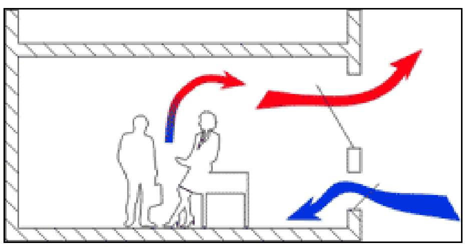
Source: Advanced Engineering Consultants.

Figure 6 – Single-Sided, Single-Opening Ventilation



Source: Dyer Environmental Controls.

Figure 7 – Single-Sided, Double-Opening Ventilation



Source: Dyer Environmental Controls.

the building, such as windows and doors. Air movement occurs as a result of wind conditions and thermal forces acting upon relative differences in air temperature or humidity between the indoors and outdoors.

A naturally ventilated building may include design features such as transom windows, louvers, grilles, open plans, cool towers, stack ventilation, ridge vents, clerestory windows, vented skylights, solar chimneys, and wind towers.[9] Landscaping, surrounding topography, and adjacent buildings can also affect air movement into the building.

Natural ventilation is not appropriate or permitted by code for all buildings. Outside air is not conditioned before it enters naturally ventilated buildings; therefore, natural ventilation is not an effective method for controlling humidity. Code requirements for smoke or fire may also limit opportunities for use of natural ventilation.

In designing natural ventilation systems, designers must analyze building layout and architectural elements, such as centrally located atriums or courtyards. A multi-story atrium building located in a mild climate would be a good candidate for natural ventilation using the stack effect. The stack effect, with cooler air entering the sides of the building and warmer air rising up a central atrium is illustrated in Figure 5.

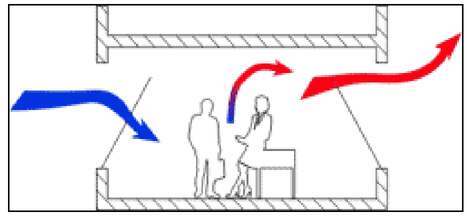
Natural ventilation can be incorporated into facility design through a number of processes. The simplest of these is single-sided, single-opening ventilation, in which wind turbulence drives the ventilation. This results in lower ventilation rates and shorter air penetration distances than is typical in other methods. Generally, single-sided, single-opening ventilation designs should limit the depth of the room to a maximum of two times the distance from floor to ceiling. Single-sided, single-opening ventilation is illustrated in Figure 6.

Placing two openings at the perimeter, one high and one low, allows the ventilation system to make use of the stack effect. Single-sided, double-opening ventilation should generally be used in cases where the depth of the room is no more than 2.5 times the distance from floor to ceiling. Single-sided, double-opening ventilation is illustrated in Figures 7.

A narrow building design allows a facility to make use of cross ventilation, which permits air to enter on one side of a room, and exit through the other side. This approach also enhances potential for use of daylighting in the building. As the air moves across the space it will increase in temperature and collect contaminants. Cross ventilation should be used in cases where the depth of the room is no more than five times the distance from floor to ceiling. An example of cross ventilation, with cooler air entering one side of a room and warmer air exiting the opposite side is illustrated in Figure 8.

Natural ventilation presents several challenges which should be understood in order to proactively mitigate potential problems. Natural ventilation provides a direct path for ambient noise, which can disrupt occupant activities. The same direct path also creates the potential for introduction of pollutants. Additionally, natural ventilation may be difficult to implement while conforming to Anti-Terrorism and Force Protection standards.

Figure 8 – Cross Ventilation



Source: Dyer Environmental Controls.

<u>Mixed-mode Ventilation</u>

Mixed-mode ventilation incorporates elements of mechanical and natural ventilation in the same facility. In some cases, part of the building will be mechanically ventilated while another part is naturally ventilated. For example, a building design could include mechanical ventilation in office and conference rooms and natural ventilation in adjacent work spaces. Alternatively, a building design could include a changeover sequence in which natural ventilation would be used when outdoor temperatures are within certain limits, and mechanical cooling would be used at temperature extremes.

<u>Infiltration</u>

Infiltration occurs when outside air leaks through cracks in the building envelope into interior spaces. Because the incoming air is neither controlled nor conditioned, building designers generally try to minimize infiltration. In smaller buildings, however, infiltration may be used as a form of ventilation.

In most cases, infiltration is minimized in order to limit incoming dust or moisture and to maintain thermal comfort, reducing HVAC energy consumption. Techniques for reducing infiltration include sealing of cracks in the building envelope, positive pressurization of the mechanical ventilation system, and use of air retarders.

Building Focus

Collaborative Support Facility, Ames Research Center

The Collaborative Support Facility includes automated windows that flush the building with cool air in the evening.

3) Implement Ventilation System Controls

Ventilation system controls ensure that a sufficient quantity of air is delivered to appropriate locations. When installed and maintained properly, ventilation controls can improve overall system performance. Controls can be manual, automatic, or a combination of the two. Settings should take daily and seasonal changes in climate and occupancy into account, and controls should include sensors which can activate alarms when ventilation rates vary outside set limits.

Ventilation controls should adjust for openings in vents, windows, ducting, blinds, and other shading devices. Mixed-mode ventilation systems in particular require specific automated control components. The type of mechanical controls depends on the type of HVAC system in a facility, but such controls are generally automatic and activated by sensors.

Recent advancements in control dependability include:[10]

- Direct digital controls
- Constant air volume systems that reset supply air temperature at the cooling coil
- Variable air volume systems that serve areas with small cooling loads
- Carbon dioxide-based controls

Natural ventilation controls can be either manual or automatic, depending on the complexity of the system. Manual controls may be appropriate for simpler systems using single-sided approaches. Color indicator lights that alert building occupants when outdoor temperatures are appropriate for opening windows can also be added. Generally, windows higher than eye level should be automated, while lower windows can be manually controlled. Indicators and automation controls should be linked to interior temperature sensors and an exterior weather station. Sensors on the façade can be used to generate inputs to the control system according to wind speed and direction.

4) Commission or Re-/Retro-Commission the Ventilation System

Commissioning or re-/retro-commissioning are essential components of energy-efficient HVAC design and operations, especially in buildings using natural ventilation. The commissioning agent should be included in the design team early in the planning process to increase team effectiveness. The commissioning agent's contract should also extend into the post-occupancy period so that adjustments, training, and documentation can be completed. For more information on commissioning and re-/retro-commissioning, see Chapter 1, page 1-45.

[10] Graham, Carl. "High-Performance HVAC" Whole Building Design Guide, 2009.

Related LEED® Credits

The LEED® credits related to building ventilation are illustrated in Table 2. Definitions for all LEED® abbreviations appear in the Introduction.

Table 2 – LEED® and Ventilation

LEED-NC®	IEQ Prerequisite 1: Minimum Indoor Air Quality Performance
	IEQ Prerequisite 2: Environmental Tobacco Smoke Control
	IEQ Credit 1: Outdoor Air Delivery Monitoring
	IEQ Credit 2: Increased Ventilation
	IEQ Credit 3.1: Construction Indoor Air Quality Management Plan - During Construction
	IEQ Credit 3.2: Construction Indoor Air Quality Management Plan - Before Occupancy
LEED-EB: O&M®	IEQ Prerequisite 1: Minimum Indoor Air Quality Performance
	IEQ Prerequisite 2: Environmental Tobacco Smoke Control
	IEQ Credit 1.1: Indoor Air Quality BMP - Indoor Air Quality Management Program
	IEQ Credit 1.2: Indoor Air Quality BMP - Outdoor Air Delivery Monitoring
	IEQ Credit 1.3: Indoor Air Quality BMP - Increased Ventilation
	IEQ Credit 1.4: Indoor Air Quality BMP - Reduce Particles in Air Distribution
	IEQ Credit 1.5: Indoor Air Quality BMP - Indoor Air Quality Management for Facility Alterations and Additions
LEED-ND®	None

TOOLS

ASHRAE Standards and Resources

The ASHRAE is an international professional organization that seeks to advance HVACR technology, standards, and education.

For more information: www.ashrae.org

Indoor Air Quality – EPA

The Environmental Protection Agency (EPA) provides a variety of indoor air quality information, publications, and tools.

For more information: *http://epa.gov/iaq/*

Building Services Engineering

The Chartered Institution of Building Service Engineers (CIBSE) provides information, tools, and networking resources covering a variety of sustainable building topics, standards, and regulations.

For more information: *http://cibse.org/*

Construction Manuals, Products, and Services

The Sheet Metal and Air Conditioning Contractors' National Association provides standards and members' services for a variety of contractors, including HVAC, sheet metal, and energy management.

For more information: *http://smacna.org/*

Indoor Air Quality Directory

The Department of Environmental Design at the University of Missouri provides a directory of websites and resources related to environmental design and indoor air quality.

For more information:
http://extension.missouri.edu/edninfo/airquality.htm

Indoor Air Quality Association

The Indoor Air Quality Association (IAQA) provides information and education regarding indoor air quality topics.

For more information: *http://iaqa.org/*

BEST MANAGEMENT PRACTICE – THERMAL COMFORT

Meet ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy, including continuous humidity control within established ranges per climate zone.

Thermal comfort is a state of mind in which a building occupant is satisfied with the thermal environment. Building occupants radiate natural body heat throughout the day. If this heat does not dissipate throughout the building, thermal conditions may result in a feeling of discomfort. Through extensive research and experience, ANSI and ASHRAE have developed thermal comfort standards and guidelines for building designers and facility managers.

The ANSI/ASHRAE standard for thermal comfort identifies a combination of factors that enable facilities to maintain an indoor environment acceptable to a majority of occupants.[11] Standard 55 is intended for use in designing, commissioning, and testing of buildings and other occupied spaces and HVAC systems, and for the evaluation of thermal environments. This standard is regularly updated, so that “55-2004” refers to the 2004 version of the standard. The 2004 edition of the standard, which includes different ventilation rate minimums, is required by NPR 8820.2F.

Heat conduction, convection, radiation, and evaporative heat loss all affect thermal comfort. The six primary thermal comfort variables of Standard 55-2004 include human metabolic rate, clothing insulation, air temperature, radiant temperature, air speed, and humidity.[12]

NASA Requirement

NPR 8820.2F requires compliance with ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy.

[11] ANSI/ASHRAE Standard 55 *Thermal Environmental Conditions for Human Occupancy.*

[12] “ASHRAE Standard 55-2004 for High Performance Buildings” Rocky Mountain Chapter, ASHRAE.

Implementing a Thermal Comfort Program

The steps necessary for implementing a thermal comfort program are listed in Table 3. These steps are discussed in additional detail in the subsequent narrative.

Table 3 - Implementing Thermal Comfort Techniques

IMPLEMENTATION STEPS	
1)	**Survey Building Occupants Regarding Thermal Comfort**
□	Conduct survey of building occupants.
□	Identify areas of success and areas that need improvement.
□	Administer survey when other building occupant surveys are given out.
2)	**Review Existing Control Systems**
□	Evaluate temperature control systems for performance and controllability.
3)	**Identify System Upgrades**
□	Satisfy thermal control needs with consideration of ventilation upgrades.
□	Estimate energy use increase with new installation.
4)	**Implement Thermal Comfort Upgrades**
□	Estimate energy savings from thermal comfort upgrades.

1) Survey Building Occupants Regarding Thermal Comfort

Occupant surveys are an excellent way to understand the thermal comfort concerns of building occupants. Surveys can help to identify building performance problems and opportunities for improvement. Questions should be designed to pinpoint issues experienced by building occupants and locations and times in which these issues typically occur. Surveys can also be part of an overall effort to enhance communication between building occupants, maintenance staff, and Center administration. To improve efficiency, a thermal comfort survey may be combined with surveys concerning other topics, such as transportation or indoor air quality.

During the summer months, building occupants generally tolerate higher temperatures when humidity is lower. During the winter months, the same occupants may tolerate lower temperatures when humidity is higher.

LEED® Focus

Thermal comfort is one of the required topics for the occupant comfort surveys and complaint response systems included in the LEED-EB: O&M® credit system.

Building Focus

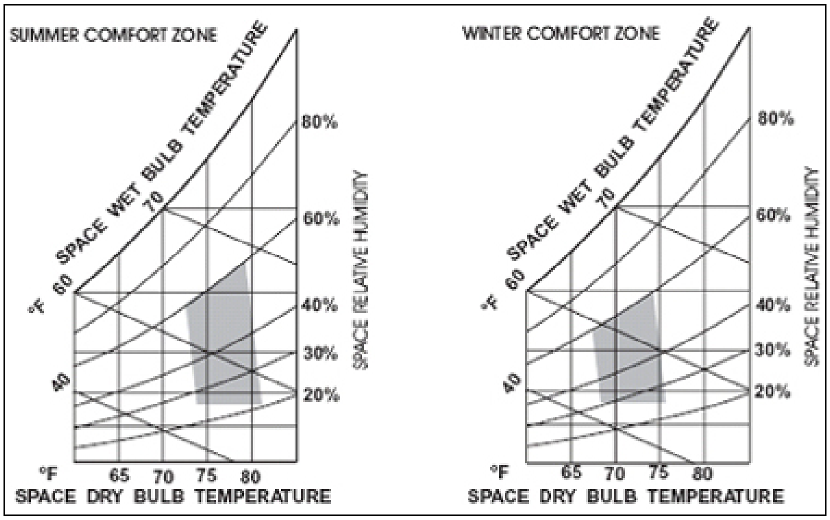
Flight Projects Center, Jet Propulsion Laboratory

Exchange Recreation Facility, Johnson Space Center

Both buildings used a thermal comfort survey distributed to building occupants within 6 to 18 months of occupancy to develop a corrective action plan if more than 20 percent of occupants express dissatisfaction.

A comparison of typical summer and winter comfort zones is illustrated in Figure 9. The grey shaded areas correspond to the typical temperature and humidity comfort zones in each season.

Figure 9 – Typical Comfort Zones, by Season.



Source: ASHRAE.

2) Review Existing Control Systems

Temperature control systems in the facility or facility design should be evaluated for both performance and controllability. High-performance buildings commonly have individual temperature controls for offices and conference rooms. These individual controls allow for customized and optimal thermal comfort in most building spaces. Where individual controls are present, system components should be checked to ensure that they are functioning properly. Ongoing monitoring is necessary to maintain high levels of occupant thermal comfort.

3) Identify System Upgrades

Thermal comfort problems identified through surveys or other means can generally be resolved through changes to HVAC controls or system equipment. Managers can cross reference thermal comfort concerns with ventilation concerns and seek ways to resolve both issues at once. Thermal comfort improvements can have significant impact on energy efficiency; accordingly, any such proposed improvements should be evaluated on an energy use basis. For more information on improving the energy efficiency of HVAC equipment, see Chapter 2, page 2-8.

Building Focus

Life Support Facility, Kennedy Space Center

The Life Support Facility uses a humidity monitoring system to allow for control of building zones within seasonal thermal comfort ranges.

Building Focus

Collaborative Support Facility, Ames Research Center

The Collaborative Support Facility is designed to utilize radiant cooling ceiling panels to reduce energy use and improve thermal comfort.

4) Implement Thermal Comfort Upgrades

Space heating and air-conditioning account for 36 and 8 percent, respectively, of total annual energy consumption in commercial buildings.[13] Although improving thermal conditions inside some facilities may be difficult and cost-prohibitive, the resulting energy savings can be significant. Each degree of thermostat offset typically saves approximately two percent of total cooling energy.

Related LEED® Credits

The LEED® credits related to thermal comfort are illustrated in Table 4. Definitions for all LEED® abbreviations appear in the Introduction.

Table 4 – LEED® and Thermal Comfort

LEED-NC®	IEQ Credit 6.2: Controllability of Systems - Thermal Comfort
	IEQ Credit 7.1: Thermal Comfort - Design
	IEQ Credit 7.2: Thermal Comfort - Verification
LEED-EB: O&M®	Indoor Environmental Quality Credit 2.1: Occupant Comfort - Occupant Survey
	Indoor Environmental Quality Credit 2.3: Occupant Comfort - Thermal Comfort Monitoring
LEED-ND®	None

TOOLS

Thermal Comfort Survey

The Center for the Built Environment (CBE) provides a web-based survey on indoor environmental quality topics, including thermal comfort.

For more information: www.cbesurvey.org

Whole Building Design Guide – Thermal Comfort

The Whole Building Design Guide (WBDG) is a web-based resource providing design, construction, management, and operations guidance as well as standards, education, and tools for government and industry practitioners.

For more information:
www.wbdg.org/design/provide_comfort.php

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[13] Commercial Building Energy Consumption Survey, Energy Information Administration, 2003.

Moisture Control

Excess indoor moisture levels contribute to mold growth, building damage, unhealthy building conditions, and poor indoor air quality.[14] High-performance and sustainable buildings incorporate an effective moisture control strategy in the design of the building envelope, which separates the building interior from the outdoors. The design of the building envelope affects air and moisture movement as indoor and outdoor temperatures vary. The moisture control strategy will balance energy, ventilation, and health concerns in the building envelope design. An example of mold/mildew growth is illustrated in Figure 10.

Figure 10 – Water Pipe Leak and Mold/Mildew Growth, Building 1210, Stennis Space Center

Source: NASA.

The BMP for moisture controls are derived from the *Guiding Principles for Federal Leadership in High-Performance and Sustainable Buildings,* Agency policy, or industry practice. Each BMP includes discussion of related NASA activities and accomplishments, relevant LEED® credits, and resources for additional information or assistance.

The moisture control BMP for new construction, major renovation, or existing buildings requires establishment and implementation of a moisture control strategy for controlling moisture flows and condensation to prevent damage, minimize mold contamination, and reduce health risks related to moisture.

[14] Prowler, Don. *Mold and Moisture Dynamics*. Whole Building Design Guide. 2010.

BEST MANAGEMENT PRACTICE – MOISTURE CONTROL

Establish and implement a moisture control strategy for controlling moisture flows and condensation to prevent building damage, minimize mold contamination, and reduce health risks related to moisture.

An important factor in determining IEQ is the intrusion of moisture and its eventual effects, including structural steel corrosion, rotting wood, and growth of mold and mildew.[15] These conditions can produce high energy costs, ongoing maintenance problems, impaired air quality, and failure of architectural and engineering building systems. The resulting poor air quality can also lead to respiratory disease and other health risks in sensitive people.[16] Properly designed HVAC systems, building envelopes, and insulation can mitigate moisture and mold problems.

Moisture generally moves through the building as a liquid or water vapor which accumulates indoors. Sources of indoor moisture can include rainwater leakage, moist air leakage, moisture diffusion through walls, roofs, and floors; groundwater intrusion into basements and crawl spaces, water pipe bursting or leaking, and construction-related moisture. Indoor moisture can lead to growth of mildew and mold, which produces spores that disperse and can remain dormant for extended periods of time. Accordingly, the key to stopping mold and mildew growth is preventing excessive moisture from entering the building. Water infiltration into a building is pictured in Figure 11.

NASA Requirement

NPR 8820.2F requires preparation of a moisture control strategy for controlling moisture flows and condensation to prevent building damage and mold contamination.

Figure 11 – Water Infiltration into Basement, Building 1298, Langley Research Center

Source: NASA.

[15] "Moisture Management in Wall Assemblies: Air, Water, and Vapor Barriers" Architectural Record, 2006.

[16] Prowler, Don. *Mold and Moisture Dynamics*. Whole Building Design Guide. 2010.

Implementing a Moisture Control Program

Table 5 lists the steps necessary for implementing a moisture control program. These steps are discussed in additional detail in the subsequent narrative.

Table 5 - Implementing Moisture Control Techniques

IMPLEMENTATION STEPS	
1)	**Identify the Local Climate Zone**
☐	Identify air temperature and relative humidity at the facility.
2)	**Assess Water and Vapor Barrier Performance**
☐	Determine potential moisture transport mechanisms present.
☐	Protect building materials from moisture damage during construction.
☐	Determine need for dehumidification equipment.
☐	Conduct routine visual inspections for water and vapor barrier performance.
3)	**Identify Moisture Control Strategies and Materials**
☐	Determine how moisture flows enter the building.
☐	Identify methods to control moisture flow.
4)	**Periodic Checkups to Monitor Performance**
☐	Use checkups to identify problem areas.

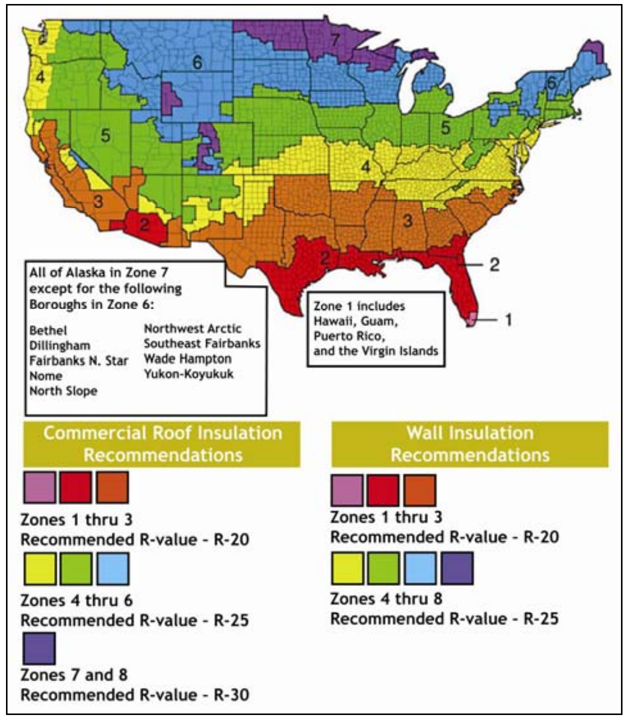
1) Identify the Local Climate Zone

Due to "the most critical design variable for the building envelope is the geographic region and climate"[17], building designers who wish to develop an effective moisture control plan must first consider the local climate zone. Air temperature and relative humidity are both critical factors in developing an appropriate moisture control strategy.

[17] Sullivan, C.C. and Barbara Horwitz-Bennett, "Moisture Control: Envelop Strategies and Techniques for Protecting Building Value" Building Design + Construction, 2008.

The eight climate zones are illustrated in Figure 12.

Figure 12 – Energy Conservation Code Climate Zones



Source: Department of Energy.

2) Assess Water and Vapor Barrier Performance

To evaluate a facility's water and vapor barrier performance, first identify any potential moisture transport mechanisms present at the facility. During construction, protect building materials such as insulation, drywall, carpeting, and wood from moisture and moisture damage. Proper storage during the construction phase is critical to prevent future mold problems and to maintain the usefulness of the materials. Dehumidification equipment may be necessary to maintain relative humidity at or below 60 percent.

Once a facility is occupied, water and vapor barrier performance can be assessed through routine visual inspections. Such inspections should note the presence of any standing water, damp ceiling tiles, walls, or carpeting, and the presence of mold or mildew, or any other evidence that excess water or water vapor is entering the facility. It can be helpful to perform this inspection during a rainstorm to detect any rain penetration.

3) Identify Moisture Control Strategies and Materials

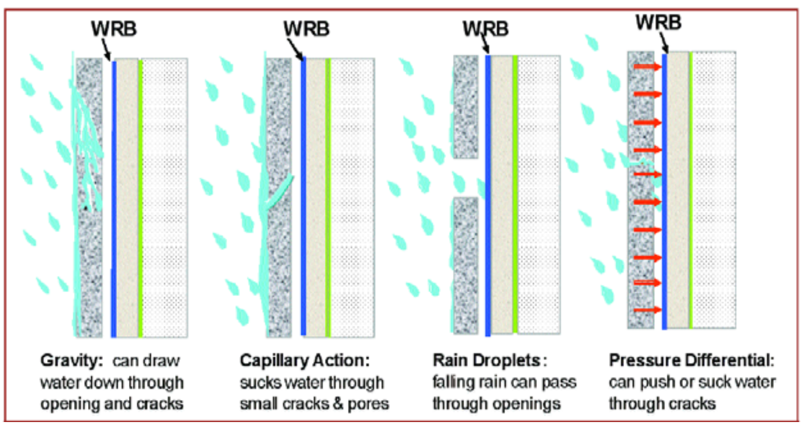
Moisture control efforts should focus on preventing moisture from entering the facility and removing existing moisture.

Moisture enters buildings through four main approaches: infiltration, air movement, diffusion through materials, and heat transfer. In developing the moisture control strategy, consider basic design elements such as site grading, gutter and downspout detailing, flashing and detailing around windows, doors, chimneys, and vent stacks, and component selection. Components such as sealants, flashings, and gaskets should be selected with consideration for the entire facility life cycle and overall moisture control strategy.

Infiltration

Water infiltration occurs when water enters a facility through openings, cracks, and gaps in the building envelope. The most common water source for above-grade infiltration is rain.[18] Rain penetration is generally limited by controlling the forces across the openings, or by eliminating the openings entirely. Pitched roofs and other building elements that protect exterior walls from wind-driven rain can reduce infiltration due to rain. A properly sloped building site can also ensure that rainwater moves away from a building during and after a storm. Common water intrusion mechanisms are illustrated in Figure 13.

Figure 13 – Water Intrusion Mechanisms Through Above-grade Wall Assemblies and Water Resistant Barriers (WRB)



Source: Architectural Record.

Air Movement

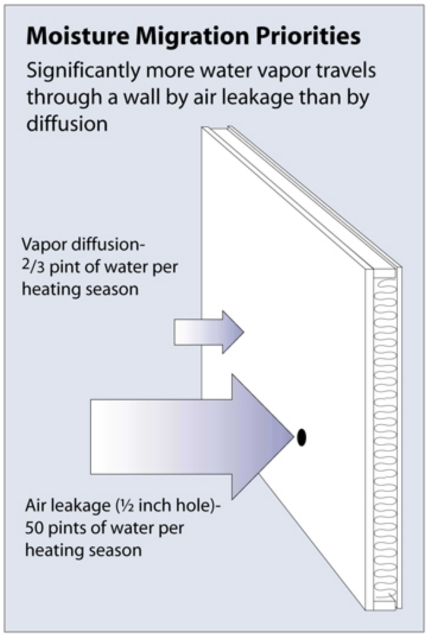
More than 98 percent of water vapor flow inside buildings is the result of air movement.[19] The natural flow of air moves from high pressure to low pressure through the path of least resistance, enabled by holes or cracks in the building

[18] "Moisture Management in Wall Assemblies: Air, Water, and Vapor Barriers" Architectural Record, 2006.

[19] "How Moisture Moves Through a Home" Department of Energy.

envelope. Any unintended paths for air movement should be carefully sealed to control this source of moisture. Air movement is a much faster process than diffusion or heat transfer, with speeds in the range of several hundred cubic feet of air per minute.[20] Controlling airflow is important, as "the air-transported moisture is one of the most damaging consequences of uncontrolled airflow."[21]

Figure 14 – Water Vapor Flow Comparison



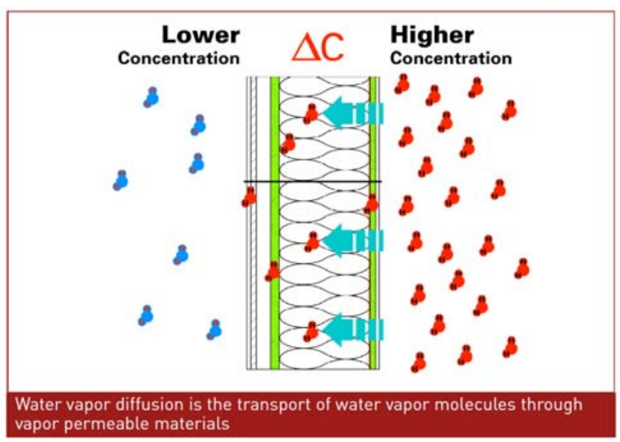
Source: Department of Energy.

Although many building materials restrict airflow to some extent, effective airtight envelopes are generally achieved by joining materials into a single airtight assembly. Air movement can be reduced by installing air barriers in the building envelope or by using sealants, caulking, or gasketing systems. The building assembly is then integrated into the air barrier to achieve a continuous air barrier system to control air and moisture flows. An illustrated comparison of types of water vapor flows appears in Figure 14.

Diffusion Through Materials

Water vapor diffusion occurs when molecules of water vapor move through water-permeable materials in the building envelope. Water vapor moves from areas of high vapor pressure or concentration to areas of low vapor pressure or concentration. The rate, or speed, of diffusion depends on the difference in pressure or concentration, as well as the degree of permeability of building materials. An illustration of water vapor diffusion appears in Figure 15.

Figure 15 – Water Vapor Diffusion



Source: Architectural Record.

[20] "How Moisture Moves Through a Home" Department of Energy.

[21] "Moisture Management in Wall Assemblies: Air, Water, and Vapor Barriers" Architectural Record, 2006.

Although building materials do not stop diffusion completely, they can reduce it significantly. Another method for controlling diffusion is use of a vapor barrier, which is different from an air barrier, and must be properly installed to function correctly. The degree of permeability is measured by perms, a unit of measurement based on the amount of water passing through a square foot of material per hour at a differential vapor pressure equal to one inch of mercury. A vapor barrier is defined as a Class I vapor retarder, and the International Building Code (IBC) defines a vapor retarder as having a permeability of 1.0 perm or less. Vapor retarder classifications are listed in Table 6.

Table 6 – Vapor Retarder Classifications

Class	Permeability	Example
I	0.1 perm or less	Polyethylene sheeting
II	Between 0.1 and 1.0 perm	Kraft-faced fiberglass batt insulation
III	Between 1.0 and 10 perm	Gypsum board with one coat of latex paint

Source: Advanced Engineering Consultants.

Heat Transfer

Heat transfer is a natural process during which heat flows from hot to cold areas. Heat flow can occur wherever there is a difference in temperature, including from room to room, from indoors to the outdoors, and from the interior of a room into its walls, floors, and ceilings. Warmer air can hold more moisture, and as the air cools to the dew point, water vapor will condense into liquid water. The condensation can occur on any surface, both within a room’s interior and in a wall cavity.

Use of insulation is the primary technique for reducing heat transfer, and thus controlling the effect of temperature across the building envelope. Increasing or otherwise improving insulation should assist in the control of heat transfer, and should have a beneficial effect on the heating and cooling load and associated energy consumption.

4) Periodic Checkups to Monitor Performance

Moisture flows may be difficult to measure directly, so facility managers should perform periodic assessments to identify potential problems. Like the initial assessment, these inspections should note the presence of any standing water, damp ceiling tiles, walls, or carpeting, and the presence of mold or mildew, or any other evidence that excess water or water vapor is entering the facility.

Rule of Thumb

Perform moisture inspections during a rainstorm to detect any rain penetration.

Related LEED® Credits

The LEED® credits related to moisture control are illustrated in Table 7. Definitions for all LEED® abbreviations appear in the Introduction.

Table 7 – LEED® and Moisture Control

LEED-NC®	IEQ Credit 3.1: Construction Indoor Air Quality Management Plan - During Construction
LEED-EB: O&M®	IEQ Credit 1.1: Indoor Air Quality BMP - Indoor Air Quality Management Program
LEED-ND®	None

TOOLS

Mold and Moisture

The EPA provides guidance, resources, training, answers to frequently asked questions, and other information on mold and moisture prevention and remediation.

For more information: www.epa.gov/mold/

Building Air Quality: A Guide for Building Owners and Facility Managers

The EPA and the National Institute for Occupational Safety and Health (NIOSH) have developed a guide which offers practical suggestions on preventing, identifying, and resolving indoor air quality problems in public and commercial buildings.

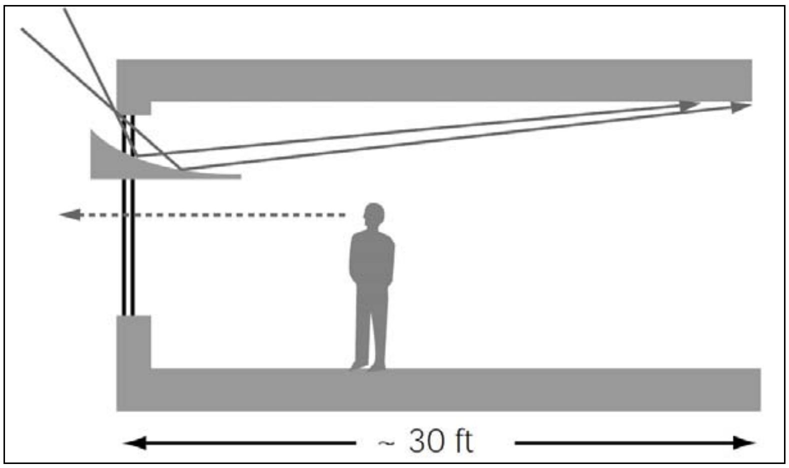
For more information: www.epa.gov/iaq/largebldgs/baqtoc.html

Daylighting

Indoor environmental quality in high-performance and sustainable buildings is affected by environmental concerns beyond air quality alone. Among these concerns is type and quantity of indoor lighting. Natural lighting, or **daylighting**, can reduce energy consumption by allowing sunlight into a building through openings such as windows and skylights and thus eliminating the need for some artificial lighting. Dimming and glare controls limit the natural and artificial lighting based on individual task requirements, and they can improve visibility. An example of daylighting with a light shelf is illustrated in Figure 16.

> **Definition**
>
> *Daylighting*
>
> *Connections between the internal and external environments, usually through windows, skylights, and building placement. Direct sunlight is diffused throughout the indoor space.*

Figure 16 – Daylighting with a Light Shelf



Source: Daylighting with Windows, Lawrence Berkeley National Laboratory.

The BMP for incorporating daylighting is derived from the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings,* Agency policy, or the energy conservation industry. Each BMP includes discussion of related NASA activities and accomplishments, relevant LEED® credits, and resources for additional information or assistance.

The daylighting BMP for new construction, major renovation, or existing buildings require achievement of a minimum daylight factor of 2 percent (excluding all direct sunlight penetration) in 75 percent of all spaces occupied for critical visual tasks; use of automatic dimming controls or accessible manual lighting controls, and appropriate glare control.

BEST MANAGEMENT PRACTICE – DAYLIGHTING

Achieve a minimum daylight factor of 2 percent (excluding all direct sunlight penetration) in 75 percent of all spaces occupied for critical visual tasks. In addition, provide automatic dimming controls or accessible manual lighting controls, and appropriate glare control.

NASA Requirement

NPR 8820.2F establishes a minimum daylight factor of 2 percent (excluding all direct sunlight penetration) in 75 percent of all spaces occupied for critical visual tasks.

Daylighting systems must include the incorporation of automatic dimming controls or accessible manual lighting controls, as well as appropriate glare controls.

High-performance lighting strategies can reduce energy consumption by using daylighting combined with appropriate lighting and glare controls. More information on daylighting and lighting systems can be found in Chapter 2, page 2-10.

Daylighting supplements artificial lighting with natural daylight in order to reduce energy consumption and maximize visual comfort.[22] Daylighting is usually diffuse light, not direct sunlight. The daylighting process provides connections between facility occupants and the outside environment through windows, skylights, building orientation, and shading devices. A passive daylighting system collects sunlight through static, non-moving, and non-tracking openings. An active daylighting system uses mechanical devices and sensors to track the sun in order to increase system efficiency.

In addition to offering improved energy efficiency, daylighting increases occupant productivity. The California Energy Commission found that “exposure to daylight was consistently linked with a higher level of concentration and better short-term memory recall.”[23] This increase in productivity can be linked to humans’ natural attraction to daylight and need for daylight.[24]

[22] “Light Harvesting” Whole Building Design Guide.

[23] Molinski, Mike, “How Daylighting Can Improve IEQ” FacilitiesNet. 2009.

[24] Molinski, Mike, “How Daylighting Works” FacilitiesNet. 2009.

Implementing a Daylighting Program

The steps necessary for implementing a lighting program are listed in Table 8 and discussed in additional detail in the subsequent narrative.

Table 8 - Implementing Daylighting Techniques

IMPLEMENTATION STEPS	
1)	**Survey Occupants About Indoor Lighting**
☐	Conduct survey.
☐	Administer survey at the same time as other building occupant surveys.
2)	**Review Existing Daylighting System for Quality and Occupant Control**
☐	Measure the amount of natural light that already exists in the building.
☐	Determine building's daylight factor.
☐	Inventory daylighting controls.
3)	**Identify Opportunities for Daylighting**
☐	Calculate and optimize the natural light available.
☐	Identify methods to improve lighting conditions.
4)	**Estimate the Life-cycle Costs and Benefits**
☐	Determine costs and benefits of implementing daylighting techniques.
5)	**Prioritize and Implement Daylighting Techniques**
☐	Prioritize implementation techniques.
☐	Implement new daylighting techniques.
6)	**Monitor Energy Savings**
☐	Measure energy savings from daylighting techniques.
☐	Adhere to Agency policy and federal regulations.

1) Survey Occupants About Indoor Lighting

To identify problems and areas for improvement, facility managers should survey building occupants regarding IEQ, including questions regarding lighting concerns. Occupants should be specifically surveyed to determine if the quantity and quality of lighting is sufficient to allow completion of critical visual tasks. As with previously discussed occupant surveys, facility managers may combine the lighting survey with surveys on other indoor environmental quality topics.

2) Review Existing Daylighting System for Quality and Occupant Control

Even if daylighting was not incorporated into the original facility design, some natural light still enters most rooms and building spaces. This natural light should be measured before new daylighting systems are implemented. Daylighting is measured by calculating an individual room or building's **daylight factor**. Generally, the daylight factor ratio is

Definition

Daylight Factor

The ratio of daylight illuminance received at a given point inside a room to the simultaneous illuminance on a horizontal plane outside exposed to an unobstructed sky.[25]

[25] Dictionary of Optometry and Visual Science, 7th edition. 2009.

expressed as a percentage; a room with a daylight factor of five percent or more is considered well-lit.

In addition to measuring the amount of natural light entering each room, managers should inventory the controls of daylight harvesting systems, including the **photosensor.** By decreasing use of artificial lighting when sufficient natural light is available, the daylight harvesting system reduces energy consumption.

> *Definition*
>
> *Photosensor*
>
> *A device that detects light levels and prompts the system to increase or dim the light of the room based on the minimum recommended light level of the space. Used with daylight harvesting systems.*

Daylighting systems can have some disadvantages, including increased sun glare and increased indoor temperatures resulting from solar heat. Glare control techniques include window treatments, window films, and glazing.

3) Identify Opportunities for Daylighting

Design of daylighting systems should incorporate a number of design factors, including building orientation, reorganizing operations, building modifications, and shading and controls. Daylighting design should be considered early in the planning process as part of an integrated approach including daylight modeling to measure and optimize natural light.

Building Orientation

The building's orientation is the largest opportunity to maximize access to sunlight while minimizing glare and heat gain.[26] Passive daylighting techniques such as architectural fins, skylights, and lightwells depend on the building's orientation, which will determine the building's ability to collect sunlight. In the Northern Hemisphere, for example, south-facing windows generally receive the most direct sunlight exposure. Designers should also consider a building's orientation relative to the surrounding area and adjacent future projects. Regardless of a building's orientation, however, the availability of natural light will change with the time of day and the season. Daylight modeling, conducted by a lighting consultant experienced in the design of daylighting systems, will assist a design team in understanding how natural light will enter a building based on the building's orientation.

Reorganizing Operations

Reorganizing internal operations by moving people and furniture to locations with better natural light exposure offers another opportunity to incorporate daylighting in facility design. While such reorganization does not increase the amount of natural light in a building, it does allow the

[26] "Designing for Daylighting" BuildingGreen, LLC. 2010.

building to make maximum use of the natural light that is already available.

Building Modifications

Building modifications improve lighting conditions by increasing the amount of natural light in the facility. Specific building modifications include **clerestory windows**, skylights, light shelves, light tubes, and glass block walls.[27] An example of a clerestory window is shown in Figure 17.

> *Definition*
>
> *Clerestory Windows*
>
> *High, vertically-placed windows that are used to increase the amount of natural light into a building.*

Shading and Controls

Shading and lighting controls adjust the level of artificial lighting, based on the level of natural light in a building or room. Such controls can also use occupancy schedules, motion sensors, and other sensors to minimize use of artificial lighting. Active daylighting systems use sensors to maximize the collection of natural light by tracking the movement of the sun in the sky. Depending on the design, these systems can affect the building's exterior appearance.

4) Estimate the Life-cycle Costs and Benefits

Although some daylighting techniques require significant capital expenditures, they can also result in significant savings; potential overall energy savings can range from 15 to 40 percent.[28] Life-cycle cost-effective reductions in energy intensity are required by Executive Order (EO) 13423 and EO 13514. Daylighting reduces energy consumption by minimizing the need for artificial lighting, and it can improve control of the indoor climate, thereby reducing the heating and cooling load. Daylighting can increase the building's cooling load if not designed properly. Energy modeling may be appropriate to fully understand these effects.

Figure 17 – Clerestory Windows, Building 265, Johnson Space Center

Source: NASA.

[27] "Daylighting" Whole Building Design Guide.

[28] Molinski, Mike, "How Daylighting Works" FacilitiesNet. 2009.

Example cost implications of daylighting strategies are illustrated in Figure 18.

Figure 18 – Cost Implications of Daylighting Strategies

	OPTIONS/ALTERNATIVES	COST*	MAINTENANCE*
Building Orientation	Sun Angles & Seasonal Solar Variatons	1	N/A
	Building Orientation (Mass, Form, Daylight, and Energy Impacts	2	N/A
	Optimizing Daylight and Balancing Thermal Discomfort	1	N/A
Drawing Daylight into a Space	Window Selection	1	1
	Lightshelves	2	3
	Solar Tubes	3	3
	Skylights	2	2
	Fiber Optic Cables	3	2
	Interior Finishes and Daylighting	1	2
Space Planning	Central Atrium or Mulitple Atria	2	3
	Interior Space Planning to Optimize Views and Reduce Glare	1	1
	Furniture Planning: Parition Heights and Material	1	1
	Lamp Selection: Efficient Lamps/Light Fixtures	2	1
	Using IES Foot-candle Requirements for Visual Tasks	1	1
Shading and Automated Controls	Shading Studies from Exterior Elements: Trees, Other Buildings	1	1
	Louvers	2	2
	Fins	2	2
	Overhangs	1	2
	Window Shades	2	2
	Daylight Sensors	2	2
Daylight Modeling	Computer Simulated Modeling	3	N/A
	Physical Building Models	2	N/A
	Space by Space Area Calculations	1	N/A
	Light Metering	1	N/A

*Evaluated on a scale of 1-3 where 1 is the lowest

Source: BuildingGreen, LLC.

Detailed estimates of energy savings depend in part on the specific type of equipment used. Incorporating daylighting into the original building design tends to be more cost-effective than installing hardware after the facility is occupied.

Potential costs of daylighting include:

- Increased design and planning
- Installation of modifications in existing buildings
- Increased cooling load
- Impact to occupant productivity during reorganization or modification
- Increased maintenance

Potential benefits of daylighting include:

- Reduction in energy cost due to decreased use of artificial lighting, heating, and cooling
- Reduction in use of fossil fuels
- Improved occupant productivity and psychological well-being[29; 30]

5) Prioritize and Implement Daylighting Techniques

Funding for daylighting design and implementation may be limited, so determining which techniques are most cost-effective is an important step. Due to potential funding limitations, facility managers should consider alternative funding instruments, including:

- Agency appropriations
- The Department of Energy's Energy Efficiency and Renewable Energy Program
- Retained energy savings
- Energy Savings Performance Contracts
- Utility Energy Services Contracts
- O&M performance incentives

6) Monitor Energy Savings

Facility managers should be sure to monitor and measure energy savings after daylighting techniques are implemented. Monitoring can be accomplished through energy analyses, reviewing maintenance records, and employee surveys. Data on energy savings will demonstrate NASA's compliance with Agency and federal requirements regarding reductions in energy consumption.

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[29] Heerwagen, et. al., "Lighting and Psychological Comfort" Design and Application, 1986.

[30] Hedge, A. "Reactions of computer users to three different lighting systems" Work and Display Units, 1994.

Related LEED® Credits

The LEED® credits related to daylighting are illustrated in Table 9. Definitions for all LEED® abbreviations appear in the Introduction.

Table 9 - LEED® and Daylighting

LEED-NC®	IEQ Credit 8.1: Daylight and Views - Daylight
	IEQ Credit 8.2: Daylight and Views - Views
LEED-EB: O&M®	IEQ Credit 2.4: Daylight and Views
LEED-ND®	None

TOOLS

Whole Building Design Guide

The Whole Building Design Guide (WBDG) presents daylighting concepts, benefits, design recommendations, materials and methods of construction, analysis and design tools, and additional resources.

For more information:
www.wbdg.org/resources/daylighting.php

Tips for Daylighting with Windows – An Integrated Approach

The guidelines for incorporating daylighting with windows were developed by the Department of Energy (DOE) to provide an integrated approach to the cost-effective design of perimeter zones in new commercial buildings. The guidelines include quick-reference materials, rules-of-thumb, practical details, and common scenarios.

For more information:
http://btech.lbl.gov/pub/designguide/dlg.pdf

Radiance Software

Radiance is a suite of programs developed by the DOE and the University of California for the analysis and visualization of lighting in design.

For more information:
http://radsite.lbl.gov/radiance/HOME.html

Low-Emitting Materials

Materials used inside a building can have a significant impact on indoor air quality. Facility managers should review materials, products, and practices from an air quality perspective, balancing these considerations against cost, energy efficiency, and other concerns.

The BMP for incorporating low-emitting materials is derived from the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings,* Agency policy, or industry practices. Each BMP includes discussion of related NASA activities and accomplishments, relevant LEED® credits, and resources offering additional information or assistance.

The low-emitting materials BMP for new construction, major renovation, or existing buildings requires facility managers to specify materials and products with low pollutant emissions, including composite wood products, adhesives, sealants, interior paints and finishes, carpet systems, and furnishings.

BEST MANAGEMENT PRACTICE – LOW-EMITTING MATERIALS

Specify materials and products with low pollutant emissions, including composite wood products, adhesives, sealants, interior paints and finishes, carpet systems, and furnishings.

Definition

Volatile Organic Compounds

Harmful chemical compounds that are emitted into the air during and after construction.

NASA Requirement

NPR 8820.2F requires use of materials and products with low-pollutant emissions (e.g. volatile organic compounds), including adhesives, sealants, paints, carpet systems, and furnishings.

Harsh chemicals known as **volatile organic compounds** (VOC) are emitted by some building materials, including adhesives, sealants, paints, coatings, carpet systems, wood, furniture, cleaning chemicals, office equipment, and other products. VOCs escape during and after construction through a process called off-gassing. Occupant health can be harmed when these VOCs are trapped inside the building and inhaled. Other harmful indoor pollutants include radon and carbon monoxide.

Exposure to VOCs is associated with a number of short- and long-term respiratory, allergic, and immune system effects. Short-term effects may include "eye and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment."[31] Other health effects may include "headaches, loss of coordination, nausea; damage to liver, kidney, and central nervous system."[31]

[31] "An Introduction to Indoor Air Quality Pollutants and Sources of Indoor Air Pollution Volatile Organic Compounds" EPA.

Implementing a Low-emitting Materials Program

Table 10 illustrates the steps necessary in implementing a low-emitting materials program, with additional detail provided in the subsequent narrative.

Table 10 - Implementing Low-emitting Materials

IMPLEMENTATION STEPS	
1)	**Identify Existing Indoor Pollutants**
□	Review product documentation for all building materials.
□	Conduct tests on the indoor environment for pollutants.
2)	**Identify Alternative Products and Materials**
□	Phase in alternative products and materials with no/low VOC.
□	Choose products that are low-emitting or environmentally friendly.
□	Use regional products when available.
3)	**Identify Ventilation Improvements**
□	Use ventilation to reduce pollution levels.
□	Install sensors or alarms to monitor indoor pollutants.
4)	**Follow Manufacturer Recommendations**
□	Read and follow manufacturer recommendations.
5)	**Update Building Documentation**
□	Update facility planning and policy documents.
□	Include product literature in building documentation.

1) Identify Existing Indoor Pollutants

The process of identifying indoor pollutants in a facility or facility design should include review of product documentation and installation history for all building materials and products. This review is intended to determine levels of VOCs and other pollutants in the building materials.

It may also be necessary to test the indoor environment for harmful levels of some or all of the common indoor pollutants. During testing and documentation review, special attention should be given to wood products, adhesives, sealants, interior paints and finishes, carpet systems, and furnishings.

2) Identify Alternative Products and Materials

Once sources of indoor pollutants have been identified, facility managers should consider alternative products to replace or decrease use of pollution-emitting products. Several organizations, including Green Seal and EcoLogo, certify products as low-emitting or otherwise environmentally friendly. Additional information on low-emitting products can be found through a variety of online databases and catalogs, including the EPA's Environmentally Preferable Purchasing (EPP) and the GSA Advantage! environmental program.

Some alternative products may be available on a limited basis, and some may require special installation or maintenance. Additionally, the performance or durability of some alternative products may differ from that of more commonly-used products. Facility managers should research and consider these differences prior to purchase.

3) Identify Ventilation Improvements

If alternative products are cost-prohibitive or otherwise not practical, improved ventilation may also help to reduce concentrations of indoor pollutants. While ventilation equipment replacement may be necessary, sensors and alarms are also important for monitoring indoor pollutants and notifying building staff and occupants when pollutant levels exceed acceptable limits. For more information on high-performance HVAC, see page 4-2 and Chapter 2, page 2-8.

4) Follow Manufacturer Recommendations

Exposure to some indoor pollutants can be minimized by carefully following product instructions. Product labeling may indicate frequency of use, safety precautions such as use of gloves or masks, required ventilation, installation method, or other considerations. Equal care should be taken when storing or disposing of products.

5) Update Building Documentation

When alternative building materials and products are selected, building documentation, including planning and policy documents, should be updated accordingly. Product literature should be added to the building documentation for reference.

Related LEED® Credits

The LEED® credits related to low-emitting materials are illustrated in Table 11. Definitions for all LEED® abbreviations appear in the Introduction.

Table 11 - LEED® and Low-emitting Materials

LEED-NC®	IEQ Credit 4.1: Low-Emitting Materials - Adhesives and Sealants
	IEQ Credit 4.2: Low-Emitting Materials - Paints and Coatings
	IEQ Credit 4.3: Low-Emitting Materials - Flooring Systems
	IEQ Credit 4.4: Low-Emitting Materials - Composite Wood and Agrifiber Products
LEED-EB: O&M®	None
LEED-ND®	None

TOOLS

Green Seal

Green Seal provides information, resources, product certification, and standards for environmentally friendly products, including adhesives and cleaning products.

For more information: http://greenseal.org/

Green Cleaning Network

The Green Cleaning Network is an information clearinghouse supporting discussion and education on green cleaning topics.

For more information: www.greencleaningnetwork.org

Environmentally Preferable Purchasing

The EPA provides information on environmentally friendly products through its EPP portal.

For more information: www.epa.gov/epp/

APPA: Leadership in Educational Facilities

The APPA is an organization of facilities management professionals from a variety of educational institutions. The organization provides information, publications, research, and credentialing.

For more information, see: www.appa.org

EcoLogo

EcoLogo provides standards and certification for environmentally friendly products in over 120 categories.

For more information: www.ecologo.org

Advantage! Environmental Program

The GSA Advantage! program provides resources for federal agency purchasing of products and services. GSA Advantage! offers the most comprehensive selection of approved products and services for GSA contracts. The Environmental program provides direct access to a variety of environmentally-friendly options.

For more information: www.gsaadvantage.gov

Protect Indoor Air Quality During Construction

Construction or renovation of a building can generate dust, mud, paint, moisture, and other contaminants that often remain once work is complete. Left unattended, these contaminants can have a negative impact on the building's indoor air quality. Post-occupancy clean-up can be disruptive, time consuming, and costly. The Sheet Metal and Air Conditioning Contractors National Association (SMACNA) has developed the *Indoor Air Quality Guidelines for Occupied Buildings Under Construction*, and these guidelines are incorporated into the BMP for protecting indoor air quality during construction.

This BMP is derived from the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings,* Agency policy, or industry practices. Each BMP includes discussion of related NASA activities and accomplishments, relevant LEED® credits, and resources that offer additional information or assistance. The protection of indoor air quality during construction BMP for new construction, major renovation, or existing buildings recommends that facility managers follow SMACNA's *Indoor Air Quality Guidelines for Occupied Buildings Under Construction,* 2007, and complete a 72-hour flush-out prior to occupancy, continuing with additional flush-outs as necessary.

Best Management Practice – Protect Air Quality During Construction

Follow SMACNA's Indoor Air Quality Guidelines for Occupied Buildings Under Construction, 2007, and perform a flush-out prior to occupancy. Continue flush-out as needed after occupancy.

NASA Requirement

NPR 8820.2F ensures compliance with SMACNA's Indoor Air Quality Guidelines for Occupied Buildings Under Construction.

NPR 8820.2F further requires after construction, but prior to occupancy, a minimum 72-hour flush-out with maximum outdoor air, consistent with achieving relative humidity no greater than 60 percent. After occupancy, the flush-out should be continued as necessary to minimize exposure from new building materials.

Significant quantities of particles and chemicals can be disturbed during construction, and construction materials themselves may also be sources of contamination. Moisture can damage construction materials and the resulting mold growth can affect occupant health after construction. Careful monitoring of air quality before, during, and after construction can significantly reduce levels of contaminants and pollutants. Before employees occupy a new or remodeled facility, the air should be replaced with outdoor air, and air filters should be replaced.

SMACNA's *Indoor Air Quality Guidelines for Occupied Buildings Under Construction* details air quality management practices, and the 2007 edition of this guidance includes management strategies for minimizing the threat to air quality during construction.

The ANSI/ASHRAE Standard 62.1-2007 provides guidance on ventilation and air quality requirements from pre-construction through occupancy. This standard recommends that air quality should be considered during a facility's planning and design. Through early planning and control of air quality during and after construction, indoor air quality can be improved.

Implementing Indoor Air Quality Improvements

Table 12 illustrates step-by-step techniques for protecting indoor air quality during construction. These steps are discussed in additional detail in the subsequent narrative.

Table 12 - Implementing Indoor Air Quality Improvements

IMPLEMENTATION STEPS	
1)	**Plan for Indoor Air Quality During Construction**
□	Follow SMACNA guidelines for control measures.
□	Protect materials from moisture.
2)	**Maintain Indoor Air Quality During Construction**
□	Implement and maintain control measures.
□	Monitor build up of construction debris.
□	Use dust curtains and unconnected ducting.
3)	**Perform Flush-out and Install Air Filters**
□	Conduct flush-out.
□	Ensure installed air filters follow ANSI/ASHRAE standards.

1) Plan for Air Quality During Construction

Before construction begins, several steps can be taken to protect indoor air quality. SMACNA's *Indoor Air Quality Guidelines for Occupied Buildings Under Construction* includes control measures for HVAC protection, source control, path interruption, housekeeping, and scheduling. It may also be necessary to provide a wash-down area to prevent contaminants from entering the building.

On-site and installed construction materials should also be protected from moisture. A dry storage area will protect materials and supplies from moisture damage and mold growth; this storage area should be maintained throughout construction. Even after the building is enclosed, activities such as concrete curing, wallboard finishing, and painting can produce significant amounts of moisture. Moisture accumulation can be minimized by enclosing the building as soon as possible, maintaining the building enclosure through temporary construction doors, or by using construction drying or dehumidification equipment. It may be necessary to seek the advice of trained consultants.

2) Maintain Indoor Air Quality During Construction

Control measures developed during the planning stage must be implemented and maintained during construction, and routine housekeeping should be performed to prevent the accumulation of construction debris. Excessive accumulation of construction debris is both a safety and an air quality concern.

Improperly installed ducting can trap contaminants and pollutants, which can harm air quality after the building is complete; accordingly, it is important to follow manufacturer recommendations for installation. Use of dust curtains to separate finished areas from building sections still under construction will ensure that dust and debris do not contaminate the entire site.

3) Perform Flush-out and Install Air Filters

Once construction is complete, but before the building is occupied, the indoor air should be flushed out. The **flush-out** should be performed after completion of interior finishes and installation of new air filters. During the flush-out, internal temperature and humidity should be maintained within recommended ranges, and a minimum total volume of air should be introduced into the building to ensure acceptable indoor air quality. If the project is pursuing LEED-NC®, the temperature should be at least 60 degrees Fahrenheit, the relative humidity no higher than 60 percent, and the total air volume at least 14,000 cubic feet of outdoor air per square foot of floor area.

> *Definition*
>
> *Flush-out*
>
> *A method of removing building contaminants, such as volatile organic compounds and other indoor pollutants, in which air is pushed through the building.*

Air filtration standards have changed over time. The current standard, ANSI/ASHRAE Standard 52.2-2007, establishes a test procedure for evaluating the performance of air-cleaning devices as a function of particle size.[32] This standard references dust particle efficiency, which describes the filter's effectiveness in capturing particulates of various size ranges. The efficiency is expressed as the Minimum Efficiency Reporting Value (MERV); higher values are associated with more effective filters.

> *Rule of Thumb*
>
> *Air filters that capture more particulates ensure higher air quality, but may require more energy to pass air through the filter.*

Generally, air filters installed during construction are less efficient than those installed immediately before occupancy. If the project is pursuing LEED-NC®, the air filter must have a MERV rating of at least 8 during construction,[33] and the filter must be replaced prior to occupancy with a MERV rating of at least 13.[33] Older air filtration standards used a rating system called the dust spot efficiency.

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[32] ANSI/ASHRAE Standard 52.2-2007 *Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size*. ASHRAE, 2007.

[33] LEED® Reference Guide for Building Design and New Construction.

A conversion table for equivalent MERV and dust spot efficiency ratings appears in Table 13.

Table 13 – Dust Spot Efficiency and MERV Rating Conversion Table

MERV Rating	Dust Spot Equivalency	Applications
1-6	Under 20%	Used in residential and industrial applications. Capable of capturing pollen and dust and other particles larger than 10 microns.
7	25-30%	Used in commercial applications. Capable of capturing pollen, mold spores, and particles between 3-10 microns.
8	30-35%	Used in commercial applications. Capable of capturing pollen, mold spores, and particles between 3-10 microns.
9	40-45%	Capable of capturing particles between 1-3 microns.
10	50-55%	Capable of capturing particles between 1-3 microns.
11	60-65%	Used in commercial applications. Capable of capturing particles between 1-3 microns.
12	65-70%	Used in commercial applications. Capable of capturing particles between 1-3 microns.
13-14	80-95%	Used in high-end commercial properties. Usually found in the bag or deep cartridge types.
15-16	95% and up	Used in general surgery and hospital inpatient care. Capable of capturing particles between 0.3-1.0 microns.
17-20	None	Used in clean rooms, biopharmaceutical, orthopedic surgery, organ transplant, and nuclear power applications. Correspond to the high-efficiency particulate air (HEPA) and ultra-low penetration air (ULPA) filter categories.

Source: ASHRAE Systems and Equipment Handbook, Chapter 24, 2004.

Related LEED® Credits

The LEED® credits related to protecting indoor air quality during construction are illustrated in Table 14. Definitions for all LEED® abbreviations appear in the Introduction.

Table 14 - LEED® and Indoor Air Quality During Construction

LEED-NC®	IEQ Credit 3.1: Construction Indoor Air Quality Management Plan - During Construction
	IEQ Credit 3.2: Construction Indoor Air Quality Management Plan - Before Occupancy
LEED-EB: O&M®	IEQ Credit 1.1: Indoor Air Quality BMP - Indoor Air Quality Management Program
	IEQ Credit 1.2: Indoor Air Quality BMP - Outdoor Air Delivery Monitoring
	IEQ Credit 1.3: Indoor Air Quality BMP - Increased Ventilation
	IEQ Credit 1.4: Indoor Air Quality BMP - Reduce Particles in Air Distribution
	IEQ Credit 1.5: Indoor Air Quality BMP - Indoor Air Quality Management for Facility Alterations and Additions
LEED-ND®	None

TOOLS

Maintaining IEQ During Construction and Renovation

The Centers for Disease Control and Prevention (CDC) has developed some guidance for maintaining IEQ during construction and renovation. The guidelines include references and resources for additional education.

For more information:
http://cdc.gov/niosh/topics/indoorenv/ConstructionIEQ.html

Environmental Tobacco Smoke Control

Exposure to tobacco smoke has serious health consequences for both smokers and non-smokers. Smoking is the largest single cause of preventable death in the United States,[34] and second-hand smoke has been shown to cause many of the same health hazards as smoking.[35] According to the CDC, tobacco use is "the single most important preventable risk to human health in developed countries and an important cause of premature death worldwide".[36] Despite the health risks, smoking remains very prevalent and it continues to pose a challenge for facility managers.

The BMP for environmental tobacco smoke control (ETS) is derived from the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings,* Agency policy, or industry practices. Each BMP discusses related NASA activities and accomplishments, relevant LEED® credits, and resources for additional information or assistance.

The ETS control BMP for new construction, major renovation, or existing buildings requires that facility managers implement a policy prohibiting smoking within the building and within 25 feet of all building entrances, operable windows, and building ventilation intakes during building occupancy. Signs explaining the policy must be posted in the facility.

[34] Actual Causes of Death in the United States, 2000, JAMA. 2004.

[35] *The Health Consequences of Involuntary Exposure to Tobacco Smoke*. Surgeon General of the United States, 2006.

[36] Nicotine: A Powerful Addiction. Centers for Disease Control and Prevention.

Best Management Practice – Environmental Tobacco Smoke Control

Implement a policy and post signage indicating that smoking is prohibited within the building and within 25 feet of all building entrances, operable windows, and building ventilation intakes during building occupancy.

NASA Requirement

NPR 1800.1 requires the Chief Health and Medical Officer provide smoking cessation programs at all Centers. The Center Medical Director must develop the smoking cessation plan focusing on the following goals:

- *Preventing tobacco use among the workforce*
- *Promoting tobacco use cessation*
- *Eliminating exposure to secondhand smoke*
- *Educating about tobacco-related health disparities*

Executive Order 13058 prohibits smoking in all interior spaces owned, rented, or leased by the executive branch of the federal government. The Executive Order also prohibits smoking in any outdoor areas in front of air intake ducts, and it recommends that each agency heads establish a smoking ban in an area of undetermined size around the building perimeter. The size of designated smoking areas and their distance from buildings must balance air quality concerns with convenience and other needs of smokers. For reference, LEED-NC® Prerequisite 2 prohibits smoking within at least 25 feet of the building entrance.

Implementing an Environmental Tobacco Smoke Control Program

Table 15 illustrates steps required for implementing an ETS control program, with additional detail provided in the subsequent narrative.

Table 15 - Implementing ETS Control Techniques

IMPLEMENTATION STEPS	
1)	**Identify Appropriate Locations for Smoking**
□	Identify indoor and outdoor locations for smoking.
2)	**Designate and Enforce Smoking Areas**
□	Monitor and enforce smoking areas.
□	Produce signs that designate area and establish building as non-smoking.
□	Use regional products when available.
3)	**Develop and Implement a Smoking Communication Plan**
□	Educate on dangers of second-hand smoke.
□	Communicate smoking policy to building occupants and maintenance workers.

1) Identify Appropriate Locations for Smoking

According to federal regulations, smoking indoors must be either prohibited or permitted only in certain ventilation-controlled rooms. Facility managers must weigh the additional costs of protecting non-smoking building occupants from exposure to tobacco smoke with the needs of smokers in the workplace. Outdoor locations appropriate for smoking should not be next to or underneath building entrances, operable windows, and ventilation air intakes, as these openings in the building envelope can permit smoke to enter the facility. Appropriate outdoor locations may be sheltered to protect smokers from rain or extreme weather and may include benches.

2) Designate and Enforce Smoking Areas

Once appropriate locations for smoking have been established, their use must be monitored and enforced. Signs or other communications that clearly identify appropriate smoking locations are necessary to ensure that building occupants and visitors know and understand the policy. Ongoing efforts to improve smoking policy compliance include maintaining signage, cleanup, and maintenance of designated smoking locations.

3) Develop and Implement a Smoking Communication Plan

Although secondhand smoke is a serious IEQ and health issue, individual smokers may not fully understand its implications. Communication with building occupants and maintenance staff can improve understanding and willingness to comply with the smoking policy. Without acceptance and buy-in, ongoing smoking policy compliance may be difficult to achieve.

Related LEED® Credits

The LEED® credits related to environmental tobacco smoke control are illustrated in Table 16. Definitions for all LEED® abbreviations appear in the Introduction.

Table 16 - LEED® and ETS Control

LEED-NC®	IEQ Prerequisite 2: Environmental Tobacco Smoke (ETS) Control
	IEQ Credit 2: Increased Ventilation
LEED-EB: O&M®	IEQ Prerequisite 2: Environmental Tobacco Smoke (ETS) Control
	IEQ Credit 1.3: Indoor Air Quality BMP - Increased Ventilation
LEED-ND®	None

TOOLS

Indoor Air and ETS

This website, sponsored by the EPA, suggests methods to encourage a smoke-free workplace and communicate with occupants and employees.

For more information:
www.epa.gov/air/community/details/i-secsmoke.html

Comprehensive Tobacco Control Programs – 2007

Researched by the CDC the *Best Practices for Comprehensive Tobacco Control Programs- 2007* discusses ETS management practices as well as funding resources.

For more information:
www.cdc.gov/tobacco/stateandcommunity/best_practices/index.htm

Integrated Pest Management

Indoor pest control and the use of pesticides can also harm air quality. Janitorial practices from top to bottom should be reviewed, improved where possible, and documented. Site landscaping can unintentionally provide a home for many indoor pests. Finally, building entryways provide a common place for pests to enter the building. An example pest control device is illustrated in Figure 21.

The BMP for Integrated Pest Management (IPM) is derived from the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings,* Agency policy, or industry practices. Each BMP includes discussion of related NASA activities and accomplishments, relevant LEED® credits, and resources that provide additional information or assistance. The IPM BMP for new construction, major renovation, or existing buildings requires use of integrated pest management techniques as appropriate to minimize pesticide usage.

BEST MANAGEMENT PRACTICE – INTEGRATED PEST MANAGEMENT

Use integrated pest management techniques as appropriate to minimize pesticide usage.

Integrated Pest Management is defined by the United States Green Building Council (USGBC) as the management of "indoor pests in a way that protects human health and the surrounding environment and that improves economic returns through the most effective, least-risk option."[37] Implementing IPM can improve a building's indoor air quality; pests can carry germs and diseases, while excessive use of pesticides can be toxic to humans. An IPM plan encourages a proactive approach to pest management.

The most common approach to the presence of indoor pests is use of pesticides. This approach is not cost-effective, as it generally uses excessive amounts of pesticides. IPM ensures appropriate use of pesticides and facilitates communication among facility managers, maintenance staff, and building occupants. Once the IPM plan is established, it should be integrated with the facility's cleaning policy.

Implementing an Integrated Pest Management Plan

Table 17 lists the required steps for establishing an IPM plan; these steps are discussed in additional detail in the subsequent narrative.

Table 17 - Implementing an IPM Plan

IMPLEMENTATION STEPS	
1)	**Gather Facility Information and Determine Action Threshold**
□	Inventory established IPM techniques.
□	Establish an action threshold.
2)	**Implement Pest Prevention**
□	Establish pest prevention techniques and implement.
3)	**Implement Pest Control Techniques**
□	Establish pest control techniques and implement.
□	Prioritize usage of effective and less-risky control techniques.
4)	**Document an IPM Program**
□	Develop program in accordance with green cleaning policies and facility plans.
□	Communicate IPM Program to maintenance staff and building occupants.
□	Monitor IPM Program elements.
□	Conduct follow-up inspections.

[37] LEED® for Existing Buildings: Operations and Maintenance Reference Guide. 2009.

1) Gather Facility Information and Determine Action Threshold

Before implementing IPM techniques, the facility manager should collect information about existing pest management techniques, including current pest or rodent issues, and pesticides and preventive measures currently in use. Such preventive measures may include traps or outdoor landscaping devices.

This information will assist the facility manager to establish an action threshold, or "a point at which pest populations or environmental conditions indicate that pest control action must be taken."[38] Once the action threshold is established, the facility manager can begin creating IPM goals, which should be particular to the facility and to the individual site, as types of pest infestation vary by region. Some goals, however, will be appropriate for every site; these include frequency and management of site inspections, routine pest inspections, regular population monitoring, and determined pest control methods.[39] Regional and federal regulations should also be considered in goal development.

Communication is an important aspect of any IPM plan. Maintenance workers and building occupants should understand how to report pest problems, and building occupants should be notified when pesticides are to be used in the building and if the pesticides pose a risk to human health.

2) Pest Prevention

Prevention is the first line of defense against infestation. Landscaping techniques, including installation of natural barriers against pests and avoiding use of plants and shrubs which are attractive to pests, can aid prevention efforts. Removal of food and water sources can also be an effective method of prevention.

3) Implement Pest Control Techniques

When prevention is insufficient, and the action threshold demands use of control measures, IPM programs determine the proper control technique.[38] Control techniques are evaluated based on effectiveness and risk, and those determined to be effective with minimum risk should be given priority. Techniques may include targeted applications of

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38 "Integrated Pest Management Principles" EPA, 2009.

39 LEED® for Existing Buildings: Operations and Maintenance Reference Guide. 2009.

chemicals that disrupt pest mating, or use of mechanical controls, such as trapping or weeding.

Pesticide use may be necessary if low-risk techniques prove ineffective. If pesticides are used, their application should be targeted to minimize the health risk to building occupants; this method of application is also generally more cost-effective. Widespread application of pesticides should be a last resort.

4) Document an IPM Program

Known pests, action thresholds, facility goals, current pest prevention efforts, and approved pest control procedures should be documented in an IPM program, which should be developed in conjunction with green cleaning policies and facility plans. Once the program is established and documented, it should be communicated to building staff and occupants to assist in pest management and awareness.

The facility manager should monitor IPM plan implementation, performing any necessary inspections and pest population monitoring. Such monitoring will enable the facility manager to identify problem areas and to adjust procedures as necessary.

Related LEED® Credits

The LEED® credits related to indoor IPM are illustrated in Table 18. Definitions for all LEED® abbreviations appear in the Introduction.

Table 18 – LEED® and IPM

LEED-NC®	None
LEED-EB: O&M®	IEQ Credit 3.6: Green Cleaning - Indoor Integrated Pest Management
LEED-ND®	None

TOOLS

Environmental Protection Agency

The EPA offers background information about IPM programs and how they function.

For more information:
www.epa.gov/pesticides/factsheets/ipm.htm

IPM Institute of North America, Inc.

This site provides recent news, information on established standards, and other IPM management resources.

For more information: www.ipminstitute.org

National Information System for the Regional IPM Centers

This site provides regionally relevant IPM information. Other resources include pest management practices and products.

For more information: www.ipmcenters.org/index.cfm

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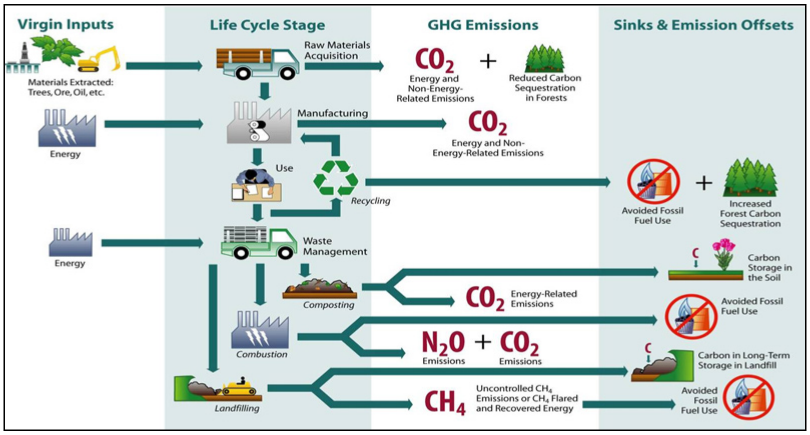
CHAPTER 5. REDUCE ENVIRONMENTAL IMPACT OF MATERIALS

Background

According to the Environmental Protection Agency (EPA), the total quantity of **municipal solid waste** (MSW) increased 67 percent, from 151.6 million tons to 254.1 million tons between 1980 and 2007. In addition to MSW, which includes packaging, food scraps, grass clippings, furniture, electronics, and appliances, Construction & Demolition (C&D) debris causes environmental harm by increasing quantities of landfill waste. It also imposes economic costs resulting from waste collection and transportation.

One strategy to reduce landfill waste is waste management. The role of waste management processes in a product's life cycle is illustrated in Figure 1. In addition, building design, material selection, supply and equipment purchases, as well as reduction of the use of ozone-depleting compounds present opportunities for reducing the environmental impact of materials.

Figure 1 - Waste Management Processes are Part of the Life Cycle



Source: EPA.

Waste and Materials Management

Federal facilities are required to develop and implement cost-effective recycling and waste prevention programs.[1] Recycling and reducing quantities of construction debris can significantly reduce the total waste stream headed to landfills. In addition, recycling this waste stream lessens the demand for additional landfills, conserves natural resources,

Chapter Outline

To achieve federally mandated sustainability goals, the Agency should employ a systematic approach to sustainability investment. The environmental impact of a building's design and maintenance can be minimized through:

- *Waste and Materials Management*
- *Building Materials*
- *Ongoing and Durable Products*
- *Ozone-depleting Compounds*

Definition

Municipal Solid Waste

Municipal solid waste is another term for trash or garbage, specifically referring to solid waste collected by a local municipality for disposal at a landfill. This includes packaging, food scraps, grass clippings, furniture, electronics, and appliances.

[1] Resource Conservation and Recovery Act.

and prevents the pollution caused by manufacturing products from virgin materials.

Reducing the ongoing waste stream can produce economic benefits in the form of lower landfill tipping fees and increased recycling revenue. Tipping fees are generally charged at the landfill and vary based on the volume, weight, or number of items. This cost is in addition to waste collection and removal charges. If the waste stream is reduced by increasing recycling, the economic benefit is even greater due to the revenue from recycling. An example of metal debris recycling is pictured in Figure 2.

Figure 2 - Metal Debris Recycling

Source: DOE.

The Best Management Practice (BMP) for waste and materials management is derived from the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings* and Agency policy. Each BMP includes discussion of related NASA activities and accomplishments, relevant Leadership in Energy and Environmental Design® (LEED) credits, and resources for additional information or assistance.

The waste and materials management BMP for new construction, major renovation, or existing buildings recommends that facility managers ensure that adequate space, equipment and transportation for recycling is incorporated into the building design, and that salvage, reuse and recycling services are available to handle waste generated from major renovations. For existing buildings, these services should be available for regular building operations and maintenance (O&M); with established recycling and salvage procedures for discarded furnishings, equipment, and property.

BEST MANAGEMENT PRACTICE – WASTE AND MATERIALS MANAGEMENT

Ensure the availability of adequate space, equipment and transport accommodations for recycling in the building design and provide salvage, reuse and recycling services for waste generated from major renovations. For existing buildings, these services should be provided for regular building operations and maintenance, repair, and minor renovations; with established procedures for handling discarded furnishings, equipment, and property.

Between 1996 and 2003, the EPA estimates that quantities of C&D debris increased from nearly 136 million tons to more than 160 million tons.[2] This figure represents nearly 40 percent of the total waste stream in the United States, and much of it is typically sent to landfills. Most of the remaining waste stream comes from normal building operations. Facility operations generate many types of solid waste, including ongoing consumables, durable goods, and waste from alterations and additions.

The process of targeting opportunities for improved sustainability in waste and materials management includes a **waste stream audit**. Analysis of this information will help managers choose appropriate waste management, recycling, and composting methods.

NASA Requirement

NPR 8820.2F requires that site-related waste should be recycled or salvaged whenever feasible.

NPR 8820.2F requires designers to incorporate into the construction contract documents a requirement that the contractor recycle or salvage at least 50 percent of construction, demolition, and land-clearing waste.

Definition

Waste Stream Audit

A waste stream audit involves the determination of the type and volume of waste generated at a site. The audit typically also determines the waste's destination; this may include a landfill, incinerator, or other disposal destination.

2 "Municipal Solid Waste in the United States" Office of Solid Waste, EPA. 2003.

> **Definition**
>
> *Ongoing Consumables*
>
> *Products defined by LEED® as having a low cost per unit and regularly used and replaced in the course of business. Examples include paper, toner cartridges, binders, batteries, and desk accessories.*

> **Definition**
>
> *Durable Goods*
>
> *Products defined by LEED® as having a useful life of two years or more, and are replaced infrequently or may require capital program outlays. Examples include furniture, office equipment, appliances, external power adapters, televisions, and audiovisual equipment.*

Implementing Waste and Materials Management Improvements

Table 1 lists a step-by-step approach to implementing waste and materials management improvements. These steps are discussed in detail in the subsequent narrative.

Table 1 – Implementing Waste and Materials Management

IMPLEMENTATION STEPS	
1)	**Establish Waste Management Goals**
□	Determine if project is new construction or an existing building.
□	Establish a waste reduction goal.
□	Use regional recycling resources.
□	Adhere to regional and federal policies.
2)	**Implementing Waste Management Techniques**
□	Determine waste management techniques that are most applicable to the facility.
□	Estimate costs and benefits of each suggested technique.
□	Install and implement cost-effective waste management techniques.
3)	**Document Recycling Performance**
□	Collect data on implemented products.
□	Relay information to appropriate federal agencies.
□	Determine if data collected can be used towards obtaining LEED® credits.
□	Develop a recycling plan.

1) Establish Waste Management Goals

The facility manager should first establish waste management and recycling goals, and determine the type and size of space needed to support recycling and waste management efforts. New construction and major renovation projects should plan to recycle or salvage at least 50 percent of non-hazardous construction, demolition, and land clearing materials.[3] Waste management goals should be determined early in the design and planning process, and space at the construction site should be dedicated for separate containers for waste and recycling. In addition, designs may require adjustment to provide sufficient space for recycling. Recycling efforts at existing buildings should include ongoing efforts to improve recycling performance.

Waste management goals may vary by type of facility. New construction and major renovation waste is generally the result of excess materials such as wood and metal, while existing building waste is usually generated by disposal of **ongoing consumables** and **durable goods**. For more information on sustainable purchasing of these goods, see page 5-19.

[3] The non-hazardous material total does not include soil, and applies where markets exist.

Recycling services and programs can vary by region and type of material. Determining which recycling services are available locally will guide the goal-setting process. It may also be helpful to study the waste management programs and goals of other agencies or local governments.[4]

2) Implementing Waste Management Techniques

Cost-effective techniques for reducing total solid waste may include diverting, recycling, salvaging, and composting. Facility mangers should determine the most cost-effective technique for the type of materials generated at the particular facility.

Diversion

Diversion, also known as waste reduction, refers to general methods of preventing solid waste from entering landfills. Specific methods include source reduction, salvaging, reuse, recycling, and composting.[4] Diversion can be an effective means of waste reduction in new construction, major renovation, and existing buildings. Solid waste may be diverted through use of separate industrial recycling bins for materials such as metal and wood, as illustrated in Figures 3 and 4.

Figure 4 – Metal Waste Diversion at Building 2 North, Johnson Space Center

Source: NASA.

Building Focus

Collaborative Support Facility, Ames Research Center

LEED® Office for Transition, Johnson Space Center

During the construction of each building more than 95 percent of on-site generated construction waste and debris was diverted from the landfill.

Figure 3 – Wood Waste Diversion at Building 2 North, Johnson Space Center

Source: NASA.

4 *Cutting the Waste Stream in Half,* EPA and Solid Waste and Emergency Response, 1999.

Recycling

Recycling can alter materials that would otherwise become waste into valuable resources.[5] Increasing the rate of recycling conserves natural resources, reduces landfill waste, conserves energy, and reduces pollution and greenhouse gas emissions. The EPA recommends the "recycling loop"; a circular recycling process which involves collecting and processing of recyclable goods, manufacturing products with the collected materials, and sale and purchase of the recycled products.[5]

There are two methods for collection of recyclables: co-mingling and separation. Co-mingled recycling combines all types of materials into a single container, which is then collected and sorted and separated off site, usually by an external organization. Separated recycling requires that sorting and separation occur on site, before collection, by internal staff or contractors. Both types of service are readily available. While co-mingling may be a better option for facilities with space limitations, the cost for outside separation should be compared to internal labor options.

Building Focus

Propellants North Facility, Kennedy Space Center

During the renovation of the Launch Control Center firing rooms, window glazings and aluminum trusses were salvaged and reused in the Propellants North Facility.

Salvaging

Salvaging employs the "selective dismantling or removal of materials from buildings prior to or instead of conventional demolition."[6] Examples of salvaged materials include structural beams and posts, flooring, doors, cabinetry, ceiling tiles, brick, and decorative items. Salvaging materials is an appropriate recycling method for newly constructed buildings or additions. An example of salvaged window and bow trusses is illustrated in Figure 5.

Figure 5 - Salvaged Window and Bow Trusses, Propellants North Facility, Kennedy Space Center

Source: NASA.

Salvaging can have several environmental and economic benefits, including reduced demolition removal costs, reduced site impact, conserved landfill space, and additional job creation. Salvaged materials can also contribute historical significance, quality, or character to a new or existing building. Salvaging may also have disadvantages. Salvage projects can be time-consuming and labor-intensive, and it may be challenging to find a market for sale of salvaged materials.

[5] "Recycling" EPA, 2010.

[6] *Deconstruction: Building Disassembly and Material Salvage*, National Association of Home Builders, 2003.

Composting

Composting makes use of "organic material… as a soil amendment or as a medium to grow plants."[7] Compost is created by combining organic wastes such as yard trimmings and food residuals with bulking agents, and subjecting the mixture to a maturing/stabilizing process. Composting materials are stored in either open bins, which are exposed to natural elements, or composting containers, which are enclosed. An illustration of a composting container appears in Figure 6.

Figure 6- Example of Small Scale Composting

Source: Leon County, Florida, Recycling Services.

Composting can also reduce the need for chemical fertilizers, remove organic materials from stormwater runoff and landfills, and suppress plant diseases and pests.[7] Composting is typically used along with ongoing recycling efforts in existing buildings.

3) Document Recycling Performance

Building occupants, construction contractors, and maintenance staff should understand the reason for waste management efforts and how well their efforts are succeeding; therefore, it is important to document recycling performance. Collecting, documenting, and distributing waste management information can encourage improved performance, and contribute toward achieving LEED® certification. Continued training is also an important part of the waste management communication process.

Facility managers may also decide to complete a Recycling Plan or other document. The Plan should include roles, responsibilities, processes, materials, and other guidance regarding waste management at the facility. It should also outline a communication process to ensure that building occupants, contractors, and maintenance staff understand current waste management policies and processes.

[7] "Composting," EPA, 2009.

Related LEED® Credits

The LEED® credits related to waste management are illustrated in Table 2. Definitions for all LEED® abbreviations appear in the Introduction.

Table 2 – LEED® and Waste and Materials Management

LEED-NC®	MR Prerequisite 1: Storage and Collection of Recyclables
	MR Credit 1.1: Building Reuse - Maintain Existing Walls, Floors, and Roof
	MR Credit 1.2: Building Reuse - Maintain Interior Nonstructural Elements
	MR Credit 2: Construction Waste Management
	MR Credit 3: Materials Reuse
LEED-EB: O&M®	MR Prerequisite 2: Solid Waste Management Policy
	MR Credit 6: Solid Waste Management - Waste Stream Audit
	MR Credit 7: Solid Waste Management - Ongoing Consumables
	MR Credit 8: Solid Waste Management - Durable Goods
	MR Credit 9: Solid Waste Management - Facility Alterations and Additions
LEED-ND®	GIB Credit 5: Existing Building Reuse
	GIB Credit 15: Recycled Content in Infrastructure
	GIB Credit 16: Solid Waste Management Infrastructure

TOOLS

Office of Solid Waste - Environmental Protection Agency

The EPA's Office of Resource Conservation and Recovery collects information and best practices for optimal waste disposal and recycling and reuse techniques, enforces relevant regulations, cleans up improperly disposed waste, and oversees disposal of hazardous and non-hazardous waste. The office also provides publications, resources, case studies, and other information.

For more information: www.epa.gov/epawaste/basicinfo.htm

Construction Materials Recycling Association

The Construction Materials Recycling Association (CMRA) promotes recycling of construction and demolition materials, provides information and resources, and lobbies on behalf of recyclers.

For more information: http://cdrecycling.org/

Resource Venture

The Resource Venture program provides a variety of local services and information on construction and demolition waste, and waste reduction programs. They also provide sustainability services, including outreach, education, and technical assistance.

For more information: www.resourceventure.org/green-your-business/green-building/construction-waste-management/construction-waste-management

Earth911 Local Recycling

Finding recycling resources can be difficult in some parts of the country. Earth911 is a public-private partnership of corporate, media, and trade associations established to deliver local information on recycling, hazardous waste disposal, reuse, and more.

For more information: http://earth911.com/

Building Materials Reuse Association

The Building Materials Reuse Association seeks to reduce depletion of natural resources, keep solid waste out of landfills, as well as to create markets and job opportunities. The site offers a directory of local materials salvage/reuse organizations.

For more information: www.buildingreuse.org/

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Building Materials

Long before construction begins, the process of bringing building materials to market can cause pollution, harm habitats, and drain natural resources. Sustainable facilities design requires careful evaluation of material and equipment sources, and managers should consider recycled, salvaged, or otherwise environmentally-friendly products when selecting **building materials**.

After construction is complete, managers should continue to seek materials, products, and equipment with recycled or otherwise environmentally preferable content. For more information on ongoing or durable good purchasing, see page 5-19. An example of scrap wood collected from construction, delivery pallets, or other sources and then turned into mulch is pictured in Figure 7.

Definition

Building Materials

The materials used to construct a facility's structural elements, such as roofing, siding, walls, and doors.

Figure 7 – Scrap Wood Used for Mulch, Goddard Space Flight Center

Source: NASA.

The BMP for use of sustainable building materials are derived from the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings and* Agency policy. Each BMP includes discussion of related NASA activities and accomplishments, relevant LEED® credits, and resources offering additional information or assistance.

The building materials BMPs for new construction, major renovation, or existing buildings requires that in all solicitations relevant to construction of or use in the building, every attempt should be made to purchase building materials that include recycled content, bio-based content, or that are designated environmentally preferable products.

Building Focus

Goddard Space Flight Center

Scrap wood from pallets and other items is collected and shredded and then used as landscaping mulch.

BEST MANAGEMENT PRACTICE – BUILDING MATERIALS

In all solicitations relevant to construction of or use in the building, every attempt should be made to purchase building materials that include recycled content, bio-based content, or that are designated environmentally preferable products.

Building material selection provides another opportunity to improve a facility's sustainability performance. Building designers should consider reusing existing structural and non-structural building elements, including doors, ceiling systems, floors, walls, and roof materials. When materials are reused, total project costs are reduced because fewer materials need to be purchased, and natural resources are preserved because fewer new products need to be produced. In renovations, careful analysis can help managers identify existing building components which may be suitable for rehabilitation. Such reuse and preservation efforts should be documented.

Managers should also consider products and materials salvaged from other sites. Salvaged and other reused products can prevent natural resource depletion, and, in many cases, reduce project costs. Markets for salvaged and used materials continue to improve and evolve, and organizations to assist Centers exist in almost every state.

When salvaged materials are not available or appropriate, every effort should be made to locate environmentally preferable new materials. A number of agencies and organizations have developed systems and criteria to ensure that products meet environmental standards. The EPA designates products through the Comprehensive Procurement Guidelines (CPG) and the Environmentally Preferable Purchasing (EPP) Program. The Forest Stewardship Council's (FSC) Principles & Criteria establish standards for **certified wood** products, encouraging sustainable forest management. Finally, the United States Department of Agriculture (USDA) has developed criteria and a labeling system for bio-based products.

NASA Requirement

NPR 8820.2F sets requirements for maximizing reuse over disposal in projects with demolition, identifying local salvage and recycling operations for processing site-related waste, and requiring contractors to recycle or salvage at least 50 percent of the construction, demolition, and land clearing waste.

NPR 8820.2F also requires utilization of building material products containing biobased and recycled content.

NPR 8530.1A requires review and revision of NASA specifications and standards to eliminate barriers to the preference for recovered materials.

Definition

Certified Wood

An environmentally friendly product which is certified through the Forest Stewardship Council (FSC). The FSC established international forest management standards to ensure that forest practices are environmentally responsible, socially beneficial, and economically viable.

Implementing Sustainable Building Materials

Table 3 lists steps for implementing a plan to ensure use of environmentally friendly building materials. These steps are discussed in detail in the subsequent narrative.

Table 3 – Implementing Sustainable Building Materials

IMPLEMENTATION STEPS	
1)	**Determine Which Environmentally Friendly Materials Can be Used**
□	Analyze which environmentally friendly materials are most applicable to the facility.
2)	**Estimate Life-cycle Costs and Benefits**
□	Determine costs and benefits of the use of environmentally friendly building materials.
3)	**Install Products and Document Implementation Efforts**
□	Install and use environmentally friendly products in building.
□	Collect data on implemented products.
□	Relay information to appropriate federal agencies.
□	Determine if data collected can be used towards obtaining LEED® credits.

1) Determine Which Environmentally Friendly Materials Can be Used

In order to reduce waste and improve the indoor environment, sustainable materials may be used in both new construction and major renovation projects. Sustainable materials may include products containing recycled or bio-based content or environmentally preferable products.

Regional and rapidly renewable products, such as locally grown foods and bamboo flooring, are additional examples of environmentally preferable products. Use of regional materials supports local economies while reducing transportation costs. Renewable materials offer an alternative to products made from natural resources with finite supplies.

Recycled Content

Recycled content products can be divided into two categories: **pre-consumer** and **post-consumer**, depending on the stage at which the product's material was recovered from the waste stream. In building construction, pre-consumer recycled material is collected during the manufacturing process, while post-consumer recycled material includes items disposed during construction or operation. Both pre-consumer products and post-consumer products can be used in new construction or existing buildings. In the past, pre-consumer content was referred to as post-industrial content.

Recycled content products include content that was previously part of another product or material. Examples of recycled content products can be found in a list of EPA-designated products that meet or exceed recycled content

Definition

Pre-Consumer Content

As defined by LEED®, pre-consumer content is the percentage of material in a product that was recycled from manufacturing waste. Examples include sawdust, trimmed materials, and obsolete inventories.

Definition

Post-Consumer Content

As defined by LEED®, post-consumer content is the percentage of material in a product that was consumer waste. Examples include C&D debris, recycling collections, discarded material, and landscaping waste.

Figure 8 - Recycled Content Plastic Utility Pipes

Source: California Department of Resources Recycling and Recovery.

Building Focus

Propellants North Facility, Kennedy Space Center

During the renovation of the Launch Control Center firing rooms, window glazings and aluminum trusses were salvaged and reused in the Propellants North Facility.

recommendations. Solicitations for construction or renovation should specify a preference for EPA-designated products over other products.[8] Using recycled content products reduces demand for natural resources and lessens overall project waste. However, recycled content products may be limited in variety and regional availability limitations may affect cost.

Typical recycled content products used in building construction include metal studs, wall panels and decking material. Other products include plastics, bricks, glass, paint, asphalt, gypsum products, countertops and ceramic tile. An example of a recycled content product is pictured in Figure 8.

Bio-based Content

Bio-based content refers to the amount of bio-based carbon in the material or product as a percent of the weight of the total organic carbon in the material.[9] Designated products include products "that is composed in whole or significant part of biological products or renewable domestic agricultural materials (including plant, animal, and marine materials) or forestry materials."[10] Bio-based content products are readily available, reasonably priced, and rapidly renewable. At a regional level, bio-based products offer an additional market for local farm products and aid in the reduction of a facility's carbon footprint.

Typical examples of bio-based content products used in new construction include certified wood, roof coatings, water tank coatings, spray foam insulation, soy based sealant, and carpet backing. Some bio-based products may not perform as well as equivalent traditional products.

Environmentally Preferred Products

Environmentally preferred products are not as clearly defined as recycled and bio-based content products. Standards and ecolabels certify products based on a variety of sustainability criteria. Generally, these products exhibit a "lesser or reduced effect on human health and the environment over their life-cycle when compared with competing products or services that serve the same purpose."[11]

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8 If the EPA-designated products meet performance requirements and are available at a reasonable cost.

9 Guidelines for Designating Biobased Products for Federal Procurement, USDA.

10 Farm Security and Rural Investment Act of 2002, USDA.

11 *Guiding Principles for High Performance and Sustainable Buildings*, 2008.

Environmentally preferable products can improve indoor environmental quality by reducing emissions of **volatile organic compounds** (VOCs). This is an important benefit because VOCs react to nitrogen and can cause ground-level ozone or pollution effects that can harm human health. As with other products, installation and use instructions for environmentally preferable products must be carefully observed, as failure to follow manufacturer's recommendation on installation and pre-occupancy waiting period can affect both the health of construction workers and future occupants.

> *Definition*
>
> *Volatile Organic Compound*
>
> *Harmful chemical compounds that are emitted into the air during and after construction. They are found in building materials such as adhesives, sealants, paints, coatings, carpet systems, wood, cleaning chemicals and office equipment.*

2) Estimate Life-cycle Costs and Benefits

Recycled or bio-based content products, as well as environmentally preferable products generally involve no capital expense and are available at little or no cost premium as compared with conventional products. These products may require additional research, but they generally are cost-effective when chosen during the initial building design.

Potential costs of using environmentally friendly products include:

- Increased per-unit cost
- Costs associated with educating users on use of unfamiliar products
- Additional products may be needed, as environmentally preferred products may be less efficient

Potential benefits of using environmentally friendly products include:

- Increased health benefits
- Reduced occurrence of harmful VOC emissions
- Diminished use of natural materials
- Reduced impact on the natural environment

3) Install Products and Document Implementation Efforts

All uses of recycled, bio-based, and environmentally preferable products should be documented. The facility manager should establish an inventory of all environmentally friendly materials used in new construction or existing buildings. This data should include the type and location of each product.

Related LEED® Credits

The LEED® credits related to building materials are illustrated in Table 4. Definitions for all LEED® abbreviations appear in the Introduction.

Table 4 – LEED® and Building Materials

LEED-NC®	MR Credit 3: Materials Reuse
	MR Credit 4: Recycled Content
	MR Credit 6: Rapidly Renewable Materials
	MR Credit 7: Certified Wood
	IEQ Credit 4.1: Low-emitting Materials - Adhesives and Sealants
	IEQ Credit 4.2: Low-emitting Materials - Paints and Coatings
	IEQ Credit 4.3: Low-emitting Materials - Flooring Systems
	IEQ Credit 4.4: Low-emitting Materials - Composite Wood and Agrifiber Products
LEED-EB: O&M®	MR Prerequisite 1: Sustainable Purchasing Policy
	MR Credit 3: Sustainable Purchasing – Facility Alterations and Additions
LEED-ND®	GIB Credit 15: Recycled Content in Infrastructure

TOOLS

Federal Green Construction Guide for Specifiers

To address the need for a comprehensive guide for procuring green building products and construction/renovation services within the Federal government, EPA has partnered with the Federal Environmental Executive and the Whole Building Design Guide (WBDG) to develop the Federal Green Construction Guide for Specifiers.

For more information:
http://wbdg.org/design/greenspec.php

Green Purchasing Guides

The EPA provides general and specific guides for purchasing products and services.

For more information:
www.epa.gov/epp/pubs/greenguides.htm

Comprehensive Procurement Guidelines

Comprehensive Procurement Guidelines (CPG) is an EPA program that includes an online database of environmentally preferable suppliers, products, and other resources.

For more information: www.epa.gov/epawaste/conserve/tools/cpg/index.htm

Cradle to Cradle Certified^{CM} Products

Cradle to Cradle Certified^{CM} Products meet specifications of Cradle to Cradle® Certification, which enables organizations to measure progress toward sustainable design and purchasing. Although Cradle to Cradle® Certification differs from LEED® Certification, there is a Silver, Gold, and Platinum rating system.

For more information: http://c2c.mbdc.com/c2c/list.php

Bio-Preferred

The USDA's Bio-Preferred program seeks to increase use of products with bio-based content.

For more information: www.biopreferred.gov/

Forest Stewardship Council

The Forest Stewardship Council's Principles & Criteria identifies standards for certified wood products.

For more information: www.fscus.org/standards_criteria/

Green Format

Green Format is a web-based directory of green products maintained by the Construction Specifications Institute.

For more information: http://www.greenformat.com/

BuildingGreen GreenSpec®

GreenSpec® is an online product guide that includes thousands of environmentally preferable products selected by the editors of BuildingGreen, LLC.

For more information: www.buildinggreen.com/menus/

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Ongoing and Durable Products

After construction is complete, sustainable purchasing should continue with ongoing and durable product purchasing. These products and equipment are used in daily facility operations, as opposed to building materials, which are used in the construction of the facility itself. For more information on Building Materials, see page 5-11.

Examples of ongoing products materials include paper, toner, binders, batteries, and other products used by occupants. Examples of durable products include furniture, office equipment, appliances, external power adapters, televisions, and audiovisual equipment. The facility manager should encourage and oversee the purchase of recycled content products, bio-based content products, and environmentally preferable products.

The BMP for use of sustainable ongoing and durable product materials are derived from the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings* and Agency policy. Each BMP includes discussion of related NASA activities and accomplishments, relevant LEED® credits, and resources for additional information or assistance.

The ongoing and durable product materials BMP for new construction, major renovation, or existing buildings requires that in all solicitations relevant to construction, operation, maintenance of, or use in the building, every attempt should be made to procure products for operations that contain recycled or bio-based content or that are designated environmentally preferable.

Building Focus

New Town, Phase I, Langley Research Center

The New Town project will utilize low-emitting materials for building furniture and seating and adheres to a green housekeeping and office supplies policy.

BEST MANAGEMENT PRACTICE – ONGOING AND DURABLE PRODUCTS

In all solicitations relevant to operation and maintenance of or use in the building, every attempt should be made to procure materials for continued consumption that contain recycled content or bio-based content, or that are considered environmentally preferable products.

NASA Requirement

NPR 8530.1A details requirements for purchasing recycled or biobased content products, as well as other environmentally preferable products.

Environmentally friendly purchasing for ongoing operations offers another opportunity to improve sustainability performance. In many cases, products with similar performance are available at little or no cost premium. A number of agencies and organizations have developed systems and criteria to ensure that products meet environmental standards.

Purchase and use of recycled, bio-based, or environmentally preferable products are highly visible ways of demonstrating a facility's commitment to sustainability, as well as meeting federal requirements.

Implementing Sustainable Purchasing Improvements

A step-by-step approach to implementing sustainable ongoing and durable product purchasing appears in Table 5. The steps are discussed in additional detail in the subsequent narrative.

Table 5 – Implementing Sustainable Ongoing and Durable Product Purchasing

	IMPLEMENTATION STEPS
1)	**Identify Appropriate Products**
□	Analyze which environmentally friendly materials are most applicable to the facility.
2)	**Estimate Life-cycle Costs and Benefits**
□	Determine costs and benefits of the use of environmentally friendly procurement materials.
3)	**Implement Products and Document Efforts**
□	Install and use environmentally friendly products in building.
□	Collect data on implemented products.
□	Relay information to appropriate federal agencies.
□	Determine if data collected can be used towards obtaining LEED credits.

1) Identify Appropriate Products

Through purchases for building operations, facility managers should consider a number of materials and products, including recycled, bio-based, and environmentally preferable products.

Recycled Content Products

Pre- and post-consumer content in ongoing and durable product purchases has the same meaning as it does in discussion of building materials. For more information on the definition of recycled products, see page 5-13. The main difference is in the types of product being purchased; common recycled content products for ongoing and durable purchases include paper, cardboard, furniture, and electronics. Post-consumer product purchases can be incorporated into purchasing plans, vendor contracts, or other building specification documents.

An example of cardboard boxes manufactured with recycled content is pictured in Figure 9.

Bio-based Content

Bio-based content has the same meaning for ongoing and durable products as it does for building materials. For more information on bio-based content, see page 5-14. Bio-based products for ongoing operations and maintenance use include landscaping and agriculture materials, carpet, and office supplies such as badge holders, trash bags, shipping packages and labels, and soaps.[12] An example of a biodegradable trash bag appears in Figure 10.

Environmentally Preferred Products

In addition to recycled or bio-based products, managers should also consider other environmentally preferable products, as discussed in additional detail on page 5-14. The EPA's environmentally preferable catalog includes paper, furniture, office equipment, food services, electronics, and cleaning products.

Due to frequent use, cleaning products and practices offer an important opportunity for improving facility sustainability. Benefits of green cleaning include decreased building-related illnesses, improved productivity, reduced liability for building owners, and reduced occurrence of VOCs, bacteria, and fungi.

Green cleaning products, including general purpose cleaners, carpet cleaners, disinfectants, hand soaps, and paper supplies, are widely available. In some cases, green cleaning alternatives have different performance characteristics than traditional products. Maintenance and custodial staff should be consulted and trained when switching products to ensure the green alternatives are utilized appropriately.

Figure 9- Recycled Content Cardboard Boxes

Source: California Department of Resources Recycling and Recovery.

Figure 10- Bio-based Content Product Trash Bags

Source: Bio Bag.

Building Focus

Marshall Space Flight Center

Custodial practices and purchasing for all buildings at Marshall Space Flight Center are managed by a Green Cleaning contract.

[12] BioPreferred Catalog, USDA.

2) Estimate Life-cycle Costs and Benefits

The costs and benefits of environmentally friendly ongoing and durable products are similar to those for environmentally friendly building materials. See page 5-15 for additional discussion.

3) Implement Products and Document Efforts

As with the use of environmentally friendly building materials, the use of environmentally friendly products and cleaning materials should be documented. The facility manager should establish an inventory of all environmentally friendly materials used throughout facility operations. This data should include the type and application of each product.

Related LEED® Credits

The LEED® credits related to ongoing and durable products are illustrated in Table 6. Definitions for all LEED® abbreviations appear in the Introduction.

Table 6 – LEED® and Ongoing and Durable Products

LEED-NC®	None
LEED-EB: O&M®	MR Prerequisite 1: Sustainable Purchasing Policy
	IEQ Prerequisite 3: Green Cleaning Policy
	IEQ Credit 1.4: Indoor Air Quality Best Management Practices - Reduce Particulates in Air Distribution
	IEQ Credit 3.3: Purchase of Sustainable Cleaning Products and Materials
	IEQ Credit 3.5: Indoor Chemical and Pollutant Source Control
LEED-ND®	GIB Credit 15: Recycled Content in Infrastructure

TOOLS

Federal Green Construction Guide for Specifiers

See page 5-16.

For more information:
http://wbdg.org/design/greenspec.php

Green Purchasing Guides

See page 5-16.

For more information:
www.epa.gov/epp/pubs/greenguides.htm

Comprehensive Procurement Guidelines

See page 5-17.

For more information:
www.epa.gov/epawaste/conserve/tools/cpg/index.htm

Cradle to Cradle Certified[CM] Products

See page 5-17.

For more information: http://c2c.mbdc.com/c2c/list.php

Bio-Preferred

See page 5-17.

For more information: www.biopreferred.gov/

Forest Stewardship Council

See page 5-17.

For more information: www.fscus.org/standards_criteria/

Green Format

See page 5-17.

For more information: http://www.greenformat.com/

BuildingGreen GreenSpec®

See page 5-17.

For more information: www.buildinggreen.com/menus/

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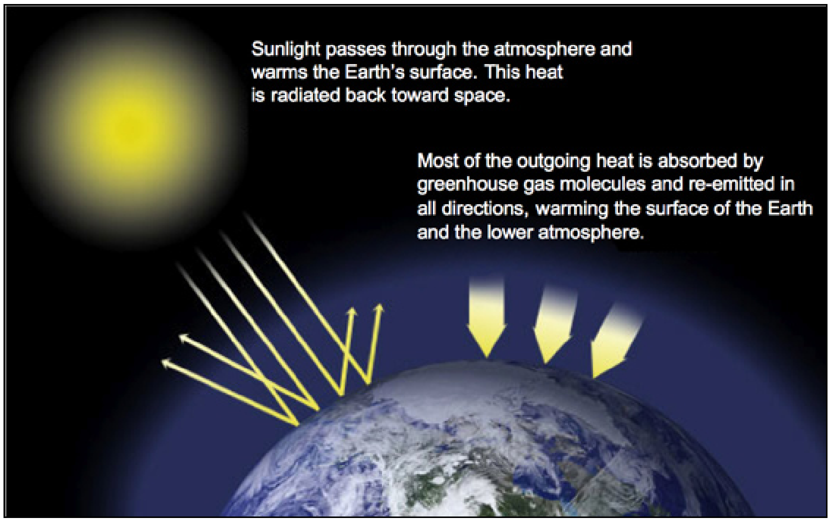
Ozone-Depleting Compounds

Ozone-depleting compounds (ODC), **chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and halons** found in older building systems pose significant threats to the ozone layer. The ozone layer prevents harmful radiation from passing through the Earth's atmosphere. Another method some gases threaten the environment is their global warming potential, through what is known as the Greenhouse Effect. An illustration of this effect appears in Figure 11.

The BMP for reduction of the use of ODCs is derived from the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings* and Agency policy. The BMP includes discussion of related NASA activities and accomplishments, relevant LEED® credits, and resources for additional information or assistance.

The ODC BMPs for new construction, major renovation, or existing buildings requires elimination of the use of ODCs during and after construction where alternative Environmentally Preferable Products are available.

Figure 11 - The Greenhouse Effect



Source: NASA.

> *Definition*
>
> *Chlorofluorocarbons*
>
> *A group of chemical compounds commonly found in refrigerants, aerosols, and other applications shown to have a negative impact on the environment, including ozone depletion.*

> *Definition*
>
> *Hydrochlorofluorocarbons*
>
> *A class of chemical compounds including hydrogen, chlorine, fluorine, and carbon. They contain chlorine and thus deplete stratospheric ozone, but to a much lesser extent than CFCs and so are being used to replace the CFCs. HCFCs do have global warming potential, and so some HCFCs are being phased out.*

> *Definition*
>
> *Halons*
>
> *In the context of the Clean Air Act, fire extinguishing agents containing bromine, fluorine, and carbon. They cause ozone depletion and are no longer produced in the United States.*

BEST MANAGEMENT PRACTICE – OZONE-DEPLETING COMPOUNDS

Eliminate the use of ozone-depleting compounds during and after construction where alternative Environmentally Preferable Products are available.

NASA Requirement

NPR 8820.2F eliminates the use of ozone-depleting compounds during and after construction where alternative environmentally preferable products are available, consistent with either the Montreal Protocol and Title VI of the Clean Air Act Amendments of 1990, or equivalent overall air quality regulations which take life-cycle impacts into account.

NPR 8820.2F also requires all new construction and major renovation projects to meet LEED® Silver certification. By extension, this requires zero use of CFC-based refrigerants in new base building heating, ventilating, air-conditioning, and refrigerating (HVACR) systems, or development of a phase-out plan for all CFC-based refrigerants. Plans should include economic analysis.

Although some ODCs are no longer produced in the United States and no longer utilized in new equipment, they are still present in numerous existing buildings. Systems and materials that contain ODCs may include refrigeration systems, heating, ventilating, and air-conditioning (HVAC) systems, fire protection systems, propellants, and solvents.

Some environmentally safe technologies or system upgrades may involve significant upfront costs. However, a variety of federal requirements, including Executive Order (EO) 12843, require maximizing the use of safe alternatives to ozone-depleting substances. Replacing refrigerant systems reduces the impact on the ozone layer, which protects human health.

Implementing Ozone-Depleting Compound Reductions

Table 7 lists a step-by-step approach to elimination of ODCs, with each step discussed in additional detail in the subsequent narrative.

Table 7 – Implementing Ozone-Depleting Compound Reductions

IMPLEMENTATION STEPS	
1)	**Determine Current ODC Uses**
□	Inventory systems that use ODCs.
□	Determine which type of ODCs are used at the facility.
2)	**Identify Areas for ODC Reduction**
□	Establish goals and a plan to reduce ODCs.
□	Use established policies as guidelines to reduce and phase-out ODCs.
3)	**Use Environmentally Friendly Alternatives**
□	Determine if equipment replacement is preferred implementation method.
□	Determine if replacement of ODC is preferred implementation method.
4)	**Estimate the Life-cycle Costs and Benefits**
□	Determine costs and benefits of the reduction of ODC techniques.
5)	**Prioritize, Finance, and Implement ODC Reduction Methods**
□	Prioritize implementation methods.
□	Determine financing methods.
□	Implement ODC reduction methods.

1) Determine Current ODC Uses

The facility manager should first determine which building systems use ODCs. This inventory should also identify the types of ODCs used within those systems. Leakage rates, to determine quantities of ODCs escaping into the atmosphere, should be calculated. For new construction, the facility manager should consider which systems will potentially use ODCs, and attempt to replace them with systems that do not use ODCs.

2) Identify Areas for ODC Reduction

Once the inventory of ODC use is completed, the facility manager should develop a management plan to reduce ODC use throughout the facility, using existing regulations as guidance. The Montreal Protocol and the Clean Air Act both establish ODC reduction goals, and these goals should be used in establishing facility goals.

Emission of ODCs can be reduced by using refrigerants with lower ozone and global warming impacts, minimizing leakage from refrigerant systems, and using efficient or long-lasting refrigerant equipment. Building system designs that eliminate active cooling systems and refrigerants benefit the ozone layer, and also provide significant opportunities for reductions in energy use. Creative and comprehensive approaches across functional areas can provide overlapping benefits.

The Montreal Protocol

In 1987, *The Montreal Protocol on Substances that Deplete the Ozone Layer* was established by the United Nations to protect the world's ozone layer, protect human health, and diminish the ecological effects of ozone depletion. The treaty ended the production of First-Generation ODCs, including halons and CFCs through a series of phase-outs from 1994-2005. The Montreal Protocol also encourages a reduction of Second-Generation ODCs, such as HCFCs, through 2030.[13]

The Clean Air Act

The *Montreal Protocol* was incorporated into United States law in 1990 through the passage of an amendment in the Clean Air Act. This amendment provides a methodology for the implementation of *Montreal Protocol* standards in the United States. Its passage has allowed the United States to develop methods to further reduce ODCs, such as taxing use of ODCs and encouraging use of safer alternatives.

[13] "Montreal Protocol," EPA, 2007.

Ozone depleting substances (ODS), which are similar to ODCs, are listed in Figure 12.

Figure 12 – Ozone Depleting Substance Phase Out Schedule

US Production of First-Generation ODS Phased Out on Schedule		
Chemical Group	**Production Phase Out Date**	**Deadline Met**
Halons	January 1, 1994	✓
Chlorofluorocarbons	January 1, 1996	✓
Carbon tetrachloride	January 1, 1996	✓
Hydrobromofluorocarbons	January 1, 1996	✓
Methyl chloroform	January 1, 1996	✓
Chlorobromomethane	August 18, 2003	✓
Methyl bromide	January 1, 2005	✓

US Production of Second-Generation ODS Being Phased Out on Schedule		
Chemical Group	**Production Phase Out Date**	**Deadline Met**
Hydrochloro-fluorocarbons	Cut production 35 percent by January 1, 2004	✓ (One year ahead of schedule)
	Cut production 65 percent by January 1, 2010	On track to meet all future requirements
	Cut production 90 percent by January 1, 2015	
	Cut production 99.5 percent by January 1, 2020	
	Complete phase out by January 1, 2030	

Source: EPA.

3) Implement Environmentally Friendly Alternatives

When the ODC inventory is complete and methods for ODC reduction are established, the facility manager should implement these methods. A reduction in ODC usage improves facility indoor environmental quality (IEQ) by providing a healthier, less contaminated atmosphere for building occupants. ODC use in facilities may be reduced through equipment replacement or ODC replacement, which substitutes a different gas refrigerant for the ODC.

Acceptable replacements can be found through the EPA's Significant New Alternatives Policy (SNAP) product lists, which include suggested substitution gas refrigerants, cleaning solvents, and fire suppression products.[14] A number of zero ODC products are available, including hydrofluorocarbon (HFC) refrigerants, carbon dioxide blowing agents and propellants, and water and clean-agent fire-suppression systems.

4) Estimate the Life-cycle Costs and Benefits

The costs and benefits of each technique should be evaluated by the facility manager. Zero ODC products are generally available at little or no additional first cost. Replacing equipment may, however, have an impact on refrigerant and energy use. Managers should consider the expected equipment lifetime in calculations of costs and savings. Calculations which can help determine the cost-effectiveness of ODC reductions and acceptable thresholds for building equipment include the Life-Cycle Ozone Depletion Potential (LCODP) and the Life-Cycle Direct Global Warming Potential (LCGWP), both of which can be found through the United States Green Building Council (USGBC).

Potential costs of a reduction in use of ODCs include:

- Purchase and installation of equipment
- Increased refrigerant cost and ongoing maintenance

Potential benefits of reduction in use of ODCs include:

- Healthier indoor environmental quality
- Reduced global warming
- Protection of the ozone layer

5) Prioritize, Finance, and Implement ODC Reduction Methods

Funding for implementation of ODC reduction techniques may not be immediately available, especially for equipment replacement, so determining which option is most cost-effective is an important first step. Due to funding limitations, facility managers should identify whether any refrigerants in use are scheduled for phase-out. In addition, older equipment that uses ODCs can sometimes be replaced with more efficient equipment, which also reduces energy consumption.

[14] "SNAP Program," EPA, 2010.

Potential funding mechanisms include:

- Agency appropriations
- Energy Savings Performance Contracts
- Utility Energy Services Contracts

Related LEED® Credits

The LEED® credits related to ozone-depleting compounds are illustrated in Table 8. Definitions for all LEED® abbreviations appear in the Introduction.

Table 8 – LEED® and Ozone Depleting Compounds

LEED-NC®	EA Prerequisite 3: Fundamental Refrigerant Management
	EA Credit 4: Enhanced Refrigerant Management
LEED-EB: O&M®	EA Prerequisite 3: Fundamental Refrigerant Management
	EA Credit 5: Enhanced Refrigerant Management
LEED-ND®	None

TOOLS

Environmental Protection Agency

The EPA provides information and tools regarding ozone, ozone-depleting substances, benefits of CFC phase-out, and ozone-related regulations, programs, and partnerships.

For more information: http://epa.gov/ozone/strathome.html

Significant New Alternatives Policy

Significant New Alternatives Policy Program is an EPA program that provides information on environmentally friendly alternatives for a variety of products, including refrigeration and air conditioning equipment, solvents, fire suppression systems, adhesives, coatings, and other substances.

For more information: www.epa.gov/ozone/snap/index.html

ASHRAE Service Life and Maintenance Cost Database

This database is a collection of up-to-date information regarding the service life and maintenance costs for HVAC equipment.

For more information: www.ashrae.org/database

APPENDIX A. LEED® CERTIFICATION CHECKLIST

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LEED-NC® v3 (2009) & EXISTING FEDERAL REGULATIONS				
LEED® CREDIT	**LEED® CREDIT DESCRIPTION**	**REQ'D CREDIT**	**FEDERAL REGULATION**	**NOTES**
Sustainable Sites (SS)				
SS-P1	Construction Activity Pollution Prevention (Prerequisite)	X	NASA NPD 8500.1B	Requires coordination/cooperation with federal, state and local regulatory agencies
			NASA NPR 8820.2F	Requires all new construction projects meet LEED® Silver
			NASA NPR 8810.1	Requires Centers establish a narrative and graphic presentation of erosion control measures
SS-C1	Site Selection		NASA NPD 8500.1B	Requires coordination/cooperation with federal, state and local regulatory agencies
			42 U.S.C. §2473d	Requires agencies to consider the purchase, lease, or expansion of NASA facilities in abandoned or underutilized buildings, grounds, and facilities in urban or rural depressed communities
			EO 13514	Requires that planning for new federal facilities and leases considers sites that are pedestrian friendly, near existing employment centers, and accessible to public transport and emphasizes existing central cities and, in rural communities, existing or planned town centers
SS-C2	Development Density & Community Connectivity			
SS-C3	Brownfield Redevelopment			
SS-C4.1	Alternative Transportation - Public Transportation Access			
SS-C4.2	Alternative Transportation - Bicycle Storage & Changing Rooms			
SS-C4.3	Alternative Transportation - Low Emitting & Fuel-Efficient Vehicles		EO 13423	Ensures, if the agency operates a fleet of at least 20 vehicles, the agency uses Plug-in Hybrid (PIH) vehicles when PIH vehicles are commercially available and life-cycle cost-competitive
SS-C4.4	Alternative Transportation - Parking Capacity		NASA NPD 8500.1B	Requires coordination/cooperation with federal, state and local regulatory agencies
SS-C5.1	Site Development - Protect or Restore Habitat		NASA NPR 8580.1	Requires discussion of the landscaping management policies and procedures regarding use of regionally native plants and design/use/promotion of construction practices that minimize adverse effects on the natural habitat
SS-C5.2	Site Development - Maximize Open Space		NASA NPD 8500.1B	Requires coordination/cooperation with federal, state and local regulatory agencies
SS-C6.1	Stormwater Design - Quantity Control		NASA NPR 8810.1	Requires Centers establish a narrative and graphic presentation of erosion control measures
			NASA NPR 8820.2F	Requires project designers minimize stormwater runoff and polluted site runoff
SS-C6.2	Stormwater Design - Quality Control		NASA NPR 8810.1	Requires Centers establish a narrative and graphic presentation of erosion control measures
			NASA NPR 8820.2F	Requires project designers minimize stormwater runoff and polluted site runoff
SS-C7.1	Heat Island Effect - Nonroof			
SS-C7.2	Heat Island Effect - Roof			
SS-C8	Light Pollution Reduction			

LEED-NC® v3 (2009) & EXISTING FEDERAL REGULATIONS				
LEED® CREDIT	LEED® CREDIT DESCRIPTION	REQ'D CREDIT	FEDERAL REGULATION	NOTES
Water Efficiency (WE)				
WE-P1	Water Use Reduction (Prerequisite)	X		
WE-C1	Water Efficient Landscaping		NASA NPR 8580.1	Requires discussion of the landscaping management policies and procedures regarding implementation of water-efficient practices
			EPAct 2005	Mandates that if water is used to achieve energy efficiency, water conservation technologies be applied
			NASA NPR 8570.1	Requires federal facilities meet 4 of 10 BMPs for water efficiency, which include water efficient landscaping
			EO 13423	Requires federal agencies reduce water consumption intensity, relative to FY 2007 baseline, by two percent annually through FY 2015 or 16 percent by the end of FY 2015
			EO 13514	Requires that federal agencies reduce industrial, landscaping, and agricultural water consumption by 2 percent annually or 20 percent by the end of FY 2020 relative to a FY 2010 baseline
			NASA NPR 8820.2F	Requires designer reduce outdoor potable water consumption by at least 50 percent over that used by conventional means
WE-C2	Innovative Wastewater Technologies		NASA NPR 8580.1	Requires discussion of the landscaping management policies and procedures regarding implementation of water-efficient practices
			EO 13423	Requires federal agencies reduce water consumption intensity, relative to FY 2007 baseline, by two percent annually through FY 2015 or 16 percent by the end of FY 2015
			EO 13514	Requires that federal agencies identify, promote, and implement water reuse strategies consistent with state law that reduce potable water consumption
			NASA NPR 8570.1	Requires implementation of water conservation measures that modernize aging facilities and infrastructure
			NASA NPR 8570.1	Requires federal facilities meet 4 of 10 BMPs for water efficiency, including toilets and urinals
			48 CFR 23	Promotes policies to acquire supplies and services that promote water efficiency
			NASA NPR 8820.2F	Requires designer reduce potable water consumption of latrine fixtures by at least 20 percent from the EPAct 1992 standards
WE-C3	Water Use Reduction	X	NASA NPR 8580.1	Requires discussion of the landscaping management policies and procedures regarding implementation of water-efficient practices
			EPAct 2005	Mandates if water is used to achieve energy efficiency, water conservation technologies be applied
			EO 13423	Requires federal agencies reduce water consumption intensity, relative to FY 2007 baseline, by two percent annually through FY 2015 or 16 percent by the end of FY 2015
			EO 13514	Requires that federal agencies reduce potable water consumption intensity by 2 percent annually through FY 2020 or 26 percent by the end of FY 2020 relative to a FY 2007 baseline
			EO 13514	Requires that agencies pursue cost-effective, innovative strategies to minimize consumption of energy, water, and materials
			48 CFR 23	Promotes policies to acquire supplies and services that promote water efficiency
			NASA NPR 8570.1	Requires Energy Managers and facilities maintenance personnel minimize water consumption without affecting safety or mission operations
			NASA NPR 8570.1	Requires federal facilities meet 4 of 10 BMPs for water efficiency, which include faucets, showerheads, boilers, and steam systems
			NASA NPR 8570.1	Requires implementation of water conservation measures that modernize aging facilities and infrastructure
			NASA NPR 8820.2F	Requires designer reduce outdoor potable water consumption by at least 50 percent over that used by conventional means
			NASA NPR 8820.2F	Requires designer reduce potable water consumption of latrine fixtures by at least 20 percent from the EPAct 1992 standards

LEED-NC® v3 (2009) & EXISTING FEDERAL REGULATIONS

LEED® CREDIT	LEED® CREDIT DESCRIPTION	REQ'D CREDIT	FEDERAL REGULATION	NOTES
Energy & Atmosphere (EA)				
EA-P1	Fundamental Commissioning of the Building Energy Systems (Prerequisite)	X	NASA NPD 8820.2C	Requires incorporating building commissioning into the planning and execution of facility projects
			NASA NPR 8820.2F	Requires all new construction projects meet LEED® Silver
			EISA 2007	Requires consideration of recommissioning and/or retrocommissioning of federal facilities
			NASA NPR 8820.2F	Requires commissioning of installed equipment, systems, building envelope, and other building elements
			NASA NPR 8820.2F	Requires total building commissioning of installed items and associated systems as prescribed by the LEED® system
			NASA NPR 8831.2D	Requires building commissioning as part of the Reliability-Centered Maintenance (RCM) process
EA-P2	Minimum Energy Performance (Prerequisite)	X	NASA NPR 8820.2F	Requires all new construction projects meet LEED® Silver
			NASA NPR 8820.2F	Mandates all new federal buildings achieve savings of at least 30 percent below the ASHRAE Standard 90.1-2004 or the 2004 IECC
			EO 13423	Requires that agencies, relative to FY 2003 baseline, improve energy efficiency by three percent annually or by 30 percent by the end of FY 2015
			EO 13514	Requires that federal agencies implement best management practices for the energy-efficient management of servers and federal data centers
			EO 13514	Requires that 95 percent of new contract actions, task orders, and delivery orders for products and services are energy efficient, water efficient, bio-based, environmentally preferable, non-ozone depleting, contain recycled content, or are non-toxic or less-toxic alternatives where such products and services meet agency performance requirements
			EO 13514	Requires that all new federal buildings entering the design phase in 2020 or later are designed to achieve zero net energy by 2030
			EO 13514	Requires that agencies pursue cost-effective, innovative strategies to minimize consumption of energy, water, and materials
			NASA NPR 8570.1	Requires implementation of energy conservation measures that modernize aging facilities and infrastructure
			NASA NPR 8570.1	Mandates a goal of improving energy efficiency of buildings by 25 percent by FY 2010 relative to FY 1990
			NASA NPR 8570.1	Requires Centers to ensure new facilities are designed and constructed to comply with federal energy performance standards
			NASA NPR 8820.2F	Requires that project designers establish a whole building performance target and design to earn the ENERGY STAR target
			NASA NPR 8820.2F	Requires that project designers reduce the energy cost budget by 30 percent compared to building baseline per ASHRAE 90.1-2004

LEED-NC® v3 (2009) & EXISTING FEDERAL REGULATIONS

LEED® CREDIT	LEED® CREDIT DESCRIPTION	REQ'D CREDIT	FEDERAL REGULATION	NOTES
EA-P3	Fundamental Refrigerant Management (Prerequisite)	X	NASA NPR 8820.2F	Requires all new construction projects meet LEED® Silver
			EO 12843	Requires federal agencies to maximize the use of safe alternatives to ozone-depleting substances
			EO 12843	Encourages revision of procurement practices, modification of specifications and contracts that require the use of ozone-depleting substances, and substitution of non-ozone-depleting substances
			NASA NPR 8820.2F	Eliminates the use of ozone-depleting compounds during and after construction, consistent with the Montreal Protocol and Title VI of the Clean Air Act, 1990, or equivalent overall air quality benefits
EA-C1	Optimize Energy Performance		EPAct 2005	Mandates a two percent reduction per year in energy consumption per gross square foot compared to 2003
			NASA NPR 8820.2F	Mandates all federal buildings achieve savings of at least 30 percent below the ASHRAE 90.1-2004 or the 2004 IECC
			NASA NPR 8570.1	Requires implementation of energy conservation measures that modernize aging facilities and infrastructure
			NASA NPR 8570.1	Mandates a goal of improving energy efficiency of buildings by 25 percent by FY 2010 relative to FY 1990
			EISA 2007	Requires reduction in fossil fuel energy uses relative to CBECS or RECS
			EO 13423	Requires agencies improve energy efficiency and reduce greenhouse emissions, through reduction of energy intensity, by three percent annually or 30 percent by FY 2015
			EO 13514	Requires that 95 percent of new contract actions, task orders, and delivery orders for products and services are energy efficient, water efficient, bio-based, environmentally preferable, non-ozone depleting, contain recycled content, or are non-toxic or less-toxic alternatives where such products and services meet agency performance requirements
			EO 13514	Requires that agencies pursue cost-effective, innovative strategies to minimize consumption of energy, water, and materials
EA-C2	On-Site Renewable Energy		EISA 2007	For all new construction, as compared to other reasonably available technologies, at least 30 percent of hot water demand shall be met through solar hot water heaters
			EPAct 2005	Requires renewable energy consumption of 3 percent through FY 2009, 5 percent through FY 2012, and 7.5 percent after FY 2013
			EPAct 2005	Establishes a goal to install 20,000 solar energy systems in federal buildings by 2010
			NASA NPR 8570.1	Requires expanded use of renewable energy for facilities by implementing renewable energy and by purchasing electricity from renewable sources
			EO 13243	Mandates that agencies ensure at least half of the statutorily required renewable energy consumed comes from new renewable sources, and to the extent possible, the agency implements renewable energy generation on agency property for agency use
EA-C3	Enhanced Commissioning		NASA NPD 8820.2C	Requires incorporating building commissioning into the planning and execution of facility projects
			EISA 2007	Requires consideration of recommissioning and/or retrocommissioning of federal facilities
			NASA NPR 8820.2F	Requires commissioning of installed equipment, systems, building envelope, and other building elements
			NASA NPR 8820.2F	Requires total building commissioning of installed items and associated systems as prescribed by the LEED® system
			NASA NPR 8831.2D	Requires building commissioning as part of the Reliability-Centered Maintenance (RCM) process
EA-C4	Enhanced Refrigerant Management		NASA NPR 8820.2F	Eliminates the use of ozone-depleting compounds during and after construction, consistent with the Montreal Protocol and Title VI of the Clean Air Act, 1990, or equivalent overall air quality benefits
			EO 12843	Encourages revision of procurement practices, modification of specifications and contracts that require the use of ozone-depleting substances, and substitution of non-ozone-depleting substances
			EO 12843	Requires federal agencies to maximize the use of safe alternatives to ozone-depleting substances

LEED® CREDIT	LEED® CREDIT DESCRIPTION	REQ'D CREDIT	FEDERAL REGULATION	NOTES
LEED-NC® v3 (2009) & EXISTING FEDERAL REGULATIONS				
EA-C5	Measurement and Verification		EPAct 2005	Mandates all federal buildings be metered for the purpose of efficient use of energy
			EISA 2007	Provides for audits of federal green building performance
			NASA NPR 8570.1	Mandates Energy Efficiency and Conservation Programs should include documenting an Energy Use Index (EUI), complete record of energy audits since 1991, and an in-depth energy audit for the facility
			NASA NPR 8570.1	Mandates a goal of conducting energy audits for approximately 10 percent of total facilites' gross square footage each year until all facilities have been audited.
			NASA NPR 8831.2D	Requires utility data management, including metering and analysis of all utilities
EA-C6	Green Power		EISA 2007	For all new construction, as compared to other reasonably available technologies, at least 30 percent of hot water demand shall be met through solar hot water heaters
			EISA 2007	Requires reduction in fossil fuel energy use relative to the CBECS
			EPAct 2005	Requires renewable energy consumption of three percent through FY 2009, five percent through FY 2012, and 7.5 percent after FY 2013
			EPAct 2005	Establishes a goal to install 20,000 solar energy systems in federal buildings by 2010
			NASA NPR 8570.1	Requires expanded use of renewable energy for facilities by implementing renewable energy and by purchasing electricity from renewable sources
			EO 13243	Mandates that agencies ensure at least half of the statutorily-required renewable energy consumed by the agency comes from new renewable sources, and to the extent possible, the agency implements renewable energy generation on agency property for agency use
Materials & Resources (MR)				
MR-P1	Storage & Collection of Recyclables (Prerequisite)	X	EO 13423	Requires cost-effective waste prevention and recycling programs in facilities
			NASA NPR 8820.2F	Requires all new construction to meet LEED® Silver
MR-C1.1	Building Reuse - Maintain Existing Walls, Floors and Roof			
MR-C1.2	Building Reuse - Maintain Interior Non-Structural Elements			
MR-C2	Construction Waste Management		NASA NPR 8820.2F	Requires identification of local recycling and salvage operations, and to recycle or salvage at least 50 percent of construction, demolition, and land clearing waste (excluding soil)
MR-C3	Materials Reuse		EO 13514	Requires increasing the diversion of compostable and organic material from the waste stream
			EO 13514	Requires diverting at least 50 percent of non-hazardous solid waste by the end of FY 2013
			EO 13514	Requires that agencies pursue cost-effective, innovative strategies to minimize consumption of energy, water, and materials
			NASA NPR 8530.1A	Requires review and revision of NASA specifications and standards to eliminate barriers to the preference for recovered materials
			NASA NPR 8820.2F	Requires maximization of reuse rather than disposal in projects that include demolition
			NASA NPR 8820.2F	Requires identification of local recycling and salvage operations, and to recycle or salvage at least 50 percent of construction, demolition and land clearing waste (excluding soil)

LEED-NC® v3 (2009) & EXISTING FEDERAL REGULATIONS

LEED® CREDIT	LEED® CREDIT DESCRIPTION	REQ'D CREDIT	FEDERAL REGULATION	NOTES
MR-C4	Recycled Content		EO 13423	Requires use of paper that is of at least 30 percent post-consumer fiber content
			EO 13514	Requires diverting at least 50 percent of non-hazardous solid waste by the end of FY 2013.
			RCRA 1976	Requires the federal government to purchase recycled materials, when possible
			NASA NPR 8820.2F	Requires use of products meeting or exceeding USDA bio-based content recommendations
			NASA NPR 8820.2F	Requires use of products meeting or exceeding EPA's recycled content recommendations
MR-C5	Regional Materials			
MR-C6	Rapidly Renewable Materials		NASA NPR 8820.2F	For products not covered by USDA bio-based content recommendations, requires use of products made from rapidly renewable resources
MR-C7	Certified Wood		NASA NPR 8820.2F	For products not covered by USDA bio-based content recommendations, requires use of products made from certified sustainable wood
Indoor Environmental Quality (IEQ)				
IEQ-P1	Minimum Indoor Air Quality (IAQ) Performance (Prerequisite)	X	NASA NPR 8820.2F	Requires compliance with ASHRAE Standard 62.1-2004, Ventilation for Acceptable Indoor Air Quality; Requires all new construction to meet LEED® Silver
IEQ-P2	Environmental Tobacco Smoke (ETS) Control (Prerequisite)	X	EO 13058	Mandates federal workplaces be smoke-free environments by prohibiting smoking in all interior spaces and outdoor spaces in front of air intake ducts. Also recommends Agency heads establish a smoking ban around building perimeters
			NASA NPR 8820.2F	Requires all new construction to meet LEED® Silver
IEQ-C1	Outdoor Air Delivery Monitoring			
IEQ-C2	Increased Ventilation		NASA NPR 8820.2F	Requires compliance with ASHRAE Standard 62.1-2004, Ventilation for Acceptable Indoor Air Quality
IEQ-C3.1	Construction IAQ Management Plan - During Construction		NASA NPR 8820.2F	Ensures compliance with SMACNA Indoor Air Quality Guidelines for Occupied Buildings under Construction, 1995
IEQ-C3.2	Construction IAQ Management Plan - Before Occupancy		NASA NPR 8820.2F	Requires after construction and prior to occupancy, a minimum 72-hour flush-out with maximum outdoor air, consistent with achieving relative humidity no greater than 60 percent
IEQ-C4.1	Low-Emitting Materials - Adhesives and Sealants		NASA NPR 8820.2F	Requires use of materials and products with low-pollutant emissions, including adhesives, sealants, paints, carpet systems, and furnishings
IEQ-C4.2	Low-Emitting Materials - Paints and Coatings		NASA NPR 8820.2F	Requires use of materials and products with low-pollutant emissions, including adhesives, sealants, paints, carpet systems, and furnishings
IEQ-C4.3	Low-Emitting Materials - Flooring Systems		NASA NPR 8820.2F	Requires use of materials and products with low-pollutant emissions, including adhesives, sealants, paints, carpet systems, and furnishings
IEQ-C4.4	Low-Emitting Materials - Composite Wood and Agrifiber Products		NASA NPR 8820.2F	Requires use of materials and products with low-pollutant emissions, including adhesives, sealants, paints, carpet systems, and furnishings
IEQ-C5	Indoor Chemical and Pollutant Source Control			
IEQ-C6.1	Controllability of Systems - Lighting			
IEQ-C6.2	Controllability of Systems - Thermal Comfort	X	NASA NPR 8820.2F	Requires compliance with ASHRAE 55-2004 and 62.1-2004
IEQ-C7.1	Thermal Comfort - Design	X	NASA NPR 8820.2F	Requires compliance with ASHRAE 55-2004
IEQ-C7.2	Thermal Comfort - Verification		NASA NPR 8820.2F	Requires compliance with ASHRAE 55-2004

LEED-NC® v3 (2009) & EXISTING FEDERAL REGULATIONS				
LEED® CREDIT	**LEED® CREDIT DESCRIPTION**	**REQ'D CREDIT**	**FEDERAL REGULATION**	**NOTES**
IEQ-C8.1	Daylight and Views - Daylight	X	NASA NPR 8820.2F	Establishes a minimum daylight factor of two percent in 75 percent of all spaces occupied for critical visual tasks, and includes automatic dimming controls and appropriate glare control
IEQ-C8.2	Daylight and Views - Views		NASA NPR 8820.2F	Establishes a minimum daylight factor of two percent in 90 percent of all spaces occupied for critical visual tasks, and includes automatic dimming controls and appropriate glare control
Innovation In Design (ID)				
ID-C1	Innovation in Design			
ID-C2	LEED® Accredited Professional			

LEED-EB:O&M® (2009) & EXISTING FEDERAL REGULATIONS				
LEED® CREDIT	LEED® CREDIT DESCRIPTION	REQ'D CREDIT	FEDERAL REGULATION	POLICY GAP/NOTES
Sustainable Sites (SS)				
SS-C1	LEED® Certified Design and Construction		NASA NPR 8820.2F	Requires new construction and major renovations after 10/01/2005 meet LEED® Silver
SS-C2	Building Exterior and Hardscape Management Plan			
SS-C3	Integrated Pest Management (IPM), Erosion Control and Landscape Management Plan		NASA NPR 8580.1	Requires a discussion of policies and procedures for IPM including initiatives to reduce pesticide use
			NASA NPR 8810.1	Requires Centers establish a narrative and graphic presentation of the existing landscape design program and erosion control
			NASA NPR 8831.2D	Recommends landscaping plans emphasize low-maintenance features
			NASA NPR 8831.2D	Requires grounds care work plans specify appropriate environmental controls for chemicals
			NASA NPR 8580.1	Requires discussion of policies and procedures for landscape management regarding construction practices that minimize adverse effects on the natural habitat, and pollution prevention
SS-C4	Alternative Commuting Transportation		NASA NPR 3600.1A	Requires allowing compressed and flexible work schedules
SS-C5	Site Development - Protect or Restore Habitat		NASA NPR 8580.1	Requires general discussion of policies and procedures for landscaping management regarding the use of regionally native plants and minimizing adverse effects on the natural habitat
SS-C6	Stormwater Quantity Control		NASA NPR 8820.2F	Requires designers minimize stormwater runoff and polluted site runoff
SS-C7.1	Heat Island Reduction - Nonroof			
SS-C7.2	Heat Island Reduction - Roof			
SS-C8	Light Pollution Reduction			
Water Efficiency				
WE-P1	Minimum Indoor Plumbing Fixture and Fitting Efficiency (Prerequisite)	X	EO 13423	Requires agencies reduce water consumption intensity, relative to FY 2007 baseline, by two percent annually or 16 percent by the end of FY 2015
			EO 13514	Requires that federal agencies reduce potable water consumption intensity by 2 percent annually through FY 2020 or 26 percent by the end of FY 2020 relative to a FY 2007 baseline
			EO 13514	Requires that federal agencies identify, promote, and implement water reuse strategies consistent with state law that reduce potable water consumption
			EO 13514	Requires management of building systems to reduce the consumption of energy, water, and materials and identification of alternatives to renovation that reduce existing asset deferred maintenance costs
			NASA NPR 8570.1	Requires federal facilities meet four of ten BMPs for water efficiency, including toilets, urinals, faucets, and showerheads
			NASA NPR 8820.2F	Requires project designer reduce potable water consumption of latrine fixtures by at least 20 percent from the EPAct 1992 fixture performance baseline
			NASA NPR 8820.2F	Requires major renovation projects to meet LEED® Silver
WE-C1	Water Performance Measurement		EISA 2007	Requires evaluation of water usage
			NASA NPR 8831.2D	Requires utility data management, including metering of all utilities

LEED-EB:O&M® (2009) & EXISTING FEDERAL REGULATIONS

LEED® CREDIT	LEED® CREDIT DESCRIPTION	REQ'D CREDIT	FEDERAL REGULATION	POLICY GAP/NOTES
WE-C2	Additional Indoor Plumbing Fixture and Fitting Efficiency		EO 13423	Requires agencies reduce water consumption intensity, relative to FY 2007 baseline, by two percent annually or 16 percent by the end of FY 2015
			EO 13514	Requires that federal agencies reduce potable water consumption intensity by 2 percent annually through FY 2020 or 26 percent by the end of FY 2020 relative to a FY 2007 baseline
			EO 13514	Requires that federal agencies identify, promote, and implement water reuse strategies consistent with state law that reduce potable water consumption
			EO 13514	Requires management of building systems to reduce the consumption of energy, water, and materials and identification of alternatives to renovation that reduce existing asset deferred maintenance costs
			NASA NPR 8570.1	Requires federal facilities meet four of ten BMPs for water efficiency, including toilets, urinals, faucets, and showerheads
			NASA NPR 8820.2F	Requires project designer reduce potable water consumption of latrine fixtures by at least 20 percent from the EPAct 1992 fixture performance baseline
WE-C3	Water Efficient Landscaping	X	EO 13423	Requires agencies reduce water consumption intensity, relative to FY 2007 baseline, by two percent annually or 16 percent by the end of FY 2015
			EO 13514	Requires that federal agencies reduce industrial, landscaping, and agricultural water consumption by 2 percent annually or 20 percent by the end of FY 2020 relative to a FY 2010 baseline
			NASA NPR 8570.1	Requires federal facilities meet four of ten BMPs for water efficiency, including water efficient landscaping
			NASA NPR 8820.2F	Requires project designer reduce outdoor potable consumption by at least 50 percent over conventional means of irrigation
WE-C4	Cooling Tower Water Management		NASA NPR 8570.1	Cooling Tower BMP recommends installing conductivity and flow meters on make-up and bleed-off lines. Requires federal facilities meet four of ten BMPs for water efficiency, including single-pass cooling systems, cooling tower systems, high-water using processes, and water reuse and recycling
Energy & Atmosphere (EA)				
EA-P1	Energy Efficiency BMP's - Planning, Documentation, and Opportunity Assessment (Prerequisite)	X	EISA 2007	Provides for audits of federal green building performance
			EO 13514	Requires that federal agencies implement best management practices for the energy-efficient management of servers and federal data centers
			NASA NPR 8570.1	Requires Centers perform energy surveys
			NASA NPR 8570.1	Requires Energy Efficiency and Conservation Management Programs include background information on energy purchases, an Energy Use Index (EUI) for the facility, records of energy audits since 1991, and an in-depth energy audit
			NASA NPR 8570.1	Sets a goal of conducting energy audits for approximately 10 percent of total facilities' gross square footage each year until all facilities have been audited
			NASA NPR 8820.2F	Requires projects to meet LEED® Silver

LEED-EB:O&M® (2009) & EXISTING FEDERAL REGULATIONS				
LEED® CREDIT	LEED® CREDIT DESCRIPTION	REQ'D CREDIT	FEDERAL REGULATION	POLICY GAP/NOTES
EA-P2	Minimum Energy Efficiency Performance (Prerequisite)	X	EPAct 2005	Mandates all federal buildings be metered for the efficient use of electricity
			EISA 2007	Requires all leased federal buildings be ENERGY STAR buildings or buildings that have been renovated for all life-cycle cost-effective energy improvements
			EO 13423	Requires that agencies improve energy efficiency by three percent annually or 30 percent by the end of FY 2015
			EO 13514	Requires that agencies pursue cost-effective, innovative strategies to minimize consumption of energy, water, and materials
			EO 13514	Requires management of building systems to reduce the consumption of energy, water, and materials and identification of alternatives to renovation that reduce existing asset deferred maintenance costs
			EPAct 2005	Mandates all agencies procure ENERGY STAR or Federal Energy Management Program products
			EPAct 2005	Requires procurement of premium efficient electric motors, air conditioning, and refrigeration equipment
			10 CFR 436	Establishes guidance for Energy Savings Performance Contracting programs to accelerate investment in cost-effective energy conservation measures
			NASA NPR 8570.1	Sets a goal of reducing overall energy use per gross square foot by 35 percent by FY 2010, relative to FY 1985 levels
			NASA NPR 8570.1	Requires Energy managers and facilities maintenance personnel minimize energy consumption without affecting safety
			NASA NPR 8570.1	Sets a goal of improving energy efficiency of buildings by 25 percent by FY 2010 relative to FY 1990 levels
			NASA NPR 8570.1	Requires implementing energy conservation measures that modernize aging facilities and infrastructure
			NASA NPR 8820.2F	Requires project designers establish a whole building performance target, and design to earn the ENERGY STAR targets for renovations
			NASA NPR 8831.2D	Requires utility data management, including metering of all utilities
			NASA NPR 8820.2F	Requires major renovation projects to meet LEED® Silver
EA-P3	Fundamental Refigerant Management (Prerequisite)	X	NASA NPR 8820.2F	Requires all major renovation projects after 10/01/2005 meet LEED® Silver
			NASA NPR 8820.2F	Eliminates the use of ozone-depleting compounds during and after construction, consistent with either the Montreal Protocol and Title VI of the Clean Air Act, 1990, or equivalent overall air quality benefits

LEED-EB:O&M® (2009) & EXISTING FEDERAL REGULATIONS				
LEED® CREDIT	LEED® CREDIT DESCRIPTION	REQ'D CREDIT	FEDERAL REGULATION	POLICY GAP/NOTES
EA-C1	Optimize Energy Efficiency Performance		EPAct 2005	Mandates all federal buildings be metered for the efficient use of electricity
			EISA 2007	Requires all leased federal buildings be ENERGY STAR buildings or buildings that have been renovated for all life-cycle cost-effective energy improvements
			EO 13423	Requires that agencies improve energy efficiency by three percent annually or 30 percent by the end of FY 2015
			EO 13514	Requires that agencies pursue cost-effective, innovative strategies to minimize consumption of energy, water, and materials
			EPAct 2005	Mandates all agencies procure ENERGY STAR or Federal Energy Management Program products
			EPAct 2005	Requires procurement of premium efficient electric motors, air conditioning, and refrigeration equipment
			10 CFR 436	Establishes guidance for Energy Savings Performance Contracting programs to accelerate investment in cost-effective energy conservation measures
			NASA NPR 8570.1	Requires Energy managers and facilities maintenance personnel minimize energy consumption without affecting safety
			NASA NPR 8570.1	Sets a goal of reducing overall energy use per gross square foot by 35 percent by FY 2010, relative to FY 1985 levels
			NASA NPR 8570.1	Sets a goal of improving energy efficiency of buildings by 25 percent by FY 2010 relative to FY 1990 levels
			NASA NPR 8570.1	Requires implementing energy conservation measures that modernize aging facilities and infrastructure
			NASA NPR 8820.2F	Requires project designers establish a whole building performance target, and design to earn the ENERGY STAR targets for renovations
			NASA NPR 8831.2D	Requires utility data management, including metering of all utilities
EA-C2.1	Existing Building Commissioning - Investigation and Analysis		NASA NPR 8820.2F	Requires major renovation projects be evaluated in terms of risks, costs and benefits
			EISA 2007	Requires evaluations of energy use
			EISA 2007	Requires consideration of recommissioning and/or retrocommissioning of federal facilities
			EISA 2007	Provides for audits of federal green building performance
			NASA NPR 8820.2F	Requires commissioning of installed equipment, systems, building envelope, and other building elements
			NASA NPR 8820.2F	Requires total building commissioning of installed items and associated systems as prescribed by the LEED® system
			NASA NPR 8831.2D	Requires building commissioning as part of the Reliability-Centered Maintenance (RCM) process
EA-C2.2	Existing Building Commissioning - Implementation		EO 13423	Requires agencies establish programs for environmental management training
			NASA NPD 8820.2C	Establishes the role of Center Directors to provide training in sustainable design concepts
			NASA NPR 8820.2F	Requires designing for maintainability to optimize operations and maintenance costs
			NASA NPR 8820.2F	Requires that projects be evaluated in terms of risks, costs, and benefits
			NASA NPR 8820.2F	Requires the project designers reduce the energy cost budget by 20 percent from the pre-renovations baseline (for major renovations)

LEED-EB:O&M® (2009) & EXISTING FEDERAL REGULATIONS				
LEED® CREDIT	LEED® CREDIT DESCRIPTION	REQ'D CREDIT	FEDERAL REGULATION	POLICY GAP/NOTES
EA-C2.3	Existing Building Commissioning - Ongoing Commissioning		NASA NPD 8820.2C	Requires industry-best practices of building commissioning be incorporated to the maximum extent possible
			EISA 2007	Requires consideration of recommissioning and/or retrocommissioning of federal facilities
			NASA NPR 8820.2F	Requires commissioning of installed equipment, systems, building envelope, and other building elements
			NASA NPR 8820.2F	Requires total building commissioning of installed items and associated systems as prescribed by the LEED® system
			NASA NPR 8831.2D	Requires commissioning as part of the Reliability-Centered Maintenance (RCM) process
EA-C3.1	Performance Measurement - Building Automation System (BAS)		NASA NPR 8831.2D	Requires utility data management, including metering and data review
EA-C3.2	Performance Measurement - System-level Metering		NASA NPR 8831.2D	Requires utility data management, including metering and data review
			EPAct 2005	Mandates that all federal buildings be metered for the purpose of efficient use of energy
EA-C4	On-Site and Off-Site Renewable Energy		EISA 2007	If life-cycle cost-effective, at least 30 percent of hot water demand shall be met through solar hot water heaters
			EPAct 2005	Requires minimum consumption for federal renewable energy consumption of 3 percent through FY 2009, 5 percent through FY 2012, and 7.5 percent after 2013
			EPAct 2005	Establishes a goal to install 20,000 solar energy systems in federal buildings by 2010
			NASA NPR 8570.1	Requires expanded use of renewable energy for facilities by implementing renewable energy projects and by purchasing electricity from renewable energy sources
			EO 13423	Mandates at least half the statutorily required renewable energy consumed by the agency comes from new renewable sources and to the extent possible is implemented on agency property
EA-C5	Enhanced Refrigerant Management		NASA NPR 8820.2F	Eliminates the use of ozone-depleting compounds during and after construction, consistent with either the Montreal Protocol and Title VI of the Clean Air Act, 1990, or equivalent overall air quality benefits
			EO 12843	Encourages revision of procurement practices, modification of specifications and contratcts that require the use of ozone-depleting substances, and substitution of non-ozone-depleting substances
			EO 12843	Requires federal agencies to maximize the use of safe alternatives to ozone-depleting substances
EA-C6	Emissions Reduction Reporting		EO 13423	Requires that agencies improve energy efficiency and greenhouse gas emissions, through reduction of energy intensity, by three percent annually or 30 percent by the end of FY 2015
			EO 13514	Requires establishing a FY 2020 reduction target of agency-wide scope 1, scope 2, and scope 3 greenhouse gas emissions relative to a FY 2008 baseline
			EO 13514	Requires establishing and reporting a comprehensive inventory of absolute greenhouse gas emissions across all three scopes for FY 2010. Comprehensive inventories shall be submitted annually thereafter at the end of each January
			NASA NPR 8831.2D	Requires utility data management, including metering and data review
			NASA NPR 8570.1	Sets a goal of reducing greenhouse gas emissions attributed to facility energy use by 30 percent by 2010, over FY 1990 baseline
			NASA NPR 8570.1	Requires switching to a less greenhouse gas intensive, non-petroleum based energy source where practical
			EPAct 2005	Mandates a two percent reduction per year in energy consumption per gross square foot for all federal buildings compared to FY 2003 baseline
			EISA 2007	Requires reduction in fossil fuel energy uses relative to CBECS or RECS
			EISA 2007	Provides for audits of federal green building performance

LEED-EB:O&M® (2009) & EXISTING FEDERAL REGULATIONS

LEED® CREDIT	LEED® CREDIT DESCRIPTION	REQ'D CREDIT	FEDERAL REGULATION	POLICY GAP/NOTES
Materials & Resources (MR)				
MR-P1	Sustainable Purchasing Policy (Prerequisite)	X	EO 13423	Requires acquiring goods and services with sustainable environmental practices, including recycled content
			EO 13514	Requires that 95 percent of new contract actions, task orders, and delivery orders for products and services are energy efficient, water efficient, bio-based, environmentally preferable, non-ozone depleting, contain recycled content, or are non-toxic or less-toxic alternatives where such products and services meet agency performance requirements
			NASA NPR 8530.1A	Establishes standard procedures for procuring EPA-designated goods and services
			RCRA 1976	Requires that the federal government purchase recycled materials, when possible
			EPAct 2005	Mandates all agencies procure ENERGY STAR or Federal Energy Management Program products
			EPAct 2005	Requires procurement of premium efficient electric motors, air conditioning, and refrigeration equipment
			NASA NPR 8820.2F	Requires using products meeting or exceeding the USDA bio-based content recommendations
			NASA NPR 8820.2F	Requires using products meeting or exceeding EPA's recycled-content recommendations
			NASA NPR 8820.2F	Requires all major renovation projects after 10/01/2005 meet LEED® Silver certification
			NASA NPR 8530.1A	Requires eliminating barriers to the preference for recovered materials
MR-P2	Solid Waste Management Policy (Prerequisite)	X	EO 13423	Requires cost-effective waste prevention and recycling programs in facilities
			EO 13514	Requires minimizing the generation of waste and pollutants through source reduction
			EO 13514	Requires diverting at least 50 percent of non-hazardous solid waste by the end of FY 2013
			EO 13514	Requires reducing printing paper use and acquiring uncoated printing and writing paper containing at least 30 percent post-consumer fiber
			EO 13514	Requires increasing the diversion of compostable and organic material from the waste stream
			RCRA 1976	Requires the federal government to take action to recover the solid waste it generates
			NASA NPR 8820.2F	Requires maximization of reuse rather than disposal in projects that include demolition
			NASA NPR 8820.2F	Requires identifying local recycling and salvage operations and recycling or salvaging at least 50 percent of the construction, demolition and land clearing waste
			NASA NPR 8820.2F	Requires projects after 10/01/2005 meet LEED® Silver certification
MR-C1	Sustainable Purchasing - Ongoing Consumables		EO 13423	Requires acquiring goods and services with sustainable environmental practices, including recycled content
			NASA NPR 8530.1A	Establishes standard procedures for procuring EPA-designated goods and services
			NASA NPR 8820.2F	Requires using products meeting or exceeding the USDA bio-based content recommendations
			NASA NPR 8820.2F	Requires using products meeting or exceeding EPA's recycled-content recommendations

LEED-EB:O&M® (2009) & EXISTING FEDERAL REGULATIONS				
LEED® CREDIT	LEED® CREDIT DESCRIPTION	REQ'D CREDIT	FEDERAL REGULATION	POLICY GAP/NOTES
MR-C2	Sustainable Purchasing - Durable Goods	X	EPAct 2005	Mandates all agencies procure ENERGY STAR or Federal Energy Management Program products
			EPAct 2005	Requires procurement of premium efficient electric motors, air conditioning, and refrigeration equipment
			NASA NPR 8570.1	Requires using ENERGY STAR products, other energy-efficient products, and products with low standby power requirements where life-cycle cost-effective
			EO 13423	Requires acquiring goods using sustainable practices, including energy-efficient products
			EO 13423	Requires acquiring goods and services with sustainable environmental practices, including bio-based and recycled-content
			EO 13423	Requires use of paper that is at least 30 percent post-consumer fiber content
			NASA NPR 8530.1A	Establishes procedures for procuring EPA-designated goods
			NASA NPR 8820.2F	Requires use of environmentally-friendly materials and maximization of reuse rather than disposal in projects that include demolition
			NASA NPR 8820.2F	Requires identifying local recycling and salvage operations and recycling or salvaging at least 50 percent of construction, demolition, and land clearing waste
			NASA NPR 8820.2F	Requires using products meeting or exceeding USDA's bio-based content recommendations
			NASA NPR 8820.2F	Requires using products meeting or exceeding EPA's recycled-content recommendations
MR-C3	Sustainable Purchasing - Facility Alterations and Additions		EO 13423	Requires acquiring goods and services with sustainable environmental practices, including bio-based and recycled-content
			EO 13423	Requires use of paper that is at least 30 percent post-consumer fiber content
			NASA NPR 8530.1A	Establishes procedures for procuring EPA-designated goods
			NASA NPR 8820.2F	Requires use of environmentally-friendly materials and maximization of reuse rather than disposal in projects that include demolition
			NASA NPR 8820.2F	Requires identifying local recycling and salvage operations and recycling or salvaging at least 50 percent of construction, demolition, and land-clearing waste
			NASA NPR 8820.2F	Requires using products meeting or exceeding USDA's bio-based content recommendations
			NASA NPR 8820.2F	Requires using products meeting or exceeding EPA's recycled-content recommendations
MR-C4	Sustainable Purchasing - Reduced Mercury in Lamps			
MR-C5	Sustainable Purchasing - Food			
MR-C6	Solid Waste Management - Waste Stream Audit			
MR-C7	Solid Waste Management - Ongoing Consumables		EO 13423	Requires cost-effective waste prevention and recycling programs in facilities
MR-C8	Solid Waste Management - Durable Goods		EO 13423	Requires cost-effective waste prevention and recycling programs in facilities
MR-C9	Solid Waste Management - Facility Alterations and Additions		EO 13423	Requires cost-effective waste prevention and recycling programs in facilities
			NASA NPR 8820.2F	Requires maximization of reuse rather than disposal in projects that include demolition

LEED-EB:O&M® (2009) & EXISTING FEDERAL REGULATIONS				
LEED® CREDIT	LEED® CREDIT DESCRIPTION	REQ'D CREDIT	FEDERAL REGULATION	POLICY GAP/NOTES
Indoor Environmental Quality (EQ)				
EQ-P1	Minimum Indoor Air Quality Performance (Prerequisite)	X	NASA NPR 8820.2F	Requires compliance with ASHRAE 55-2004 and 62.1-2004
			NASA NPR 8820.2F	Requires all projects after 10/01/2005 to meet LEED® Silver certification
EQ-P2	Environmental Tobacco Smoke (ETS) Control (Prerequisite)	X	NASA NPR 8820.2F	Requires projects after 10/01/2005 to meet LEED® Silver certification
			EO 13058	Mandates federal workplaces be smoke-free environments by prohibiting smoking in all interior spaces, outside in front of air ducts, and recommends establishing a ban around the building perimeter
EQ-P3	Green Cleaning Policy (Prerequisite)	X	NASA NPR 8820.2F	Requires projects after 10/01/2005 to meet LEED® Silver certification
			EO 13423	Requires acquiring goods using sustainable practices, including environmentally preferable products
			NASA NPR 8530.1A	Establishes procedures for procuring EPA-designated and other environmentally preferable goods
			NASA NPR 8530.1A	Encourages publicizing and promotion of use of environmentally preferable goods
			NASA NPR 8820.2F	Requires use of environmentally-friendly materials
EQ-C1.1	Indoor Air Quality (IAQ) BMPs - IAQ Management Program		NASA NPR 8820.2F	Requires preparation of a moisture control strategy for controlling moisture flows and condensation to prevent building damage and mold contamination
EQ-C1.2	IAQ BMPs - Outdoor Air Delivery Monitoring			
EQ-C1.3	IAQ BMPs - Increased Ventilation		NASA NPR 8820.2F	Requires compliance with ASHRAE 55-2004 and 62.1-2004
EQ-C1.4	IAQ BMPs - Reduce Particulates in Air Distribution			
EQ-C1.5	IAQ BMPs - IAQ Management for Facility Alterations and Additions		NASA NPR 8820.2F	Ensures compliance with SMACNA Indoor Air Quality Guidelines for Occupied Buildings under Construction, 1995
			NASA NPR 8820.2F	Requires after construction and prior to occupancy a minimum 72-hour flush-out with maximum outdoor air be conducted, consistent with achieving relative humidity no greater than 60 percent
			NASA NPR 8820.2F	Requires compliance with ASHRAE 55-2004 and 62.1-2004
			NASA NPR 8820.2F	Requires preparation of a moisture control strategy for controlling moisture flows and condensation to prevent building damage and mold contamination
EQ-C2.1	Occupant Comfort - Occupant Survey			
EQ-C2.2	Controllability of Systems - Lighting			
EQ-C2.3	Occupant Comfort - Thermal Comfort Monitoring			
EQ-C2.4	Daylight and Views		NASA NPR 8820.2F	Establishes a minimum daylight factor of two percent in 75 percent of all spaces occupied for critical visual tasks
			NASA NPR 8820.2F	Requires automatic dimming controls and appropriate glare control
EQ-C3.1	Green Cleaning - High-Performance Cleaning Program		EO 13423	Requires agencies establish programs for environmental management training and environmental compliance review and audit
			NASA NPR 8820.2F	Requires use of environmentally-friendly materials
EQ-C3.2	Green Cleaning - Custodial Effectiveness Assessment			

LEED-EB:O&M® (2009) & EXISTING FEDERAL REGULATIONS

LEED® CREDIT	LEED® CREDIT DESCRIPTION	REQ'D CREDIT	FEDERAL REGULATION	POLICY GAP/NOTES
EQ-C3.3	Green Cleaning- Purchase of Sustainable Cleaning Products and Materials		EO 13423	Requires acquiring goods using sustainable practices, including bio-based, environmentally preferable, energy- and water-efficient, and recycled-content products
			NASA NPR 8530.1A	Establishes procedures for procuring EPA-designated goods
			NASA NPR 8820.2F	Requires use of environmentally-friendly materials
			NASA NPR 8820.2F	Requires use of products meeting or exceeding USDA bio-based content recommendations
			NASA NPR 8820.2F	Requires use of products meeting or exceeding EPA's recycled-content recommendations
			EO 13423	Requires use of paper that is at least 30 percent post-consumer fiber content
			EO 13514	Requires reducing printing paper use and acquiring uncoated printing and writing paper containing at least 30 percent post-consumer fiber
EQ-C3.4	Green Cleaning - Sustainable Cleaning Equipment		NASA NPR 8820.2F	Requires use of environmentally-friendly processes and equipment
EQ-C3.5	Green Cleaning - Indoor Checmical and Pollutant Source Control			
EQ-C3.6	Green Cleaning - Indoor Integrated Pest Management (IPM)		NASA NPR 8580.1	Requires a discussion of current policies and procedures for IPM including initiatives to reduce pesticide use, management practices, and a list of commonly used pesticides
			NASA NPR 8831.2D	Requires that grounds care work plans specify appropriate environmental controls for chemicals including pesticides, herbicides, and fertilizers
Innovation In Operations				
IO-C1.1	Innovation in Operations			
IO-C2	LEED® Accredited Professional			
IO-C3	Documenting Sustainable Building Cost Impacts		NASA NPD 8820.2C	Ensures that facility projects are delivered with the most economical life-cycle cost
			NASA NPD 8820.2C	Establishes the role of Center Directors to promote use of life-cycle cost analysis when evaluating sustainable design policies
			NASA NPR 8570.1	Requires use of life-cycle cost analysis in decisions on energy efficient products
			NASA NPR 8820.2F	Requires use of life-cycle cost for project systems, equipment, materials, and methods rather than first cost
			NASA NPR 8820.2F	Requires that projects be evaluated in terms of risks, benefits, and costs

LEED-ND® (2009) & EXISTING FEDERAL REGULATIONS				
LEED® CREDIT	LEED® CREDIT DESCRIPTION	REQ'D CREDIT	FEDERAL REGULATION	POLICY GAP/NOTES
Smart Location and Linkage (SLL)				
SSL-P1	Smart Location	X		
SSL-P2	Imperiled Species and Ecological Communities Conservation	X	NASA NPD 8500.1B	Requires coordination/cooperation with Federal, state and local regulatory agencies
SSL-P3	Wetland and Water Body Conservation	X	NASA NPD 8500.1B	Requires coordination/cooperation with Federal, state and local regulatory agencies
SSL-P4	Agricultural Land Conservation	X	NASA NPD 8500.1B	
			NASA NPR 8580.1	Requires identification of and cooperation in retention of important Agricultural Lands in areas of impact of a proposed agency action.
SSL-P5	Floodplain Avoidance	X	NASA NPD 8500.1B	Requires coordination/cooperation with Federal, state and local regulatory agencies
SSL-C1	Preferred Locations			
SSL-C2	Brownfields Redevelopment			
SSL-C3	Locations with Reduced Automobile Dependence		NASA NPR 3600.1A	Requires allowing compressed and flexible work schedules
SSL-C4	Bicycle Network and Storage		EPAct 2005	Requires the establishment of pilot programs designed to conserve energy resources by encouraging the use of bicycles in place of motor vehicles.
SSL-C5	Housing and Jobs Proximity			
SSL-C6	Steep Slope Protection			
SSL-C7	Site Design for Habitat or Wetland and Water Body Conservation		NASA NPR 8580.1	Requires discussion of the landscaping management policies and procedures regarding use of regionally native plants and design/use/promotion of construction practices that minimize adverse effects on the natural habitat
SSL-C8	Restoration of Habitat or Wetlands and Water Bodies		NASA NPR 8580.1	Requires discussion of the landscaping management policies and procedures regarding use of regionally native plants and design/use/promotion of construction practices that minimize adverse effects on the natural habitat
Neighborhood Pattern and Design (NPD)				
NPD-P1	Walkable Streets	X	EO 13514	Requires that planning for new Federal facilities and leases considers sites that are pedestrian friendly, near existing employment centers, and accessible to public transport and emphasizes existing central cities and, in rural communities, existing or planned town centers
NPD-P2	Compact Development	X		
NPD-P3	Connected and Open Community	X		
NPD-C1	Walkable Streets			
NPD-C2	Compact Development			
NPD-C3	Mixed-Use Neighborhood Centers			
NPC-C4	Mixed-Income Diverse Communities			
NPD-C5	Reduced Parking Footprint		NASA NPD 8500.1B	Requires coordination/cooperation with Federal, state and local regulatory agencies
NPD-C6	Street Network			
NPD-C7	Transit Facilities			
NPD-C8	Transportation Demand Management			
NPD-C9	Access to Civic and Public Space			
NPD-C10	Access to Recreation Facilites			

LEED-ND® (2009) & EXISTING FEDERAL REGULATIONS

LEED® CREDIT	LEED® CREDIT DESCRIPTION	REQ'D CREDIT	FEDERAL REGULATION	POLICY GAP/NOTES
NPD-C11	Visitability and Universal Design			
NPD-C12	Community Outreach and Involvement			
NPD-C13	Local Food Production			
NPD-C14	Tree-Lined and Shaded Streets			
NPD-C15	Neighborhood Schools			
Green Infrastructure and Buildings				
GIB-P1	Certified Green Building	X		
GIB-P2	Minimum Building Energy Efficiency	X	NASA NPR 8820.2F	Requires all new construction projects meet LEED® Silver
			NASA NPR 8820.2F	Mandates all new Federal buildings achieve savings of at least 30 percent below the ASHRAE Standard 90.1-2004 or the 2004 IECC
			EO 13423	Requires that agencies, relative to FY 2003 baseline, improve energy efficiency by three percent annually or by 30 percent by the end of FY 2015
			EO 13514	Requires that federal agencies implement best management practices for the energy-efficient management of servers and federal data centers
			NASA NPR 8570.1	Requires implementation of energy conservation measures that modernize aging facilities and infrastructure
			NASA NPR 8570.1	Mandates a goal of improving energy efficiency of buildings by 25 percent by FY 2010 relative to FY 1990
			NASA NPR 8570.1	Requires Centers to ensure new facilities are designed and constructed to comply with Federal energy performance standards
			NASA NPR 8820.2F	Requires that project designers establish a whole building performance target and design to earn the ENERGY STAR target
			NASA NPR 8820.2F	Requires that project designers reduce the energy cost budget by 30 percent compared to building baseline per ASHRAE 90.1-2004
GIB-P3	Minimum Building Water Efficiency	X	NASA NPR 8580.1	Requires discussion of the landscaping management policies and procedures regarding implementation of water-efficient practices
			EPAct 2005	Mandates if water is used to achieve energy efficiency, water conservation technologies be applied
			EO 13423	Requires Federal agencies reduce water consumption intensity, relative to FY 07 baseline, by two percent annually through FY 2015 or 16 percent by the end of FY 2015
			EO 13514	Requires that Federal agencies reduce potable water consumption intensity by 2 percent annually through FY 2020 or 26 percent by the end of FY 2020 relative to a FY 2007 baseline
			48 CFR 23	Promotes policies to acquire supplies and services that promote water efficiency
			NASA NPR 8570.1	Requires Energy Managers and facilities maintenance personnel minimize water consumption without affecting safety or mission operations
			NASA NPR 8570.1	Requires Federal facilities meet four of ten BMPs for water efficiency, which include faucets, showerheads, boilers, and steam systems
			NASA NPR 8570.1	Requires implementation of water conservation measures that modernize aging facilities and infrastructure
			NASA NPR 8820.2F	Requires designer reduce outdoor potable water consumption by at least 50 percent over that used by conventional means
			NASA NPR 8820.2F	Requires designer reduce potable water consumption of latrine fixtures by at least 20 percent from the EPAct 1992 standards

LEED-ND® (2009) & EXISTING FEDERAL REGULATIONS

LEED® CREDIT	LEED® CREDIT DESCRIPTION	REQ'D CREDIT	FEDERAL REGULATION	POLICY GAP/NOTES
GIB-P4	Construction Activity Pollution Prevention	X	NASA NPD 8500.1B	Requires coordination/cooperation with Federal, state and local regulatory agencies
			NASA NPR 8820.2F	Requires all new construction projects meet LEED® Silver
			NASA NPR 8810.1	Requires Centers establish a narrative and graphic presentation of erosion control measures
GIB-C1	Certified Green Buildings			
GIB-C2	Building Energy Efficiency		NASA NPR 8820.2F	Requires all new construction projects meet LEED® Silver
			NASA NPR 8820.2F	Mandates all new Federal buildings achieve savings of at least 30 percent below the ASHRAE Standard 90.1-2004 or the 2004 IECC
			EO 13423	Requires that agencies, relative to FY 2003 baseline, improve energy efficiency by three percent annually or by 30 percent by the end of FY 2015
			EO 13514	Requires that Federal agencies implement best management practices for the energy-efficient management of servers and Federal data centers
			NASA NPR 8570.1	Requires implementation of energy conservation measures that modernize aging facilities and infrastructure
			NASA NPR 8570.1	Mandates a goal of improving energy efficiency of buildings by 25 percent by FY 2010 relative to FY 1990
			NASA NPR 8570.1	Requires Centers to ensure new facilities are designed and constructed to comply with Federal energy performance standards
			NASA NPR 8820.2F	Requires that project designers establish a whole building performance target and design to earn the ENERGY STAR target
			NASA NPR 8820.2F	Requires that project designers reduce the energy cost budget by 30 percent compared to building baseline per ASHRAE 90.1-2004
GIB-C3	Building Water Efficiency		NASA NPR 8580.1	Requires discussion of the landscaping management policies and procedures regarding implementation of water-efficient practices
			EPAct 2005	Mandates if water is used to achieve energy efficiency, water conservation technologies be applied
			EO 13423	Requires Federal agencies reduce water consumption intensity, relative to FY 2007 baseline, by two percent annually through FY 2015 or 16 percent by the end of FY 2015
			EO 13514	Requires that Federal agencies reduce potable water consumption intensity by 2 percent annually through FY 2020 or 26 percent by the end of FY 2020 relative to a FY2007 baseline
			48 CFR 23	Promotes policies to acquire supplies and services that promote water efficiency
			NASA NPR 8570.1	Requires Energy Managers and facilities maintenance personnel minimize water consumption without affecting safety or mission operations
			NASA NPR 8570.1	Requires Federal facilities meet four of ten BMPs for water efficiency, which include faucets, showerheads, boilers, and steam systems
			NASA NPR 8570.1	Requires implementation of water conservation measures that modernize aging facilities and infrastructure
			NASA NPR 8820.2F	Requires designer reduce outdoor potable water consumption by at least 50 percent over that used by conventional means
			NASA NPR 8820.2F	Requires designer reduce potable water consumption of latrine fixtures by at least 20 percent from the EPAct 1992 standards

LEED-ND® (2009) & EXISTING FEDERAL REGULATIONS

LEED® CREDIT	LEED® CREDIT DESCRIPTION	REQ'D CREDIT	FEDERAL REGULATION	POLICY GAP/NOTES
GIB-C4	Water-Efficient Landscaping		NASA NPR 8580.1	Requires discussion of the landscaping management policies and procedures regarding implementation of water-efficient practices
			EPAct 2005	Mandates that if water is used to achieve energy efficiency, water conservation technologies be applied
			NASA NPR 8570.1	Requires Federal facilities meet four of ten BMPs for water efficiency, which include water efficient landscaping
			EO 13423	Requires Federal agencies reduce water consumption intensity, relative to FY 2007 baseline, by two percent annually through FY 2015 or 16 percent by the end of FY 2015
			EO 13514	Requires that Federal agencies reduce industrial, landscaping, and agricultural water consumption by 2 percent annually or 20 percent by the end of FY 2020 relative to a FY 2010 baseline
			NASA NPR 8820.2F	Requires designer reduce outdoor potable water consumption by at least 50 percent over that used by conventional means
GIB-C5	Existing Building Reuse		42 U.S.C. §2473d	Requires agencies to consider the purchase, lease, or expansion of NASA facilities in abandoned or underutilized buildings, grounds, and facilities in urban or rural depressed communities
GIB-C6	Historic Resources Preservation and Adaptive Use		42 U.S.C. §2473d	Requires agencies to consider the purchase, lease, or expansion of NASA facilities in abandoned or underutilized buildings, grounds, and facilities in urban or rural depressed communities
GIB-C7	Minimized Site Distrubance in Design and Construction		NASA NPR 8580.1	Requires discussion of the landscaping management policies and procedures regarding use of regionally native plants and design/use/promotion of construction practices that minimize adverse effects on the natural habitat
GIB-C8	Stormwater Management		NASA NPR 8810.1	Requires Centers establish a narrative and graphic presentation of erosion control measures
			NASA NPR 8820.2F	Requires project designers minimize storm water runoff and polluted site runoff
GIB-C9	Heat Island Reduction			
GIB-C10	Solar Orientation			
GIB-C11	On-Site Renewable Energy Sources		EISA 2007	For all new construction, as compared to other reasonably available technologies, at least 30 percent of hot water demand shall be met through solar hot water heaters
			EPAct 2005	Requires renewable energy consumption of 3 percent through FY 2009, 5 percent through FY 2012, and 7.5 percent after FY 2013
			EPAct 2005	Establishes a goal to install 20,000 solar energy systems in Federal buildings by 2010
			NASA NPR 8570.1	Requires expanded use of renewable energy for facilities by implementing renewable energy and by purchasing electricity from renewable sources
			EO 13243	Mandates that agencies ensure at least half of the statutorily required renewable energy consumed comes from new renewable sources, and to the extent possible, the agency implements renewable energy generation on agency property for agency use
GIB-C12	District Heating and Cooling		EPAct 2005	Provides rebates for expenditures made for the installation of a renewable energy system in connection with a dwelling unit or small business

LEED-ND® (2009) & EXISTING FEDERAL REGULATIONS				
LEED® CREDIT	LEED® CREDIT DESCRIPTION	REQ'D CREDIT	FEDERAL REGULATION	POLICY GAP/NOTES
GIB-C13	Infrastructure Energy Efficiency		NASA NPR 8820.2F	Mandates all new Federal buildings achieve savings of at least 30 percent below the ASHRAE Standard 90.1-2004 or the 2004 IECC
			EO 13423	Requires that agencies, relative to FY 2003 baseline, improve energy efficiency by three percent annually or by 30 percent by the end of FY 2015
			NASA NPR 8570.1	Requires implementation of energy conservation measures that modernize aging facilities and infrastructure
			NASA NPR 8570.1	Mandates a goal of improving energy efficiency of buildings by 25 percent by FY 2010 relative to FY 1990
			NASA NPR 8570.1	Requires Centers to ensure new facilities are designed and constructed to comply with Federal energy performance standards
			NASA NPR 8820.2F	Requires that project designers establish a whole building performance target and design to earn the ENERGY STAR target
			NASA NPR 8820.2F	Requires that project designers reduce the energy cost budget by 30 percent compared to building baseline per ASHRAE 90.1-2004
GIB-C14	Wastewater Management		NASA NPR 8580.1	Requires discussion of the landscaping management policies and procedures regarding implementation of water-efficient practices
			EO 13423	Requires Federal agencies reduce water consumption intensity, relative to FY 2007 baseline, by two percent annually through FY 2015 or 16 percent by the end of FY 2015
			EO 13514	Requires that Federal agencies identify, promote, and implement water reuse strategies consistent with state law that reduce potable water consumption
			NASA NPR 8570.1	Requires implementation of water conservation measures that modernize aging facilities and infrastructure
			NASA NPR 8570.1	Requires Federal facilities meet four of ten BMPs for water efficiency, including toilets and urinals
			48 CFR 23	Promotes policies to acquire supplies and services that promote water efficiency
			NASA NPR 8820.2F	Requires designer reduce potable water consumption of latrine fixtures by at least 20 percent from the EPAct 1992 standards
GIB-C15	Recycled Content in Infrastructure		RCRA 1976	Requires the Federal government to purchase recycled materials, when possible
			NASA NPR 8820.2F	Requires use of products meeting or exceeding EPA's recycled content recommendations
GIB-C16	Solid Waste Management Infrastructure		EO 13423	Requires cost-effective waste prevention and recycling programs in facilities
			EO 13514	Requires diverting at least 50 percent of non-hazardous solid waste by the end of FY 2013
			EO 13514	Requires increasing the diversion of compostable and organic material from the waste stream
			RCRA 1976	Requires the Federal government to take action to recover the solid waste it generates
			NASA NPR 8820.2F	Requires maximization of reuse rather than disposal in projects that include demolition
			NASA NPR 8820.2F	Requires identifying local recycling and salvage operations and recycling or salvaging at least 50 percent of the construction, demolition and land clearing waste
			NASA NPR 8820.2F	Requires projects after 10/01/2005 meet LEED® Silver certification
GIB-C17	Light Pollution Reduction			
Innovation and Design Process (IDP)				
IDP-C1	Innovation and Exemplary Performance			
IDP-C2	LEED Accredited Professional			

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APPENDIX B. NASA LEED® CERTIFIED, REGISTERED, AND PENDING PROJECTS

LEED-NC® Certified Buildings

Center	Building	Name	Completion Date	LEED® Rating
GRC	304	Management Conference Center	2009	Silver
GSFC	34	Exploration Sciences Building	2009	Gold
JPL	321	Flight Projects Center	2009	Gold
JSC	2 North	Public Affairs Office	2010	Gold
JSC	20	Office Building	2010	Platinum
JSC	26	Human Spaceflight Performance & Research Facility	2010	Gold
JSC	27	Astronaut Quarantine Facility (AQF)	2005	Certified
JSC	207A	Exchange Recreation Facility	2009	Silver
JSC	265	Source Evaluation Board Facility	2010	Gold
JSC-WSTF	107	Columbia Health and Fitness Center	2006	Silver
KSC	M6-0490	Life Support Facility	2009	Silver
KSC	N/A	Visitor Center Commissary Warehouse	2007	Silver
MSFC	4346	Child Development Center	2007	Certified
MSFC	4600	Office Building	2005	Silver
MSFC	4601	Office Building	2009	Gold
SSC	8000	Emergency Operations Center	2010	Gold

LEED-NC® Registered Buildings Under Construction

Center	Building	Name	Anticipated Completion Date	Anticipated LEED® Rating
ARC	N232	Collaborative Support Facility	2011	Platinum
GRC	351	Warehouse	2011	Silver
GRC	154	Main Gatehouse	2011	Silver
GRC	162	Centralized Office Building	2012	Silver
GRC	60	Rehab and Modification	2010	Silver
JSC	12	Refurbish Administration Support Bldg	N/A	N/A
JSC	29	CEV Avionics Integration Lab	2011	Silver
KSC	K7-0558	Ordnance Operations Facility	N/A	N/A
KSC	N/A	Electrical Maintenance Facility	N/A	N/A
KSC	N/A	Propellants North Administration and Maintenance Facility	2010	Platinum
LaRC	1	New Town, Phase 1	2011	Gold

Center	Building	Name	Anticipated Completion Date	Anticipated LEED® Rating
MSFC	4602	Laboratory	2011	Gold
MSFC	4494	Building	N/A	N/A
SSC	3418	Cryogenic Control Center	2010	Silver

LEED-EB: O&M® Registered Projects

Center	Building	Name	Anticipated Completion Date	Anticipated LEED® Rating
GRC	N/A	Space Power Facility	N/A	N/A
JSC	4 South	Flight Operations Facility	N/A	N/A
WFF	E-109	Engineering Building	N/A	N/A
MSFC	4203	Office Building	N/A	Gold
SSC	1100	Administration Building	N/A	N/A

Projects Anticipating LEED-EB: O&M® Registration

Center	Building	Name	Anticipated Completion Date	Anticipated LEED® Rating
GRC	49	Materials and Structures Laboratory	2015	N/A
GSFC	3	Central Flight Control/Range Bldg	2015	N/A
GSFC	14	Spacecraft Operations Facility Bldg	2015	N/A
GSFC	28	Technical Processing Facility	2015	N/A
LaRC	1216	Outreach Center	2015	N/A
PBS	141	Engineering Building	2015	N/A
SSC	3225	Propulsion Test Office Building	2015	N/A
WFF	F4	Dormitory	2015	N/A
WFF	F5	Dormitory	2015	N/A

APPENDIX C. LESSONS LEARNED FROM THE LEED® PROCESS

NASA Case Studies

Project Managers (PMs) for all NASA facilities who had completed the LEED® Certification process as of October 2008 responded to a questionnaire regarding their experiences. Most respondents represented projects for new facilities, although one was considered major renovation. All projects qualified for the LEED-NC® rating system, though the version number varied. The full questionnaire, along with PM responses, can be found at the end of this Appendix.

While each project included a variety of different sustainability strategies, commonly pursued LEED-NC® credits included:

- Sustainable Sites Credit 5.1 — Site Development: Protect or Restore Habitat
- Sustainable Sites Credit 7.2 — Heat Island Effect: Roof
- Water Efficiency Credits 1.1 and 1.2 — Water Efficient Landscaping
- Water Efficiency Credit 2 — Innovative Wastewater Technologies
- Water Efficiency Credits 3.1 and 3.2 — Water Use Reduction
- Energy and Atmosphere Credit 1 — Optimize Energy Performance
- Indoor Environmental Quality Credits 4.1 - 4.4 — Low-Emitting Materials
- Indoor Environmental Quality Credits 8.1 and 8.2 — Daylight and Views

Challenges

During the LEED® process, PMs encountered a number of challenges, including:

Planning. Sustainability principles should be integrated into building development from the planning phase, which is important to the LEED® process. Based on the questionnaires, some NASA LEED® projects began considering LEED® certification during the construction or renovation process rather than as part of the planning process. PMs found this added new challenges to the process and wished they had incorporated LEED® principles at the beginning.

Recommendation

- *Incorporate LEED® planning into all facility projects from the beginning, regardless if certification is originally planned.*
- *Develop Building Operating Plans describing the various building systems and how they are intended to function. This document will aid in facility system efficiency, building commissioning, and the LEED® process.*

Documentation. Documentation for the LEED® Certification process is extensive. Nearly every project reported significant time spent completing the necessary documentation for each credit pursued. PMs recommended starting the paperwork during the planning phase and trying to keep up with it throughout the construction process. While maintaining required documentation is a significant task, leaving most or all the work until the end of the certification process is an even greater challenge. Further, contractors and subcontractors may not be familiar with required LEED® documentation, requiring additional time to compile all required documentation.

Recommendation

- *Implement documentation training for all facility managers, including checklists/templates of required information and steps to complete during all project phases. Clearly identify what information facility managers will need to obtain from contractors.*
- *Implement enhanced project record-keeping, including all sustainability-related information and documentation at the end of all new construction and major renovations. This "project dossier" must be kept complete and up-to-date throughout the LEED® certification process.*

Certified wood. Although most sustainable products and equipment were relatively easy to acquire, PMs and/or contractors found certified wood especially challenging to locate and earn LEED-NC® Credit 7 or LEED-EB:O&M® Prerequisites 1 and 2 or Credits 2.1, 2.2, and 3. During the initial LEED® evaluation process, additional effort should be made to ensure that sustainable products and materials are available or that alternate credits can be used in lieu of the Certified Wood credit.

Recommendation

- *Determine availability of sustainably harvested wood products early in the process.*
- *Pursue other credits to achieve desired LEED® certification level.*

Energy efficiency. NASA operates facilities across the world thus facing a variety of climate conditions. Facilities at the Johnson Space Center (JSC) in Houston found energy efficiency a difficult credit to achieve given the hot and humid local climate. Because energy efficiency is a major component of the LEED® program for all types of certification, special consideration should be given early-on in the process to identify energy-saving measures. Building type and location should be carefully evaluated to determine whether LEED® certification is a realistic possibility.

Recommendation

- *Identify one member of the project team to specifically concentrate on creative ways to pursue energy efficiency, taking into consideration the individual facility's mission and climate.*
- *Coordinate energy-efficiency recommendations with other conflicting goals (i.e. thermal comfort).*

Lessons Learned

After completing the LEED® process, PMs reported a variety of lessons learned, including:

Sustainability kickoff/LEED® charrette. PMs should insist on holding a kickoff/charrette to establish project goals and identify potential LEED® credits. All project stakeholders should attend, including facility tenants and employees, contractors, subcontractors, A/E representatives (including a LEED® Accredited Professional), NASA Agency staff, Center Environmental and Energy Managers, and other relevant parties. Gathering relevant stakeholders will help resolve potentially conflicting sustainability goals. Planning for a LEED-NC® certified building should start years prior to construction.

Recommendation

- *Hold a sustainability kickoff and/or LEED® charrette for all new construction, major renovations, or retro-commissioning/building system upgrades.*

Regular meetings. To ensure ongoing communication, PMs should hold regular (weekly) meetings beginning very early in the planning process with as many project stakeholders as possible, including most or all kickoff/charrette participants. As the project progresses, meetings may shift to biweekly or monthly, but should continue through project completion. Regular meetings will help ensure all facility participants understand processes and protocol and will greatly help with maintaining required documentation.

Recommendation

- *Hold weekly meetings during the project's early phases, as well as monthly meetings for all later phases, continuing until project completion.*
- *Document all major design, construction, or policy decisions and disseminate minutes to all members of the project team.*

Submission planning. Project Managers had many suggestions for preparing LEED® submittals to make the process smoother. First, project teams should target more credits than needed to achieve the desired level of certification should some credits be denied during the appeals process. Next, PMs should consider splitting the application between design and construction phases so that all design-related credits are submitted prior to construction. Finally, PMs should keep up with all paperwork and documentation requirements because the workload can easily become insurmountable near the end of the process.

Recommendation

- *Incorporate documentation planning into the project's overall sustainability plan.*
- *Consider targeting additional credits and split phase applications.*

Credit balance. Project teams should balance LEED® credits between the owner/operator's needs and achieving easy/low cost credits. Teams should also take time to think through strategies where it is possible to achieve multiple credits with the same equipment or design. For example, several facilities reduced the required heating, ventilation, and air conditioning (HVAC) system by combining increased energy efficiency, increased daylighting, and underfloor air conditioning.

Recommendation

- *Create a template of zero cost and low cost LEED® credits that is cross-referenced with the various building systems and Center functions. This template may include several model renovation and construction projects.*

Learning curve. Project Managers reported as that the project progressed, more time was spent on strategies and implementation rather than learning LEED® requirements and documentation. Contractors and subcontractors experienced similar improvements in efficiency as they became more familiar with relevant requirements. It would helpful to assign people who have already completed the certification process to future project teams.

Recommendation

- *Schedule all facility Energy and Environmental Managers for LEED® training, with the goal of at least one accredited professional per Center.*

Lessons Learned from non-NASA Facilities

Sustainable facilities neither owned nor operated by NASA also provide important lessons for designing appropriate NASA policies. Multiple sources were consulted as part of this analysis, including several programs at the Office of Energy Efficiency and Renewable Energy (EERE) at the US Department of Energy (DOE) and the US Green Building Council (USGBC). EERE programs include the Federal Energy Management Program (FEMP) and the High Performance Buildings Initiative in the Building Technologies Program. FEMP promotes energy efficiency and the use of renewable energy in Federal facilities and continually assesses high-performance Federal buildings, including those with LEED® certification. The High Performance Buildings Initiative also promotes energy efficiency and maintains an online database of environmentally friendly buildings.

The case studies and project descriptions provided on the EERE and LEED® websites (www.eere.energy.gov and http://www.usgbc.org) give additional insight into ways to improve NASA's sustainable building portfolio. Among the sustainable projects in this analysis, facilities commonly implemented energy and potable water use reductions, daylighting increases, and natural ventilation inclusion or increases. Although the individual projects ranged widely in scope, location, and function, some common lessons learned can be identified including:

Building system reduction. Several facilities were able to improve operations so dramatically that they removed or avoided the need for entire building systems. In addition to the energy- and water-use reduction, removing building systems also saved equipment and reduced design costs. For example, facilities implemented practices like daylighting and natural ventilation to save energy, and the combined impact allowed reduction or removal of traditional HVAC systems. Other facilities used practices like passive solar walls and radiant heating panels that, when combined, removed the need for a central heating system entirely.

Return on investment. Sustainability improvements in several facilities improved operational costs over existing or traditional systems (usually in terms of energy and water use) so dramatically that the payback time for their installation cost was only a few years. These savings were in addition benefits from other sustainability practices, which could be implemented at low or no cost.

Site improvements. Site improvements contributed significantly to the sustainability of the project. Site operations and maintenance costs can be reduced in many ways including:

- Stormwater runoff reduction can be achieved through low-cost design changes
- Pavement and roadway demolition or non-restoration may decrease initial paving cost and ongoing maintenance costs for repaving or re-striping

- Irrigation costs may be lowered through design changes and the use of native plants
- Pesticide costs may be lowered through the use of native plants
- Landscape maintenance costs may be lowered through design changes and the use of native plants

NASA LEED® Facility Project Manager Questionnaire Responses

Building 27, Astronaut Quarantine Facility, Johnson Space Center

Project Manager: Edward Faircloth, JSC-JA

1. **What LEED® Certification Program was your project registered under?**

   LEED® NC V2.1 NC

2. **What LEED® Certification Level did/will your building achieve? (E.g., Silver, Gold, etc.)**

   Certified

3. **Describe the building that you had certified – what is its use, where is it located, how did these factors play into the design decisions?**

   The building is a single-story 12,000 sq ft building. The building supports the Astronauts prior to and after Space Flights either from the Shuttle or the Space Station. The main design decisions were centered around "preparing the Astronauts for Space Missions." It is located north of Building 28 on the east side of 5th Street.

4. **What features/equipment/designs were included in your project?**

   Native plants and adapted species to reduce maintenance and water use; condensate water as the primary irrigation source; ENERGY STAR compliant highly reflective roof. Low flow restroom fixtures including waterless urinals, dual flush valves, and flow restrictors on the faucets. Building oriented to maximize Daylight Harvesting. Specified recycled content for carpet and other materials. Use only certified wood, use low VOC paint/carpet/adhesives.

5. **What specific building or system improvements did you make?**

   We tried to design in all high efficiency equipment and materials and the use of an energy recovery system with enthalpy wheel and preconditioned outside air. We used minimum energy efficient windows and added insulation on the exterior walls.

6. **How difficult were products/equipment to obtain? Were they available regionally or nationally?**

   Products for the most part were not difficult to obtain with the exception of FSC certified wood.

7. **Did your LEED® points come primarily from a few categories, or were you able to distribute your credits across all categories?**

   Points were from all categories.

8. **Which credits did you find most difficult to obtain?**

   Certainly the most challenging credits in a hot and humid climate are those that relate to energy efficiency, specifically EAc1. Achieving a high level of energy efficiency is an interdisciplinary effort in which the team must execute a wide variety of strategies.

9. **What parts of the project worked well together, providing overlapping/double impact? (e.g. upgraded windows provide temperature control, leading to smaller needed HVAC equipment)**

   Certainly the design of the HVAC system, specifically utilizing the enthalpy wheel which improved energy performance and outdoor air ventilation rates, is one good example of parts of the project that worked well together.

10. **What about the LEED® process was easy? Difficult? Time consuming?**

    If you start upfront with the LEED® process, designing the credits into the project is fairly patented. Making everyone on the team aware of exactly what the requirements are for each credit and what documentation must be maintained along the way was by far the most time-consuming aspect of the LEED® process. As the team became more knowledgeable about LEED®, far less time was spent on discussing requirements and far more time was spent on discussing strategies to get there.

11. **What would you do again? Avoid?**

    Holding a comprehensive LEED® kickoff/sustainability charrette was extremely important in establishing sustainable design goals and determining what credits to pursue in order to meet these goals. Regularly scheduled meetings to talk through progress and determine additional opportunities were also very important. In general it's best to avoid strategies that just earn LEED® points and focus on those that offer clear benefit for the owner/occupants (which we definitely did for all of the other strategies/credits we pursued).

12. **What are the water/energy/waste reduction/etc savings per year? Long-term?**

    As designed the NASA Astronaut Quarantine Facility is expected to reduce potable water consumption for landscape irrigation by 50%, be 55% more energy-efficient than ASHRAE 90.1, and divert greater than 50% of all construction waste from disposal.

13. **What was the upfront cost of the improvements/equipment?**

    Not sure since we had a lump sum construction bid. New Building with efficiency equipment designed into the project.

14. **What was the payback period?**

    Not sure for entire process. Expected to be around 18 months to two years due to the energy savings being substantial, however, offering a very attractive payback.

15. **How far in advance of construction/renovation did you start the planning process?**

    Planning started four years prior to construction.

16. **How well have the improvements/equipment held up over time vs. conventional?**

    After initial adjustment and training of the maintenance personnel the systems are still functioning efficiently.

17. **If your building was LEED-NC® Certified, do you plan to pursue LEED-EB: O&M® Certification in the future?**

    Probably no, this building is already efficient.

18. If you could provide advice to other NASA Centers undergoing the LEED® certification process, what would it be?

Insist on a sustainability kickoff/LEED® charrette to establish goals and populate a preliminary LEED® checklist. Hold bi-weekly meetings when the project is first starting and then monthly meetings as the project progresses to track progress and determine additional opportunities. Go after the low cost LEED® credits first and pursue strategies that result in earning multiple LEED® points. Keep up with documentation from day one and try and not get behind, this will make the submission process easier. Also, consider a split-phase application for certification, where all design credits are submitted upfront instead of waiting to the end of construction to submit everything. This will help speed up the process.

Building 2N, Public Affairs Office (Renovation), Johnson Space Center

Project Manager: George Farley, JSC-JA

1. **What LEED® Certification Program was your project registered under?**

   LEED NC v2.1

2. **What LEED® Certification Level did/will your building achieve? (E.g. Silver, Gold, etc.)**

   Gold

3. **Describe the building that you had certified – what is its use, where is it located, how did these factors play into the design decisions?**

   The building that is being renovated is the Public Affairs Office Building. It is approximately 18,000 sq ft and contains offices, break room, film vault, briefing room, team rooms & conference rooms used by the Public Affairs Office for all of the Centers external and internal public communications. The briefing room is used for Astronaut mission briefings and press conferences before/during/after shuttle missions. The building is located in the main mall area of the JSC campus just west of Building 1. Design decisions were made to improve the office environment.

4. **What features/equipment/designs were included in your project?**

   Daylight harvesting lighting control system, special ENERGY STAR coating on the roof, bicycle storage/changing room/shower, reduced water usage by 30% with efficient fixtures, specified recycled content for carpet and other materials, diverted 75% of construction waste, specified local materials, used only certified wood, used low VOC paint/carpet/adhesives, daylight views 90% of space.

5. **What specific building or system improvements did you make?**

   Removed all spray-applied asbestos from roof deck and structure. Removed all other asbestos materials in building. Installed more efficient underfloor air conditioning system. Installed daylight harvesting lighting control system and more energy-efficient lighting. Installed Solarban 60 energy efficient windows. Replaced roof and installed R-25 insulation and ENERGY STAR coating.

6. **How difficult were products/equipment to obtain? Were they available regionally or nationally?**

   Products for the most part were not difficult to obtain with the exception of certified wood.

7. **Did your LEED® points come primarily from a few categories, or were you able to distribute your credits across all categories?**

   Points were from all categories.

8. **Which credits did you find most difficult to obtain?**

   Since we have not finished construction, I do not know if we are going to have difficulty obtaining any of the credits.

9. **What parts of the project worked well together, providing overlapping/double impact? (e.g. upgraded windows provide temperature control, leading to smaller needed HVAC equipment)**

   Windows and daylighting controls contributed to smaller HVAC needs.

10. **What about the LEED® process was easy? Difficult? Time consuming?**

    Registering the project is easy. Obtaining LEED® information from contractor and subcontractors is difficult because they are not used to providing the additional information with product submittals. Organizing and obtaining all of the LEED® documentation required for final submissions was time-consuming.

11. **What would you do again? Avoid?**

    I would do everything again with the exception of certified wood because it seemed to be the most difficult for the contractor.

12. **What are the water/energy/waste reduction/etc savings per year? Long-term?**

    Based on the energy model the savings will be 11%.

13. **What was the upfront cost of the improvements/equipment?**

    Not sure since we had a lump sum construction bid. New Building with efficiency equipment designed into the project.

14. **What was the payback period?**

    Do not have data to determine.

15. **How far in advance of construction/renovation did you start the planning process?**

    Planning typically starts four years prior to construction.

16. **How well have the improvements/equipment held up over time vs. conventional?**

    Still in construction, so TBD.

17. **If your building was LEED-NC® Certified, do you plan to pursue LEED-EB: O&M® Certification in the future?**

    Probably not for this facility.

18. **If you could provide advice to other NASA Centers undergoing the LEED® certification process, what would it be?**

    Keep up with documentation from day one and try and not get behind; this will make the submission process easier.

Office Building 20, Johnson Space Center

Project Manager: Charles Noel, JSC-JA

1. **What LEED® Certification Program was your project registered under?**

   LEED NC V2.1 hybrid

2. **What LEED® Certification Level did/will your building achieve? (E.g. Silver, Gold, etc.)**

   Gold

3. **Describe the building that you had certified – what is its use, where is it located, how did these factors play into the design decisions?**

   The building is a 3-story, 83,000 sq ft building. The building supports the building refurbishment program to provide "flex" space for employees temporarily relocated due to refurbishment of their building. The building is located on the corner, 2nd street and Avenue "C", at JSC. The main design decisions were centered around "flex" space which could be altered quickly with minimum cost. Second was the efficiency/environment of the building.

4. **What features/equipment/designs were included in your project?**

   Native plants and adapted species to reduce maintenance and water use; condensate water as the primary irrigation source; ENERGY STAR-compliant highly-reflective roof. Low-flow restroom fixtures including waterless urinals, dual flush valves, and flow restrictors on the faucets. Solar hot water heating for restrooms. Building oriented to maximize daylight harvesting. Showers for bicycle riders. Specified recycled content for carpet and other materials. Use only certified wood, use low VOC paint/carpet/adhesives.

5. **What specific building or system improvements did you make?**

   We tried to design in all high efficiency equipment and materials. Installed more efficient underfloor air conditioning system. Installing Solarban 70 energy efficient windows.

6. **How difficult were products/equipment to obtain? Were they available regionally or nationally?**

   Products for the most part were not difficult to obtain with the exception of FSC certified wood.

7. **Did your LEED® points come primarily from a few categories, or were you able to distribute your credits across all categories?**

   Points were from all categories.

8. **Which credits did you find most difficult to obtain?**

   Certainly the most challenging credits in a hot and humid climate are those that relate to energy efficiency, specifically EAc1. Achieving a high level of energy efficiency is an interdisciplinary effort, in which the team must execute a wide variety of strategies.

9. **What parts of the project worked well together, providing overlapping/double impact? (e.g. upgraded windows provide temperature control, leading to smaller needed HVAC equipment)**

   Certainly the design of the HVAC system, specifically utilizing an Underfloor Air Distribution system, which provides improved energy performance and outdoor air ventilation rates, but also allows for a high degree of controllability for individual occupants is one good example of parts of the project that worked well together.

10. **What about the LEED® process was easy? Difficult? Time consuming?**

    If you start upfront with the LEED® process, designing the credits into the project is fairly patented. Making everyone on the team aware of exactly what the requirements are for each credit and what documentation must be maintained along the way was by far the most time consuming aspect of the LEED® process. As the team became more knowledgeable about LEED®, far less time was spent on discussing requirements and far more time was spent on discussing strategies to get there.

11. **What would you do again? Avoid?**

    Holding a comprehensive LEED® kickoff/sustainability charrette was extremely important in establishing sustainable design goals and determining what credits to pursue in order to meet these goals. Regularly scheduled meetings to talk through progress and determine additional opportunities were also very important. If you had to twist my arm for things to avoid, I am curious if the plug-in access provided for 3% of the vehicle parking capacity will be regularly utilized or of it was a strategy we decided on simply to earn a LEED® point. In general it's best to avoid strategies that just earn LEED® points and focus on those that offer clear benefit for the owner/occupants(which we definitely did for all of the other strategies/credits we pursued).

12. **What are the water/energy/waste reduction/etc savings per year? Long-term?**

    As designed the new Office Building is expected to reduce potable water consumption for landscape irrigation by 54%, use 34% less water than a building that just meets baseline fixture performance requirements of the Energy Policy Act of 1992, be 55% more energy efficient than ASHRAE 90.1, and divert greater than 50% of all construction waste from disposal.

13. **What was the upfront cost of the improvements/equipment?**

    Not sure since we had a lump sum construction bid. New Building with efficiency equipment designed into the project.

14. **What was the payback period?**

    Not sure for entire process. Expected energy savings are substantial, however, offering a very attractive payback.

15. **How far in advance of construction/renovation did you start the planning process?**

    Planning started 4 years prior to construction.

16. **How well have the improvements/equipment held up over time vs. conventional?**

    Still in construction so TBD.

17. If your building was LEED-NC® Certified, do you plan to pursue LEED-EB: O&M® Certification in the future?

Probably no, this building is already efficient. I would take the funds and upgrade an older building, to best use the resources.

18. If you could provide advice to other NASA Centers undergoing the LEED® certification process, what would it be?

Insist on a sustainability kickoff/LEED® charrette to establish goals and populate a preliminary LEED® checklist. Hold bi-weekly meetings when the project is first starting and then monthly meetings as the project progresses to track progress and determine additional opportunities. Go after the low-cost LEED® credits first and pursue strategies that result in earning multiple LEED® points. Keep up with documentation from day one and try and not get behind, this will make the submission process easier. Also, consider a split phase application for certification, where all design credits are submitted upfront instead of waiting to the end of construction to submit everything. This will help speed up the process.

Maintenance/Storage/Office/Snack shack, Johnson Space Center

Project Manager: Todd Pryor, JSC-JA

1. **What LEED® Certification Program was your project registered under?**

   New Construction

2. **What LEED® Certification Level did/will your building achieve? (E.g. Silver, Gold, etc.)**

   Silver

3. **Describe the building that you had certified – what is its use, where is it located, how did these factors play into the design decisions?**

   Maintenance/storage facility, offices, snack shack.

4. **What features/equipment/designs were included in your project?**

   Recycled construction material, recycled construction debris, low VOC paints/carpet, low flush toilets, day lighting, and sustainable landscaping.

5. **What specific building or system improvements did you make?**

   New building.

6. **How difficult were products/equipment to obtain? Were they available regionally or nationally?**

   Medium difficulty! Mostly regionally but some were hard to find.

7. **Did your LEED® points come primarily from a few categories, or were you able to distribute your credits across all categories?**

   Most categories were used.

8. **Which credits did you find most difficult to obtain?**

   N/A

9. **What parts of the project worked well together, providing overlapping/double impact? (e.g. upgraded windows provide temperature control, leading to smaller needed HVAC equipment)**

   N/A

10. **What about the LEED® process was easy? Difficult? Time consuming?**

    Paperwork and buying regionally were tough.

11. **What would you do again? Avoid?**

    LEED® is the right thing for NASA to be doing.

12. **What are the water/energy/waste reduction/etc savings per year? Long-term?**

    Don't know.

13. **What was the upfront cost of the improvements/equipment?**

    Don't know.

14. **What was the payback period?**

    Don't know.

15. **How far in advance of construction/renovation did you start the planning process?**

    Two years

16. **How well have the improvements/equipment held up over time vs. conventional?**

    N/A

17. **If your building was LEED-NC® Certified, do you plan to pursue LEED-EB: O&M® Certification in the future?**

    N/A

18. **If you could provide advice to other NASA Centers undergoing the LEED® certification process, what would it be?**

    Documentation is key throughout the entire process.

Building 265 – Source Board, Johnson Space Center

Project Manager: Richard Tomlinson, JSC-JA

1. **What LEED® Certification Program was your project registered under?**

   New Construction

2. **What LEED® Certification Level did/will your building achieve? (E.g. Silver, Gold, etc.)**

   Silver

3. **Describe the building that you had certified – what is its use, where is it located, how did these factors play into the design decisions?**

   5000 SF addition to the Source Board building at JSC.

4. **What features/equipment/designs were included in your project?**

   Optimized Energy Performance, Indoor Environmental Quality and Water Efficiency.

5. **What specific building or system improvements did you make?**

   Highly reflective white roof and north-facing insulated glass windows for daylighting.

6. **How difficult were products/equipment to obtain? Were they available regionally or nationally?**

   Most were available.

7. **Did your LEED® points come primarily from a few categories, or were you able to distribute your credits across all categories?**

   Distributed across all categories.

8. **Which credits did you find most difficult to obtain?**

   Use of recycled aggregate in concrete slab. Could not find a ready-mix company in the area.

9. **What parts of the project worked well together, providing overlapping/double impact? (e.g. upgraded windows provide temperature control, leading to smaller needed HVAC equipment)**

   Upgraded windows were North–facing, resulting in reduced energy from sensor-controlled lighting and HVAC systems.

10. **What about the LEED® process was easy? Difficult? Time consuming?**

    Easy - material and resource credits.

    Difficult - energy performance optimization

    Time consuming - energy model

11. **What would you do again? Avoid?**

    Concentrate more on stormwater reuse from roof rainwater harvest.

12. **What are the water/energy/waste reduction/etc savings per year? Long-term?**

    Water use reduction 30%, Landscaping uses no potable water. Native plants used for landscaping.

13. **What was the upfront cost of the improvements/equipment?**

    10% additional

14. **What was the payback period?**

    Seven years

15. **How far in advance of construction/renovation did you start the planning process?**

    One year

16. **How well have the improvements/equipment held up over time vs. conventional?**

    TBD

17. **If your building was LEED-NC® Certified, do you plan to pursue LEED-EB: O&M® Certification in the future?**

    Yes, as new technology and funding becomes available.

18. **If you could provide advice to other NASA Centers undergoing the LEED® certification process, what would it be?**

    Environmentally responsible, but not always fun.

Columbia Health and Fitness Center, White Sands Test Facility

Project Manager: Jason Noble, WSTF-RC

1. **What LEED® Certification Program was your project registered under?**

   LEED NC v2.0

2. **What LEED® Certification Level did/will your building achieve? (E.g. Silver, Gold, etc.)**

   Silver

3. **Describe the building that you had certified - what is its use, where is it located, how did these factors play into the design decisions?**

   The facility we had certified was the White Sands Test Facility Fitness Center. The facility is located in the 100 Area of WSTF.

4. **What features/equipment/designs were included in your project?**

   See addendum.

5. **What specific building or system improvements did you make?**

   See addendum.

6. **How difficult were products/equipment to obtain? Were they available regionally or nationally?**

   The construction contractor did not have any huge issues obtaining products and equipment within the 500 mile radius. It did take a little more effort on their part to ensure this was the case though, and records had to be kept of where the materials were coming from.

7. **Did your LEED® points come primarily from a few categories, or were you able to distribute your credits across all categories?**

   The credits for the Fitness Center were distributed relatively evenly with the exception of the "Energy and Atmosphere" category, where we only achieved 1 point out of 17 that were available.

8. **Which credits did you find most difficult to obtain?**

   The Energy and Atmosphere credits were difficult to obtain on this project.

9. **What parts of the project worked well together, providing overlapping/double impact? (e.g. upgraded windows provide temperature control, leading to smaller needed HVAC equipment)**

   See addendum.

10. **What about the LEED® process was easy? Difficult? Time consuming?**

    The only item that was relatively simple about the LEED® process was the initial registration of the project with the USGBC. The rest of the process was not difficult, but it was challenging at times and it required extensive detailed record keeping throughout the construction effort. The appeals process required a very close attention to detail as well, and definitely took some time.

11. **What would you do again? Avoid?**

    I would do all of it again. Nothing to avoid.

12. **What are the water/energy/waste reduction/etc savings per year? Long-term?**

    Water use reduction was calculated to be ~44% from a baseline design. Energy performance is 15.5% better than the ASHRAE 90.1 baseline case. 98% of construction waste was diverted from landfills.

13. **What was the upfront cost of the improvements/equipment?**

    Data not readily available.

14. **What was the payback period?**

    Data not readily available.

15. **How far in advance of construction/renovation did you start the planning process?**

    We started looking at LEED® certification later than we should have. The design was probably 75% complete when we had the A-E start looking at it.

16. **How well have the improvements/equipment held up over time vs. conventional?**

    Neither better nor worse at this point.

17. **If your building was LEED-NC® Certified, do you plan to pursue LEED-EB: O&M® Certification in the future?**

    Not at this time.

18. **If you could provide advice to other NASA Centers undergoing the LEED® certification process, what would it be?**

    Start the planning process early, and develop a game-plan for how you want to proceed towards certification. Also, you should definitely target several more points than the minimum certification level desired because the USGBC will almost certainly deny you some of the points. Using an A-E firm experienced with LEED® buildings is definitely a must, and include the Commissioning Agent as early as possible. Also, as soon as you are able to begin discussions with the construction contractor regarding the LEED® certification, the easier it is to get them on-board.

ADDENDUM

NASA – Johnson Space Center – White Sands Test Facility (WSTF) set out to achieve a LEED® Silver Certification on the new Health and Fitness Center that was planned for construction. NASA was increasing its commitment towards sustainable architecture, and the Fitness Center was an ideal candidate to be one of the first LEED® Silver facilities in the agency.

Working towards the LEED® Silver certification required a strong commitment from all of the parties involved. This included the architects (PDG Architects), the engineers (Thompson Engineering), the construction contractor (Brewbaker General Contractors), and the owner (NASA/WSTF). The teamwork between these four entities was critical to the success of this project.

The design and construction of this facility yielded several highlights related to sustainability and green building practices. However the four listed below are especially pertinent:

1) The Construction Waste Management by the building contractor was outstanding. Through closely working with his suppliers, the architect, the owner, and the local recycling community, he was able to divert over 98% of the construction waste from local landfills.

2) The use of daylighting throughout the facility is very extensive, and during the multiple sunny days here at WSTF none of the indoor lighting in either the workout area or the gymnasium is required. Over the life of the building this will result in energy savings for the owner.

3) The Water Efficiency attributes of the Fitness Center are also worth highlighting. All five points under the Water Efficiency credits are being applied for in the facility's LEED® submittal. This was achieved through the use of landscaping that requires no irrigation; waterless urinals; ultra-low-flow water closets utilizing 0.8 gallons per flush; and automatic cut-off low-flow lavatory fixtures. Since WSTF is located in an arid desert climate, water efficiency is absolutely necessary.

4) During the construction of the facility and prior to user occupancy, several steps were taken by the contractor to ensure a high indoor air quality. Some of these steps were: a) selecting building materials with low VOC content, b) practicing good housekeeping techniques, and c) HVAC ductwork was sealed during construction activities and the system was not activated until construction was complete. Additionally, before the building was occupied, a two week flush-out was completed with 100% outside air and all filters were replaced once this operation was completed.

One additional item worth noting is that during the design phase of this building, NASA had the tragedy of the Space Shuttle Columbia exploding upon re-entry. As a tribute and memorial to Columbia, WSTF named the new facility the Columbia Health and Fitness Center.

APPENDIX D. NASA SUSTAINABILITY, ENVIRONMENTAL, AND ENERGY MANAGERS

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APPENDIX E. SUMMARY OF FEDERAL REGULATIONS RELATING TO SUSTAINABILITY GOALS

Sustainable Design and Construction – General		
Regulation	**Subject**	**Requirements**
EISA 2007 Section 441	Public Building Life-Cycle Costs	Changes life-cycle cost period for facilities-related projects from 25 to 40 years.
EO 12956	Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements	Calls federal agencies to be innovators of programming designed to reduce pollution and environmental impacts of operations.
		Requires compliance with Right-to-Know laws and pollution reduction requirements.
EO 13423	Strengthening Federal Environmental, Energy, and Transportation Management	Ensures that all new construction and major renovations comply with the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding (2006)*.
		Requires that 15 percent of existing federal buildings incorporate the sustainable practices in the *Guiding Principles* by FY 2015.
		Requires that agencies implement Environmental Management Systems (EMS) to address environmental aspects of internal agency operations and activities.
		Requires that agencies establish programs for environmental management training and environmental compliance review and audit.
EO 13514	Federal Leadership in Environmental, Energy, and Economic Performance	Requires that all new federal buildings entering the design phase in 2020 or later are designed to achieve zero net energy by 2030.
		Requires that all new construction, major renovations, repair, or alteration of federal buildings comply with the *Guiding Principles of Federal Leadership in High Performance and Sustainable Buildings*.
		Requires that at least 15 percent of existing agency buildings and leases meet the Guiding Principles by FY 2015 and that the agency makes annual progress towards 100 percent compliance across its building inventory.
		Requires that agencies pursue cost-effective, innovative strategies to minimize consumption of energy, water, and materials.
		Requires management of building systems to reduce the consumption of energy, water, and materials and to identify alternatives to renovation that reduce existing asset deferred maintenance costs.

Sustainable Design and Construction – General		
Regulation	**Subject**	**Requirements**
EO 13514	Federal Leadership in Environmental, Energy, and Economic Performance	When adding assets to agency building inventories, requires identification of opportunities to consolidate and eliminate existing assets, optimize the performance of portfolio property, and reduce associated environmental impacts.
NASA NPD 8500.1B	NASA Environmental Management	Requires that NASA incorporate sustainable practices to the extent practicable through programs, projects, and activities.
		Requires that sustainable practices be integrated into the planning, development, implementation, and operation phases of development.
		Requires consideration of environmental factors throughout the life-cycle of programs, projects, and activities.
		Requires active communication, coordination, and cooperation with federal, state, local regulatory agencies, and nongovernmental organizations to leverage resources and comply with environmental requirements.
NASA NPR 8810.1 Chapter 1	Master Planning Procedural Requirements – The Master Plan	Requires that the Center Master Plan (CMP) discuss sustainable design principles incorporated into the changes and development proposed for the Center. Integration of sustainable design principles incorporated into individual projects should also be discussed.
NASA NPD 8820.2C	Design and Construction of Facilities	Requires that industry best practices of sustainable design, maintainable design, building commissioning, safety and security be incorporated to the maximum extent possible, into the planning and execution of facility projects.
		Ensures that facility projects are delivered with the most economical life-cycle cost, least environmental impact, and maximum benefits in occupant's health, safety, security, and productivity.
		Establishes the role of the Director of the Facilities Engineering and Real Property Division to recommend appropriate LEED® goals for NASA facility projects and provide technical leadership for training related to sustainable design initiatives.
		Establishes the role of Center Directors to ensure appropriate application of sustainable design principles on facilities projects, promote the use of life-cycle cost analysis when evaluating sustainable design polices, provide training in sustainable design concepts, and conduct assessments of Center progress toward achieving sustainable design goals.

Sustainable Design and Construction – General		
Regulation	**Subject**	**Requirements**
NASA NPR 8820.2F Chapter 1	Facility Project Requirements – NASA's Facilities Program	Defines NASA-accepted Facility Program Best Practices.
		Requires use of life-cycle cost rather than first cost for project systems, equipment, materials, and methods.
		Requires designing for maintainability to optimize operations and maintenance costs and efforts.
		Requires use of USGBC LEED® concepts in planning and design of facilities.
NASA NPR 8820.2F Chapter 2	Facility Project Requirements – Project Development and Planning	Requires that all new construction and major renovation projects planned for award after October 1, 2005 meet the LEED® Silver rating.
		Requires that projects be evaluated in terms of risks, benefits, and costs.
		Additional information should be provided that shows the additional project components required to achieve the LEED® Gold rating.
		Requires that sustainability elements be documented in the Facility Project Management Plan.

Sustainable Sites		
Regulation	**Subject**	**Requirements**
EO 13514	Federal Leadership in Environmental, Energy, and Economic Performance	Requires that planning for new federal facilities and leases considers sites that are pedestrian friendly, near existing employment centers, and accessible to public transport and emphasizes existing central cities and, in rural communities, existing or planned town centers.
NASA NPR 3600.1A	Attendance and Leave – Hours of Duty	Permits the establishment of compressed and flexible work schedules in accordance with the provision of 5 U.S.C. Chapter 61, Subchapter II, providing potential reductions in conventional commuting trips.
NASA NPR 8570.1 Chapter 1	Energy Efficiency and Water Conservation	Establishes a goal that sustainable design principles be applied to the siting, design, construction, and operations and maintenance of new facilities and to the rehabilitation and modification of existing facilities to optimize life-cycle costs, prevent pollution, and minimize energy and water usage.

Sustainable Sites		
Regulation	**Subject**	**Requirements**
NASA NPR 8580.1 Chapter 9	Implementing the National Environmental Policy Act and Executive Order 12114 – Environmental Resources Document	Requires general discussion of the current policies and procedures for landscaping management under the following topics: ▪ Use of regionally native plants ▪ Design, use, or promotion of construction practices that minimize adverse effects on the natural habitat ▪ Pollution prevention ▪ Implementation of water efficient practices ▪ Creation of demonstration projects as part of the Environmental Resources Document (ERD).
		Requires discussion of activities currently located in floodplain or wetlands and existing measures to minimize harm to lives, property, and the natural and beneficial values of floodplains and wetlands in the ERD.
		Requires a discussion of current polices and procedures for integrated pest management including initiatives to reduce pesticide use; management practices for permitting, training, storing, and disposing of regulated pesticides; and a list of commonly used pesticides.
NASA NPR 8810.1 Chapter 2/3	Master Planning Procedural Requirements – The Master Planning Process and the Master Plan	Establishes requirements for Center Master Plan (CMP) documents.
		Requires that Centers establish a narrative and graphic presentation of the existing landscape design program, erosion control, floodplain management, wetlands, habitat, and threatened/endangered species protection.
NASA NPR 8820.2F Chapter 2	Facility Project Requirements – Project Development and Planning	Requires that project designers minimize stormwater runoff and polluted site water runoff.
		Requires that the project designer reduces outdoor potable water consumption by a minimum of 50 percent over that consumed by conventional means (plant species and plant densities) by using water-efficient landscape and irrigation strategies, including water reuse and recycling.

Sustainable Sites		
Regulation	**Subject**	**Requirements**
NASA NPR 8831.2D Chapter 10	Facilities Maintenance Management – Facilities Maintenance Standards and Actions	Recommends that facility landscaping plans emphasize low-maintenance features.
		Requires that grounds care work plans specify appropriate environmental controls for chemicals including pesticides, herbicides, and fertilizers.

Water Efficiency		
Regulation	**Subject**	**Requirements**
EPAct 2005 Section 109	Federal Building Performance Standards	Mandates that if water is used to achieve energy efficiency, water conservation technologies be applied, if cost-effective.
EISA 2007 Section 432	Management of Energy and Water Efficiency in Federal Buildings	Requires evaluations of water usage.
EO 13423	Strengthening Federal Environmental, Energy, and Transportation Management	Requires that federal agencies reduce water consumption intensity, relative to the baseline of the agency's water consumption in FY 2007, through life-cycle cost-effective measures by two percent annually through the end of FY 2015 or 16 percent by the end of FY 2015.
EO 13514	Federal Leadership in Environmental, Energy, and Economic Performance	Requires that federal agencies reduce potable water consumption intensity by two percent annually through FY 2020 or 26 percent by the end of FY 2020 relative to a FY 2007 baseline.
		Requires that federal agencies reduce industrial, landscaping, and agricultural water consumption by two percent annually or 20 percent by the end of FY 2020 relative to a FY 2010 baseline.
		Requires that federal agencies identify, promote, and implement water reuse strategies consistent with state law that reduce potable water consumption.
48 CFR 23	Environment, Energy and Water Efficiency, Renewable Technologies, Occupational Safety and Drug-Free Workplace Federal Acquisition Regulation	Promotes policies to acquire supplies and services that promote water efficiency and help foster markets for emerging technologies.

Water Efficiency		
Regulation	**Subject**	**Requirements**
NASA NPR 8570.1 Introduction	Energy Efficiency and Water Conservation	Requires that Energy Managers and facilities maintenance personnel minimize water consumption without affecting safety or mission operations.
		Requires that personnel be aware of the importance of limiting water use to the minimum requirements.
		Requires implementation of water conservation measures that modernize aging facilities and infrastructure, maximize funds allocated to NASA programs and projects through reduced expenditures on water services, and demonstrate environmental stewardship.
		Encourages partnering with other agencies for utility needs and using Energy Savings Performance Contracts (ESPC) and Utility Energy Service Contracts (UESC).
		Sets a goal to reduce water consumption and associated energy use by implementing appropriate Best Management Practices (BMPs) as identified by the Department of Energy (DOE).
		Sets a goal of conducting water audits for approximately 10 percent of total facilities' gross square footage each year until all facilities have been audited.
		Requires that Centers identify and request funds for water conservation methods that are cost-effective over the life-cycle.
		Requires Centers to implement an awareness program to reduce water consumption.

Water Efficiency		
Regulation	**Subject**	**Requirements**
NASA NPR 8570.1 Chapter 3	Energy Efficiency and Water Conservation – Energy Efficiency and Conservation Management Program	Requires preparation of an Energy Efficiency and Water Conservation 5-Year Plan that contains: ▪ A mission and values statement about plan goals ▪ Authorities relating to energy and water management issues ▪ Specific plan goals and what is required to meet them ▪ A description of the Center's organization for energy efficiency and conservation management ▪ A complete record of energy audits since 1991, including a schedule of any future audits ▪ Water- or energy-efficiency projects that will be implemented within the timeframe of the plan ▪ Resources needed to implement the plan ▪ Operations and maintenance procedures or process improvements that can be implemented and sustained during the course of the plan ▪ Awareness activities to draw attention to water and energy conservation
NASA NPR 8570.1 Chapter 8	Energy Efficiency and Water Conservation – Water Conservation	Requires that a water management plan has been developed and incorporated into existing facility planning processes and operating plans.
		Requires that federal facilities meet 4 of 10 BMPs for water efficiency, including: ▪ Public information and education ▪ Distribution system audit, leak detection, and repair ▪ Water efficient landscaping ▪ Toilets and urinals ▪ Faucets and showerheads ▪ Boilers and steam systems ▪ Single-pass cooling systems ▪ Cooling tower systems ▪ Miscellaneous high-water using processes ▪ Water reuse and recycling

Water Efficiency		
Regulation	**Subject**	**Requirements**
NASA NPR 8580.1 Chapter 9	Implementing the National Environmental Policy Act and Executive Order 12114 – Environmental Resources Document	Requires general discussion of the current policies and procedures for landscaping management under the following topics: ▪ Use of regionally native plants ▪ Design, use, or promotion of construction practices that minimize adverse effects on the natural habitat ▪ Pollution prevention ▪ Implementation of water efficient practices ▪ Creation of demonstration projects as part of the Environmental Resources Document (ERD)
NASA NPR 8810.1 Chapter 2/3	Master Planning Procedural Requirements – The Master Planning Process and the Master Plan	Requires that Centers establish a narrative and graphic presentation of water conservation measures.
NASA NPR 8820.2F Chapter 2	Facility Project Requirements – Project Development and Planning	Requires that the project designer reduces the potable indoor water consumption of latrine fixtures (e.g., showerheads, faucets, water closets, and urinals) by at least 20 percent from the baseline as calculated using the Energy Policy Act (EPAct) of 1992 fixture performance standards.
		Requires that the project designer reduce potable outdoor water consumption by a minimum of 50 percent over that consumed by conventional means (plant species and plant densities) by using water-efficient landscaping and irrigation strategies, including water reuse and recycling.
NASA NPR 8831.2D Chapter 11	Facilities Maintenance Management – Utilities Management	Requires utility data management, including metering of all utilities. Utility data should be used to review billing transactions, usage patterns and levels, and system efficiencies.

Energy and Atmosphere		
Regulation	**Subject**	**Requirements**
EPAct 2005 Section 102	Energy Management Requirements	Mandates a two percent reduction per year in energy consumption per gross square foot for all federal buildings as compared with the reported 2003 values.
EPAct 2005 Section 103	Energy Use Measurement and Accountability	Mandates that all federal buildings be metered for the purpose of efficient use of energy and reduction in the cost of electricity by 2012.

Energy and Atmosphere		
Regulation	**Subject**	**Requirements**
EPAct 2005 Section 104	Procurement of Energy Efficient Products	Mandates that all agencies procure ENERGY STAR or Federal Energy Management Program (FEMP)-designated products when cost-effective.
		Requires energy efficient specifications to be included in procurement bids and evaluations.
		Requires premium efficient electric motors, air conditioning, and refrigeration equipment procurement.
EPAct 2005 Section 105	Energy Saving Performance Contracting	Reauthorizes use of Energy Saving Performance Contracting through 2016.
EPAct 2005 Section 109	Federal Building Performance Standards	Mandates that all new federal buildings achieve savings of at least 30 percent below the American Society of Heating, Refrigeration, and Air-conditioning Engineers, Inc. (ASHRAE) Standard 90.1-2004 or the 2004 IECC, if cost-effective.
		Requires that buildings use sustainable design practices for siting, designing, and constructing, if cost-effective.
EPAct 2005 Section 111	Enhancing Efficiency in Management of Federal Lands	Requires use of energy-efficient technologies in public and administrative buildings to the extent possible.
EPAct 2005 Section 203	Federal Purchase Requirements	Sets minimum requirements for federal renewable electricity consumption of 3 percent through FY 2009, 5 percent through FY 2012, and 7.5 percent after FY 2013.
		Doubles credit for on-site renewable energy production at Federal facilities.
EPAct 2005 Section 207	Use of Photovoltaic Energy in Public Buildings	Establishes a goal to install 20,000 solar energy systems in federal buildings by 2010.
EISA 2007 Section 431	Energy Reduction Goals for Federal Buildings	Strengthens energy reduction goals for federal agencies over requirements in EPAct 2005.
EISA 2007 Section 432	Management of Energy and Water Efficiency in Federal Buildings	Requires establishment of Energy Managers for federal facilities.
		Requires evaluations of energy use.
		Requires consideration of re-commissioning and/or retro-commissioning of federal facilities.

Energy and Atmosphere		
Regulation	**Subject**	**Requirements**
EISA 2007 Section 433	Federal Building Energy Efficiency Performance Standards	Requires reduction in fossil fuel energy uses relative to usage in the DOE's Commercial Building Energy Consumption Survey (CBECS) or Residential Energy Consumption Survey (RECS).
		Applies only to public buildings, buildings with $2.5M in annual costs, or buildings for which General Services Administration (GSA) must file a prospectus to Congress.
		Includes new construction and major renovations.
EISA 2007 Section 434	Management of Federal Building Efficiency	Requires that large capital energy investments that are not major renovations be life-cycle cost-effective.
		Requires installation of steam and natural gas meters in 2016.
EISA 2007 Section 435	Leasing	Requires that all leased federal buildings be ENERGY STAR buildings or buildings that have been renovated for all life-cycle cost-effective energy improvements.
EISA 2007 Section 437	Federal Green Building Performance	Provides for audits of federal green building performance.
EISA 2007 Section 523	Solar Hot Water	For all federal new construction or major renovation, if life-cycle cost-effective, as compared to other reasonably available technologies, at least 30 percent of hot-water demand shall be met through use of solar hot water heaters.
EO 12843	Procurement Requirements and Polices for Federal Agencies for Ozone-Depleting Substances	Requires federal agencies to maximize the use of safe alternatives to ozone-depleting substances.
		Encourages revision of procurement practices, modification of specifications and contracts that require the use of ozone-depleting substances, and substitution of non-ozone depleting substances.
		Requires dissemination of information relating to successful efforts to phase-out ozone-depleting substances.

Energy and Atmosphere		
Regulation	**Subject**	**Requirements**
EO 13423	Strengthening Federal Environmental, Energy, and Transportation Management	Requires that agencies improve energy efficiency and reduce greenhouse gas emissions, through reduction of energy intensity, by 3 percent annually through the end of FY 2015, or by 30 percent by the end of FY 2015 relative to the baseline of the agency's energy use in FY 2003.
		Mandates that agencies ensure that at least half of the statutorily required renewable energy consumed by the agency in a fiscal year comes from new renewable sources and, to the extent possible, that the agency implements renewable energy generation projects on agency property for agency use.
EO 13514	Federal Leadership in Environmental, Energy, and Economic Performance	Requires that federal agencies implement best management practices for the energy-efficient management of servers and Federal data centers.
		Requires establishing a FY 2020 reduction target of agency-wide scope 1, scope 2, and scope 3 greenhouse gas emissions relative to a FY 2008 baseline.
		Requires establishing and reporting a comprehensive inventory of absolute greenhouse gas emissions across all three scopes for FY 2010. Comprehensive inventories shall be submitted annually thereafter at the end of each January.
10 CFR 433	Energy Efficiency Standards for New Federal Commercial and High-Rise Multi-Family Buildings	Requires that federal agencies design commercial and high-rise residential buildings to meet ASHRAE Standard 90.1-2004.
		Requires that, if life-cycle cost-effective, energy consumption be at least 30 percent below the levels in a baseline building meeting ASHRAE 90.1.
		Requires that buildings that cannot meet the 30 percent reduction be designed to meet the maximum energy-efficient level possible that is cost-effective.
10 CFR 436	Federal Energy Management and Planning Programs	Establishes procedures for determining life-cycle cost-effectiveness.
		Sets priorities for energy conservation measures in retrofits of existing federal buildings.
		Establishes guidance for Energy Savings Performance Contracting programs to accelerate investment in cost-effective energy-conservation measures in federal buildings.

Energy and Atmosphere		
Regulation	**Subject**	**Requirements**
48 CFR 23	Environment, Energy and Water Efficiency, Renewable Technologies, Occupational Safety and Drug-Free Workplace Federal Acquisition Regulation	Promotes policies to acquire supplies and services that promote energy efficiency, advance the use of renewable energy products, and help foster markets for emerging technologies.
NASA NPR 8570.1 Introduction	Energy Efficiency and Water Conservation	Requires that Energy Managers and facilities maintenance personnel minimize energy consumption without affecting safety or mission operations.
		Requires that personnel be aware of the importance of limiting energy use to the minimum requirements.
		Requires implementation of energy conservation measures that modernize aging facilities and infrastructure, maximize funds allocated to NASA programs and projects through reduced expenditures on water services, and demonstrates environmental stewardship.
		Encourages partnering with other agencies for energy and utility needs and using Energy Savings Performance Contracts (ESPC) and Utility Energy-Efficiency Service Contracts (UESC).
		Sets a goal of reducing greenhouse gas emissions attributed to facility energy use by 30 percent by FY 2010 over baseline FY 1990 levels.
		Sets a goal of reducing overall energy use per gross square foot by 35 percent by FY 2010, relative to 1985 levels.
		Sets a goal of improving energy efficiency of buildings by 25 percent by FY 2010 relative to FY 1990 levels.
		Requires expanded use of renewable energy for facilities and operational activities by implementing renewable energy projects and by purchasing electricity from clean, efficient, and renewable energy sources.

Energy and Atmosphere		
Regulation	**Subject**	**Requirements**
NASA NPR 8570.1 Introduction	Energy Efficiency and Water Conservation	Requires reduction in petroleum use in facility operations by switching to a less greenhouse-gas-intensive, non-petroleum-based energy source where practical and cost-effective.
		Sets a goal of conducting energy audits for approximately 10 percent of total facilities' gross square footage each year until all facilities have been audited.
		Requires use of life-cycle cost analysis in making investment decisions on energy-efficient products.
		Requires that where cost-effective over the life-cycle, ENERGY STAR products, other energy-efficient products in the upper 25 percent of energy efficiency, and products with low standby power requirements as designated by the DOE and EPA be used.
		Requires the appointment of an Energy Manager to serve as the focal point for all energy matters and to manage and monitor energy consumption and conservation.
		Requires that Centers perform energy surveys and identify and request funds for energy-conservation methods that are cost-effective over the life-cycle.
		Requires Centers to ensure that new facilities are designed and constructed to comply with federal energy performance standards.
		Requires Centers to implement an awareness program to reduce energy consumption.
NASA NPR 8570.1 Chapter 3	Energy Efficiency and Water Conservation – Energy Efficiency and Conservation Management Program	Specifies that Center Energy Efficiency and Conservation Management Programs should address: ▪ Low- and no-cost operations and maintenance measures to ensure peak energy performance ▪ Retrofits to provide improvements in existing buildings and equipment ▪ Replacement of worn-out equipment with new, high-efficiency equipment ▪ Installation of energy-efficient equipment in all new facilities and major renovations ▪ Load sharing and peak shaving to reduce utility demand charges

Energy and Atmosphere		
Regulation	**Subject**	**Requirements**
NASA NPR 8570.1 Chapter 3	Energy Efficiency and Water Conservation – Energy Efficiency and Conservation Management Program	Dictates that the planning process for Energy Efficiency and Conservation Management Programs should include: ▪ Support from top Center management ▪ An organized Energy Efficiency Team (EET) ▪ Collection of background information including energy purchases, an Energy Use Index (EUI) for the facility, and other necessary data ▪ An in-depth energy audit; a 5-year energy efficiency and water conservation plan including priorities for schedules, budgets, and goals ▪ Implementation, promotion, and monitoring of the plan
		Requires that the Energy Efficiency and Water Conservation 5-Year Plan contain: ▪ A mission and values statement about plan goals ▪ Authorities relating to energy and water management issues ▪ Specific plan goals and what is required to meet them ▪ A description of the Center's organization for energy efficiency and conservation management ▪ A complete record of energy audits since 1991, including a schedule of any future audits ▪ Water- or energy-efficiency projects that will be implemented within the timeframe of the plan ▪ Resources needed to implement the plan ▪ Operations and maintenance procedures or process improvements that can be implemented and sustained during the course of the plan ▪ Awareness activities to draw attention to water and energy conservation
NASA NPR 8810.1 Chapter 2/3	Master Planning Procedural Requirements – The Master Planning Process and the Master Plan	Requires that Centers establish a narrative and graphic presentation of energy conservation measures.

Energy and Atmosphere		
Regulation	**Subject**	**Requirements**
NASA NPR 8820.2F Chapter 1	Facility Project Requirements – NASA's Facilities Program	Requires commissioning of installed equipment, systems, building envelope, and other building elements to ensure quality, reliability, and systems integration.
NASA NPR 8820.2F Chapter 2	Facility Project Requirements – Project Development and Planning	Requires that project designers establish a whole building performance target that takes into account the intended use, occupancy, operations, plug loads, other energy demands, and design to earn the ENERGY STAR targets for new construction and major renovation where applicable.
		Requires that new construction project designers reduce the energy cost budget by 30 percent compared to the baseline building performance rating per the ASHRAE Standard 90.1-2004, Energy Standard for Buildings Except Low-Rise Residential.
		Requires that major renovation project designers reduce the energy cost budget by 20 percent from pre-renovations 2003 baseline.
		Requires total building commissioning of installed items and associated systems as proscribed by the LEED® rating system.
		Eliminates the use of ozone-depleting compounds during and after construction where alternative environmentally preferable products are available, consistent with either the Montreal Protocol and Title VI of the Clean Air Act Amendments of 1990, or equivalent overall air quality benefits that take into account life-cycle impacts.
NASA NPR 8831.2D Chapter 8	Facilities Maintenance Management – Reliability Centered Building and Equipment Acceptance	Requires building commissioning as part of NASA's Reliability Centered Maintenance (RCM) process, which applies to both new construction and existing operations and maintenance.
NASA NPR 8831.2D Chapter 11	Facilities Maintenance Management – Utilities Management	Promotes use of Utility Energy Service Contracts to implement energy savings projects.
		Requires utility data management, including metering of all utilities. Utility data should be used to review billing transactions, usage patterns and levels, and system efficiencies.

Materials and Resources		
Regulation	**Subject**	**Requirements**
RCRA 1976 Sections 1008 and 6004	Solid Waste Generation	Requires that the federal government take action to recover the solid waste it generates; provides a basis for recycling programs.
RCRA 1976 Section 6002	Federal Procurement	Requires that the federal government purchase recycled materials, when possible.
EO 13423	Strengthening Federal Environmental, Energy, and Transportation Management	Requires that in acquisition of goods and services agencies use sustainable environmental practices, including acquisition of bio-based, environmentally-preferable, energy-efficient, water-efficient, and recycled-content products.
		Requires use of paper that is of at least 30 percent post-consumer fiber content.
		Requires cost-effective waste prevention and recycling programs in facilities.
EO 13514	Federal Leadership in Environmental, Energy, and Economic Performance	Requires that 95 percent of new contract actions, task orders, and delivery orders for products and services are energy-efficient, water-efficient, bio-based, environmentally preferable, non-ozone depleting, contain recycled content, or are non-toxic or less-toxic alternatives where such products and services meet agency performance requirements.
		Requires minimizing the generation of waste and pollutants through source reduction.
		Requires decreasing agency use of chemicals where such decreases will assist the agency in achieving greenhouse gas reduction targets.
		Requires diverting at least 50 percent of non-hazardous solid waste by the end of FY 2013.
		Requires reducing printing paper use and acquiring uncoated printing and writing paper containing at least 30 percent post-consumer fiber.
		Requires increasing the diversion of compostable and organic material from the waste stream.
NASA NPR 8530.1A	Affirmative Procurement Program and Plan for Environmentally Preferable Products	Establishes NASA standard procedures for procuring US Environmental Protection Agency (EPA)-designated and other environmentally preferable goods and services to the maximum extent practicable.
		Encourages publicizing and promotion of NASA's use of environmentally preferable goods and services through convenient and cost-effective methods.
		Requires review and revision of NASA specifications and standards to eliminate barriers to the preference for recovered materials.

Materials and Resources		
Regulation	**Subject**	**Requirements**
NASA NPR 8530.1A	Affirmative Procurement Program and Plan for Environmentally Preferable Products	Requires submission of Annual Affirmative Procurement Progress Reports to the Federal Environmental Executive.
NASA NPR 8820.2F Chapter 1	Facility Project Requirements – NASA's Facilities Program	Requires use of environmentally friendly processes, materials, and equipment as well as maximization of reuse rather than disposal in projects that include demolition.
NASA NPR 8820.2F Chapter 2	Facility Project Requirements – Project Development and Planning	Requires that during the planning stage of construction, local recycling and salvage operations that could process site-related waste be identified. The designer is required to incorporate into the construction documents to have the contractor recycle or salvage at least 50 percent of construction, demolition, and land clearing waste, excluding soil, where markets or on-site recycling opportunities exist.
		Requires use of products meeting or exceeding the US Department of Agriculture's (USDA) biobased content recommendations. For products not covered by the USDA's recommendations, biobased products made from rapidly renewable resources and certified sustainable wood products must be used.
		Requires use of products meeting or exceeding EPA's recycled content recommendations, for EPA-designated products. For products not covered by the EPA's recommendations, materials with recycled content must be such that the sum of post-consumer recycled content, plus one-half of the pre-consumer recycled content, constitutes at least 10 percent (based on cost) of the total value of the materials in the project.

Indoor Environmental Quality		
Regulation	**Subject**	**Requirements**
EO 13058	Protecting Federal Employees and the Public from Exposure to Tobacco Smoke in the Federal Workplace	Mandates that federal workplaces be smoke-free environments by prohibiting smoking in all interior spaces owned, rented, or leased by the executive branch of the federal government.
		Prohibits smoking in any outdoor areas under executive branch control in front of air intake ducts.
		Recommends that agency heads establish a smoking ban around building perimeters or within certain distances of doorways; does not provide guidance as to the extent of the smoke-free area.

Indoor Environmental Quality		
Regulation	**Subject**	**Requirements**
NASA NPR 8820.2F Chapter 2	Facility Project Requirements – Project Development and Planning	Ensures compliance with Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) Indoor Air Quality Guidelines for Occupied Buildings under Construction, 1995. Requires that after construction and prior to occupancy, a minimum 72-hour flush-out with maximum outdoor air must be conducted, consistent with achieving relative humidity no greater than 60 percent. Requires that after occupancy, flush-out be continued as necessary to minimize exposure to contaminants from new building materials.
		Requires compliance with ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy, including continuous humidity control within established ranges per climate zone, and ASHRAE Standard 62.1-2004, Ventilation for Acceptable Indoor Air Quality.
		Requires preparation of a moisture control strategy for controlling moisture flows and condensation to prevent building damage and mold contamination.
		Establishes a minimum daylight factor of two percent (excluding all direct sunlight penetration) in 75 percent of all spaces occupied for critical visual tasks. Requires automatic dimming controls and appropriate glare controls.
		Requires use of materials and products with low-pollutant emissions (e.g., volatile organic compounds), including adhesives, sealants, paints, carpet systems, and furnishings.

APPENDIX F. LEED® REGIONAL PRIORITY CREDITS, BY CENTER

The 2009 version of the LEED® credit systems includes points for Regional Priorities. Each Regional Priority is an existing LEED® point deemed of special local significance. No additional work is required to earn the points; if a project is awarded a point that is identified as a Regional Priority, the project is awarded one extra point toward certification. Each LEED-NC® and LEED-EB: O&M® project can earn up to four total Regional Priority points. The LEED-ND® credit system does not currently include Regional Priority points.

The Regional Priority credits for 15 NASA locations in the continental United States are identified in the following tables, organized alphabetically by Center. The priorities were established for each zip code or location by USGBC's regional councils, chapter, and affiliates. If the zip code for an individual location could not be found in the USGBC database, an adjacent zip code was used.

Ames Research Center - Mountain View, California Zip code: 94043 (94035 not found)	
LEED-NC®	**LEED-EB: O&M®**
SS Credit 4.1 - Alternative Transportation - Public Transportation Access	SS Credit 4 - Alternative Commuting Transportation (50%)
SS Credit 7.1 - Heat Island Effect - Nonroof	WE Credit 2 - Additional Indoor Plumbing Fixture and Fitting Efficiency (30%)
WE Credit 2 - Innovative Wastewater Technologies	IEQ Credit 2.4 - Daylight and Views
WE Credit 3 - Water Use Reduction (40%)	EA Credit 1 - Optimize Energy Efficiency Performance (85 rating/35th percentile)
EA Credit 2 - On-site Renewable Energy (1%)	EA Credit 4 - On-site and Off-site Renewable Energy (7.5%/62.5%)
IEQ Credit 8.1 - Daylight and Views - Daylight	MR Credit 7 - Solid Waste Management - Ongoing Consumables

Dryden Flight Research Center - Edwards, California Zip code: 93523	
LEED-NC®	**LEED-EB: O&M®**
SS Credit 1 - Site Selection	SS Credit 4 - Alternative Commuting Transportation (50%)
SS Credit 2 - Development Density and Community Connectivity	SS Credit 7.1 - Heat Island Effect - Nonroof
SS Credit 4.1 - Alternative Transportation - Public Transportation Access	WE Credit 3 - Water Efficient Landscaping (75%)
WE Credit 1.1 - Water Efficient Landscaping	EA Credit 1 - Optimize Energy Efficiency Performance (85 rating/35th percentile)
WE Credit 3 - Water Use Reduction (40%)	EA Credit 4 - On-site and Off-site Renewable Energy (7.5%/62.5%)
EA Credit 2 - On-site Renewable Energy (1%)	MR Credit 7 - Solid Waste Management - Ongoing Consumables

Glenn Research Center - Cleveland, Ohio Zip code: 44135	
LEED-NC®	**LEED-EB: O&M®**
SS Credit 6.1 - Stormwater Design - Quality Control	SS Credit 6 - Stormwater Quality Control
SS Credit 6.2 - Stormwater Design - Quality Control	SS Credit 7.2 - Heat Island Reduction - Roof
WE Credit 2 - Innovative Wastewater Technologies	WE Credit 3 - Water Efficient Landscaping (50%)
EA Credit 2 - On-site Renewable Energy (3%)	EA Credit 1 - Optimize Energy Efficiency Performance (85 rating/35th percentile)
MR Credit 2 - Construction Waste Management (75%)	EA Credit 4 - On-site and Off-site Renewable Energy (3%/25%)
MR Credit 6 - Rapidly Renewable Materials	MR Credit 6 - Solid Waste Management - Waste Stream Audit

Glenn Research Center - Plum Brook Station - Sandusky, Ohio Zip code: 44870	
LEED-NC®	**LEED-EB: O&M®**
SS Credit 3 - Brownfield Redevelopment	SS Credit 6 - Stormwater Quality Control
SS Credit 6.1 - Stormwater Design - Quality Control	WE Credit 3 - Water Efficient Landscaping (50%)
SS Credit 6.2 - Stormwater Design - Quality Control	EA Credit 1 - Optimize Energy Efficiency Performance (85 rating/35th percentile)
WE Credit 2 - Innovative Wastewater Technologies	EA Credit 4 - On-site and Off-site Renewable Energy (3%/25%)
EA Credit 1 - Optimize Energy Performance (25%)	MR Credit 5 - Sustainable Purchasing - Food
MR Credit 6 - Rapidly Renewable Materials	MR Credit 9 - Solid Waste Management - Facility Alterations and Additions

Goddard Space Flight Center - Greenbelt, Maryland Zip code: 20771	
LEED-NC®	**LEED-EB: O&M®**
SS Credit 5.1 - Site Development - Protect or Restore Habitat	SS Credit 5 - Site Disturbance - Protect or Restore Open Habitat
SS Credit 6.1 - Stormwater Design - Quality Control	SS Credit 6 - Stormwater Quality Control
WE Credit 2 - Innovative Wastewater Technologies	SS Credit 7.1 - Heat Island Reduction - Non-roof
EA Credit 1 - Optimize Energy Performance (40%)	SS Credit 8 - Light Pollution Reduction
EA Credit 2 - On-site Renewable Energy (3%)	WE Credit 3 - Water Efficient Landscaping (50%)
MR Credit 1 - Building Reuse (75%)	EA Credit 4 - On-site and Off-site Renewable Energy (3%/25%)

Goddard Space Flight Center - Wallops Flight Facility - Chincoteague, Virginia Zip code: 23337	
LEED-NC®	**LEED-EB: O&M®**
SS Credit 4.1 - Alternative Transportation - Public Transportation Access	SS Credit 4 - Alternative Commuting Transportation (10%)
SS Credit 4.4 - Alternative Transportation- Parking Capacity	SS Credit 6 - Stormwater Quality Control
SS Credit 5.1 - Site Development - Protect or Restore Habitat	SS Credit 6 - Stormwater Quality Control
SS Credit 6.2 - Stormwater Design - Quality Control	SS Credit 8 - Light Pollution Reduction
WE Credit 2 - Innovative Wastewater Technologies	WE Credit 3 - Water Efficient Landscaping (100%)
WE Credit 3 - Water Use Reduction (40%)	MR Credit 7 - Solid Waste Management - Ongoing Consumables

Goddard Space Flight Center - White Sands Test Facility - White Sands, New Mexico Zip code: 88012	
LEED-NC®	**LEED-EB: O&M®**
SS Credit 2 - Development Density and Community Connectivity	SS Credit 4 - Alternative Commuting Transportation (75%)
SS Credit 4.1 - Alternative Transportation - Public Transportation Access	SS Credit 5 - Site Disturbance - Protect or Restore Open Habitat
WE Credit 1, Opt. 2 - Water Efficient Landscaping	WE Credit 2 - Additional Indoor Plumbing Fixture and Fitting Efficiency (20%)
WE Credit 3 - Water Use Reduction (40%)	WE Credit 3 - Water Efficient Landscaping (75%)
EA Credit 1 - Optimize Energy Performance (18%/14%)	EA Credit 1 - Optimize Energy Efficiency Performance (71 rating/21st percentile)
MR Credit 2 - Construction Waste Management (75%)	MR Credit 9 - Solid Waste Management - Facility Alterations and Additions

NASA Headquarters - Washington D.C. Zip code: 20024 (20546 not found)	
LEED-NC®	**LEED-EB: O&M®**
SS Credit 5.1 - Site Development - Protect or Restore Habitat	SS Credit 5 - Site Disturbance - Protect or Restore Open Habitat
SS Credit 6.1 - Stormwater Design - Quality Control	SS Credit 6 - Stormwater Quality Control
WE Credit 2 - Innovative Wastewater Technologies	WE Credit 2 - Additional Indoor Plumbing Fixture and Fitting Efficiency (30%)
EA Credit 1 - Optimize Energy Performance (40%/36%)	WE Credit 4, Option 2 - Cooling Tower Water Management
EA Credit 2 - On-site Renewable Energy (1%)	EA Credit 4 - On-site and Off-site Renewable Energy (3%/25%)
MR Credit 1 - Building Reuse (75%)	IEQ Credit 2.3 - Occupant Comfort - Thermal Comfort Monitoring

Jet Propulsion Laboratory - Pasadena, California Zip code: 91101 (91109 not found)	
LEED-NC®	**LEED-EB: O&M®**
SS Credit 5.2 - Site Development - Maximize Open Space	SS Credit 4 - Alternative Commuting Transportation (75%)
WE Credit 2 - Innovative Wastewater Technologies	WE Credit 2 - Additional Indoor Plumbing Fixture and Fitting Efficiency (30%)
WE Credit 3 - Water Use Reduction (40%)	IEQ Credit 2.4 - Daylight and Views
EA Credit 2 - On-site Renewable Energy (1%)	EA Credit 1 - Optimize Energy Efficiency Performance (85 rating/35th percentile)
MR Credit 1.1 - Building Reuse (50%)	EA Credit 4 - On-site and Off-site Renewable Energy (7.5%/62.5%)
IEQ Credit 8.1 - Daylight and Views - Daylight	MR Credit 7 - Solid Waste Management - Ongoing Consumables

Johnson Space Center - Houston, Texas Zip code: 77058	
LEED-NC®	**LEED-EB: O&M®**
SS Credit 3 - Brownfield Redevelopment	SS Credit 5 - Site Disturbance - Protect or Restore Open Habitat
SS Credit 5.1 - Site Development - Protect or Restore Habitat	SS Credit 6 - Stormwater Quality Control
SS Credit 6.1 - Stormwater Design - Quality Control	SS Credit 7.1 - Heat Island Effect - Nonroof
SS Credit 6.2 - Stormwater Design - Quality Control	EA Credit 4 - On-site and Off-site Renewable Energy (3%/25%)
EA Credit 2 - On-site Renewable Energy (1%)	MR Credit 7 - Solid Waste Management - Ongoing Consumables
MR Credit 2 - Construction Waste Management (75%)	IEQ Credit 1.4 - Indoor Air Quality Best Management Practices - Reduce Particulates in Air Distribution

Kennedy Space Center - Cape Canaveral, Florida Zip code: 32899	
LEED-NC®	**LEED-EB: O&M®**
SS Credit 2 - Development Density and Community Connectivity	SS Credit 7.2 - Heat Island Reduction - Roof
SS Credit 4.1 - Alternative Transportation - Public Transportation Access	WE Credit 2 - Additional Indoor Plumbing Fixture and Fitting Efficiency (10%)(20%)
WE Credit 2 - Innovative Wastewater Technologies	WE Credit 3 - Water Efficient Landscaping (75%)
EA Credit 1 - Optimize Energy Performance (28%)	EA Credit 1 - Optimize Energy Efficiency Performance (77 rating/27th percentile)
EA Credit 2 - On-site Renewable Energy (13%)	EA Credit 4 - On-site and Off-site Renewable Energy (7.5%/62.5%)
MR Credit 5 - Regional Materials (20%)	MR Credit 5 - Sustainable Purchasing - Food

Langley Research Center - Hampton Roads, Virginia Zip code: 23662 (23681 not found)	
LEED-NC®	**LEED-EB: O&M®**
SS Credit 4.1 - Alternative Transportation - Public Transportation Access	SS Credit 4 - Alternative Commuting Transportation (10%)
SS Credit 4.4 - Alternative Transportation-Parking Capacity	SS Credit 6 - Stormwater Quality Control
SS Credit 5.1 - Site Development - Protect or Restore Habitat	SS Credit 6 - Stormwater Quality Control
SS Credit 6.2 - Stormwater Design - Quality Control	SS Credit 8 - Light Pollution Reduction
WE Credit 2 - Innovative Wastewater Technologies	WE Credit 3 - Water Efficient Landscaping (100%)
WE Credit 3 - Water Use Reduction (40%)	MR Credit 7 - Solid Waste Management - Ongoing Consumables

Marshall Space Flight Center - Huntsville, Alabama Zip code: 35805 (35812 not found)	
LEED-NC®	**LEED-EB: O&M®**
SS Credit 6.1 - Stormwater Design - Quality Control	SS Credit 4 - Alternative Commuting Transportation (25%)
EA Credit 1 - Optimize Energy Performance (28%/24%)	SS Credit 6 - Stormwater Quality Control
EA Credit 2 - On-site Renewable Energy (1%)	WE Credit 2 - Additional Indoor Plumbing Fixture and Fitting Efficiency (20%)
WE Credit 3 - Water Use Reduction (40%)	EA Credit 1 - Optimize Energy Efficiency Performance (75 rating/25th percentile)
IEQ Credit 7.1- Thermal Comfort - Design	EA Credit 4 - On-site and Off-site Renewable Energy (3%/25%)
MR Credit 2 - Construction Waste Management (50%)	IEQ Credit 2.3 - Occupant Comfort - Thermal Comfort Monitoring

Michoud Assembly Facility - New Orleans, Louisiana Zip code: 70129	
LEED-NC®	**LEED-EB: O&M®**
SS Credit 3 - Brownfield Redevelopment	SS Credit 5 - Site Disturbance - Protect or Restore Open Habitat
SS Credit 5.1 - Site Development - Protect or Restore Habitat	SS Credit 6 - Stormwater Quality Control
SS Credit 6.1 - Stormwater Design - Quality Control	SS Credit 7.1 - Heat Island Effect - Nonroof
SS Credit 6.2 - Stormwater Design - Quality Control	EA Credit 4 - On-site and Off-site Renewable Energy (3%/25%)
EA Credit 2 - On-site Renewable Energy (1%)	MR Credit 7 - Solid Waste Management - Ongoing Consumables
MR Credit 2 - Construction Waste Management (75%)	IEQ Credit 1.4 - Indoor Air Quality Best Management Practices - Reduce Particulates in Air Distribution

Stennis Space Center - Biloxi, Mississippi Zip code: 39466 (39529 not found)	
LEED-NC®	**LEED-EB: O&M®**
SS Credit 4.1 - Alternative Transportation - Public Transportation Access	SS Credit 4 - Alternative Commuting Transportation (25%)
SS Credit 6.1 - Stormwater Design - Quality Control	SS Credit 6 - Stormwater Quality Control
WE Credit 3 - Water Use Reduction (40%)	WE Credit 2 - Additional Indoor Plumbing Fixture and Fitting Efficiency (20%)
EA Credit 1 - Optimize Energy Performance (28%/24%)	EA Credit 1 - Optimize Energy Efficiency Performance (75 rating/25th percentile)
EA Credit 2 - On-site Renewable Energy (1%)	EA Credit 4 - On-site and Off-site Renewable Energy (3%/25%)
IEQ Credit 7.1 - Thermal Comfort - Design	IEQ Credit 2.3 - Occupant Comfort - Thermal Comfort Monitoring

APPENDIX G. DEFINITIONS

Air-Handling Unit (AHU) - A device used to circulate or condition air throughout a facility. Consists of a blower, heating or cooling elements, filter chambers, and damper that connect to ductwork.

Alternative Energy - Energy produced from non-petroleum-based sources such as solar, wind, water, biomass, geothermal, or other. Also referred to as renewable energy, green energy, or green power.

Basis of Design - The basis of design (BoD) documents the assumptions behind the systems, components, conditions, and methods described to meet the Owner's Project Requirements. The BoD is generally prepared by the design team.

Biomass – Plant or other organic matter that is converted into a fuel source, usually to be burned.

Blackwater – Blackwater is untreated wastewater that contains potential toxins, such as water from toilets and urinals. This water source must be treated before it can be reused.

Blowdown – Blowdown is the periodic or continuous removal of water from a boiler to remove accumulated dissolved solids and/or sludge.

Blowout Urinal – Blowout urinals include models that flush automatically at given intervals and can be equipped with sensors to limit flushing frequency or shut off the urinal after operating hours.

Building Commissioning - A structured process that documents that all the building subsystems are installed, calibrated, and monitored to manufacturer's specifications and operated efficiently.

Building Envelope - The outer shell of a building, including foundation, walls, roof, doors, and windows that keep the external environment outside of the building.

Building Materials - The materials used to construct a facility's structural elements, such as roofing, siding, walls, and doors.

Building Modeling – A computer-based tool that utilizes facility information and design drawings to produce a three-dimensional virtual building. This tool can incorporate all the physical and functional characteristics of the facility throughout the entire life-cycle and facilitates the exchange and use of building information in digital formats.

Building Orientation – The physical direction the building is facing in relation to solar energy. A building's orientation maximizes solar heat and energy in relation to cardinal directions. For example, in the northern hemisphere sunlight is maximized on the southern and western sides of the building.

Building Systems - Subsystems of the building, such as HVAC, plumbing, electrical, fire safety, building security, and others.

Certified Wood – An environmentally friendly product that is certified through the Forest Stewardship Council (FSC). The FSC established international forest management standards to ensure that forest practices are environmentally responsible, socially beneficial, and economically viable.

Chlorofluorocarbon (CFC) - A group of chemical compounds commonly found in refrigerants, aerosols, and other applications shown to have a negative impact on the environment, including causing ozone depletion.

Clerestory Windows – High horizontal windows located near the ceiling or roof that increase the amount of natural light into a building.

Climate Zone – Developed by the International Energy Conservation Code, climate zones use county boundaries to delineate zones of similar average temperatures and relative humidity. The climate zones have been adopted by ENERGY STAR, ASHRAE, and other organizations.

Composting Toilet - A waterless toilet that conveys waste to a bin where it is allowed to decompose into organic compost and usable soil.

Computerized Maintenance and Management System – A computerized maintenance and management system (CMMS) is a set of computer software modules and equipment databases containing facility data with the capability to process the data for facilities maintenance management functions. This system provides historical data, report writing capabilities, job analysis, and more. The data describes equipment, parts, jobs, crafts, costs, step-by-step instructions, and other information involved in the maintenance effort. This information may be stored, viewed, analyzed, reproduced, and updated. The maintenance-related functions typically include facility and equipment inventory, facility and equipment history, work input control, job estimating, work scheduling and tracking, preventive and predictive maintenance, facility inspection and assessment, and materials and utilities management.

Cross Ventilation – A method of building ventilation that permits air to enter on one side of a room and exit on the other side.

Daylighting - Connections between the internal and external environments, usually through windows, skylights, and building placement.

Daylight Factor – According to the Dictionary of Optometry and Visual Science, "ratio of daylight illuminance received at a given point inside a room to the simultaneous illuminance on a horizontal plane outside exposed to an unobstructed sky."

Deferred Maintenance - A facility condition assessment model that uses relationships based on existing engineering data and associated algorithms to establish parametric cost estimates required to remedy the maintenance on plant, property, and equipment.

Design Charrette – A collaborative, structured multi-day process that brings many stakeholders together for group decision-making and project design development. A charrette can greatly enhance the goal-setting process by integrating energy and environmental issues in the facility's design, construction, and operation, in addition to increasing consensus and communication.

Dual-flush Toilet – Dual-flush toilets include models with two different flush settings, usually 0.8 gallons per flush (gpf) for liquid removal and 1.6 gpf for full flush solid removal.

Durable Goods – Products defined by LEED® as having a useful life of two years or more and replaced infrequently or may require capital program outlays. Examples include furniture, office equipment, appliances, external power adapters, televisions, and audiovisual equipment.

Economizer Mode – The economizer mode conserves energy consumption by HVAC equipment by utilizing varying amounts of outside air, which is mixed with recirculated air. In some cases conditioning outside air uses less energy than conditioning recirculated air, and the economizer mode uses a computer to maximize these savings.

Energy Efficiency – The quantity of energy consumed during operations or to perform an activity. Increasing energy efficiency includes reducing the energy consumption for a given operation or increasing the output from a given amount of energy.

Energy Savings Performance Contracts – Energy Savings Performance Contracts (ESPC) are a method of financing and implementing a capital improvement project by using utility cost savings to recover project costs. This type of contract is provided by private energy service companies.

Entryways - The places people enter and exit a building.

Environmental Management System - A comprehensive, systematic, planned, and documented collection of an organization or agency's environmental programs and organizational structure.

Failure Modes and Effects Analysis - Analysis used to determine what parts fail, why they usually fail, and what effect the failure has on the systems in total. This process is an element of reliability-centered maintenance.

Flush-Out – A method of removing building contaminants, such as volatile organic compounds and other indoor pollutants, in which air is pushed through the building. During the process internal air temperature and humidity should be monitored. Flush-outs should occur after construction and interior finishes are installed, but before building occupancy.

Front-End Planning – Front-End Planning (FEP) establishes the project requirements and concept and provides the basis for project budget and approval. The primary tool to accomplish FEP is the Project Definition Rating Index (PDRI). Once the facility project manager and the planning team have identified the initial project goals and objectives, the FEP process starts and continues through the approval of the design statement of work and the start of final design.

Geothermal – Energy produced by utilizing the consistent temperature of the Earth's crust or groundwater to reduce the energy demand to heat or cool a building.

Glazing – Glass panels placed into a building's wall, door, skylight, or window.

Global Climate Change - Refers to measured increases in the average temperature of the Earth since the mid-20th century, and the projected impacts on the climate and various ecosystems; also called global warming.

Green Building – Green building means to significantly reduce or eliminate the negative impact of buildings on the environment and on building occupants. Green building and design and construction practices address: sustainable site planning, safeguarding water and water efficiency, energy efficiency, conservation of materials and resources, and indoor environmental quality.

Green Infrastructure/Low-Impact Development - Provides a framework for implementing stormwater management practices. This framework includes a comprehensive planning strategy that protects natural resources, manages erosion and sediment controls, and minimizes site imperviousness.

Greywater – Greywater is untreated domestic wastewater from showers, sinks, washing machines, and fountains that can be reused on site for non-potable uses such as irrigation and flushing toilets and urinals. State and local regulations often dictate whether kitchen wastewater may be used as greywater; wastewater from lavatories (blackwater) is not included.

Halon - In the context of the Clean Air Act, a fire extinguishing agent containing bromine, fluorine, and carbon. It causes ozone depletion and is no longer produced in the United States.

Hawthorne Effect – The phenomenon where individuals that know they are being measured in some way adjust or improve their normal behaviors merely because they are being measured, not from any particular experimental manipulation.

High-Efficiency Toilet – High-efficiency toilets (HETs) include high-performance, water-efficient toilets that meet EPA WaterSense criteria through independent laboratory testing.

High-Efficiency Urinals – High-efficiency urinals include high-performance, water-efficient urinals that meet EPA WaterSense criteria through independent laboratory testing.

Hydrochlorofluorocarbon (HCFC) – A class of chemical compounds including hydrogen, chlorine, fluorine, and carbon. They contain chlorine and thus deplete stratospheric ozone, but to a much lesser extent than CFCs and so are being used to replace the CFCs. HCFCs do have global warming potential, and therefore some HCFCs are being phased out.

Impervious Surface - An impervious surface includes any surface that does not allow stormwater or other water sources to infiltrate into the ground.

Integrated Design - A design approach that analyzes the project from many perspectives, includes wide-ranging design objectives, involves a team process where all members understand the issues and concerns of other members, and where team members interact throughout the design process.

K-Factor - The K-Factor is a rating that signifies the ability of the transformer to handle non-sinusoidal loads without overheating. To get a higher K-Factor, one needs a bigger core and insulated windings. Higher K-Factor transformers will demand more power to energize the core. Higher K-Factor transformers are utilized for computer rooms and servers, where non-linear loads will reflect harmonics back on the transformer.

Life-Cycle Cost – Life-cycle cost includes the long-term economic impact of a decision that encompasses all program costs associated with a facility including costs of planning, design, construction, operation, maintenance, salvage, or residual value at the end of the intended period of use.

Lighting controls - A set of controls that increase and decrease the amount of artificial lighting, based on the amount of the natural light entering a building or a room. They also can incorporate occupancy schedules, motion sensors, and other sensors to reduce the use of artificial lighting.

Luminosity – A measurement of the brightness of a light source, as it is perceived by the eye at that wavelength.

Municipal Solid Waste - Another term for trash or garbage, specifically referring to solid waste collected by a local municipality for disposal at a landfill. This includes packaging, food scraps, grass clippings, furniture, electronics, and appliances.

Net Metering - A process where individual consumers who use less energy than they generate are credited for the difference in energy by the utility provider. This requires an advanced electricity meter and is usually performed through distributed renewable generation and energy conservation.

Ongoing Consumables - Products defined by LEED® as having a low cost per unit and regularly used and replaced in the course of business. Examples include paper, toner cartridges, binders, batteries, and desk accessories.

Owner's Project Requirements - The owner's project requirements (OPR) is a dynamic document that provides the explanation of the ideas, concepts, and criteria that are considered very important by the project owner. The OPR is developed during the programming and conceptual design phase and is a primary input for the basis of design.

Passive Daylighting Techniques – Methods of managing solar energy that include building orientation and solar chimneys.

Performance-Based Acquisition – A performance-based acquisition (PBA) is a technique for structuring all aspects of an acquisition around the purpose and outcome desired as opposed to the process by which the work is to be performed. PBA was formerly known as performance-based contracting.

Pest Control – Methods of integrated pest management (IPM) that are evaluated on effectiveness and risk. Less-risky options should be prioritized. Examples include targeted applications of chemicals or mechanical controls such as traps.

Pest Prevention – Methods of IPM that are the first line of defense against infestation. Techniques include landscaping efforts and managing food and water sources.

Photosensor – A device that detects light levels and prompts the system to increase or dim the light of the room based on the minimum recommended light level of the space. Used with daylight harvesting systems.

Plug Load – A facility's plug load accounts for all the electrical equipment in the building and the corresponding energy demand.

Post-Consumer Content – As defined by LEED®, post-consumer content is the percentage of material in a product that was consumer waste. Examples include C&D debris, recycling collections, discarded material, and landscaping waste.

Pre-Consumer Content – As defined by LEED®, pre-consumer content is the percentage of material in a product that was recycled from manufacturing waste. Examples include sawdust, trimmed materials, and obsolete inventories. Formerly called post-industrial content.

Potable Water – Potable water includes water suitable for drinking that meets or exceeds EPA drinking water standards; it is supplied from wells or municipal water systems.

Predictive Testing and Inspection – Predictive Testing and Inspection (PT&I) is the use of advanced technology to assess condition of equipment, utilities, and systems. When using Reliability Centered Maintenance, obtaining the PT&I data allows for planning and scheduling preventive maintenance or repairs prior to failure.

Project Definition Rating Index – The Project Definition Rating Index (PDRI) is a Construction Industry Institute best practice tool used in front-end planning to determine how well a project is defined. This tool is used throughout project development, but is scored at the 30 percent design stage. The scoring system is based upon a 1000-point scale, and a low score (i.e. 200 or less) reflects a well-defined project.

Reclaimed Water – Reclaimed water includes water that has been treated to remove solids and other impurities and is captured for reuse. Without additional treatment, reclaimed water is generally not safe to drink.

Reliability-Centered Building Equipment and Acceptance – Reliability-Centered Building Equipment and Acceptance (RCBE&A) is the use of RCM and PT&I technologies in conjunction with traditional and total building commissioning process prior to and during the equipment start-up/checkout phase of new construction, repair, and rehabilitation projects to ensure quality installation and accurate baseline documentation.

Reliability-Centered Maintenance - The process used to determine the life-cycle cost effective mix of preventive, predictive, and reliability-centered maintenance technologies, coupled with equipment calibration, tracking, and computerized maintenance management capabilities all targeting reliability, safety, occupant comfort, and system efficiency.

Solar Chimney – A passive daylighting technique that uses an air convection system to improve the natural ventilation of a building. The chimney (sometimes painted black) uses hot air that is heated by the sun to ventilate the indoor area by creating a suction effect, which encourages hot air to rise and cool air to remain in the building.

Solar Energy Factor - A description of the energy-efficiency of a solar water heating system, determined through calculating the energy delivered to the system divided by the electricity or natural gas energy put into the system.

Sub-Metering - Sub-metering involves installing secondary meters to measure the consumption of specific end uses or subsystems (e.g. the energy of the lighting system or water of the irrigation system). Sub-metering provides more detailed information that more accurately tracks consumption and can reveal unexpected patterns. Sub-metering may also be used to measure use of specialized systems, such as alternative energy, reclaimed greywater, or rainwater.

Sustainability – Sustainability is an overarching concept incorporating appropriate sustainable design practices, maintainable design elements, building commissioning processes, and safety and security features into facility planning, design, construction, activation, operation and maintenance, and decommissioning. The result enhances and balances facility life-cycle cost, environmental impact, and occupant health, safety, security, and productivity. Done properly, sustainability will optimize the facility acquisition process to ensure the “best fit” of the built environment to the natural environment. It requires a practical and balanced approach to responsible stewardship of our natural, human, and financial resources.

Thermal Comfort – A component of indoor environmental quality that refers to the state of mind that expresses satisfaction with the surrounding environment.

Triple Bottom Line – The triple bottom line is an accounting method that expands the traditional reporting framework to take into account environmental and social performance in addition to financial performance.

Ultra-Low-Flow Toilet – An ultra-low-flow toilet uses an average of 1.6 gpf compared with the traditional 3.5 gpf of traditional toilets. The DOE has mandated low-flow and ultra-low-flow toilets in home construction since the 1990s.

Volatile Organic Compounds – Harmful chemical compounds that are emitted into the air during and after construction. They are in building materials such as adhesives, sealants, paints, coatings, carpet systems, wood, cleaning chemicals, and office equipment.

Waste Stream Audit – An aspect of waste and materials management that involves the determination of the type and volume of waste generated at a site.

Waterless Urinal – Waterless urinals use a replaceable trap insert filled with a sealant liquid instead of water to prevent odors and maintain cleanliness. Other models use an outlet system that traps odors instead of the trap cartridge in traditional waterless urinal models.

Water Meter – Water meters measure consumption of water, usually by total volume or rate of flow. Similar to electricity meters, water meters provide consumption data for tracking and trending.

Xeriscaping – Defined by LEED® as a landscaping method that makes routine irrigation unnecessary. It uses drought-adaptable and low-water plants as well as soil amendments such as compost and mulches to reduce evaporation.

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APPENDIX H. BUILDING PROFILES

The following Building Profiles highlight 10 examples of sustainable design or operation at a NASA facility. Each profile includes basic information about the facility and details some of the major sustainability features or elements. The information in each profile conforms to the Department of Energy's High-Performance Buildings Database data guidelines. These profiles are not an exhaustive list of green building or operations at NASA; instead, the profiles provide examples of different technologies and sustainability topics that have been implemented.

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Langley Research Center (LaRC) – New Town Phase I

OVERVIEW

- Location: Hampton Roads, Virginia
- Building type(s): Offices
- New construction
- Building size: 72,000 ft^2 (6,689 m^2)
- Project scope: Single building
- Suburban setting
- Expected completion: 2010

BACKGROUND

Administration 1 Building at LaRC is designed as a three-floor office building serving 260 occupants. The facility is part of Phase 1 of the LaRC New Town Master Plan and is projected to be completed later in 2010. In addition, the developers and builders communicated effectively with the General Services Administration (GSA) and NASA to ensure a successful design and inclusion of green initiatives.

GREEN STRATEGIES

The facility includes several green design elements, including Building Information Modeling (BIM), a green roof, under-floor air distribution system, and demountable walls. The project team utilized BIM to simulate materials, finishes, electrical circuiting, cable trays, and raceways. The proposed green roof, which will contain a number of different plant species, addresses several sustainability initiatives. The plants on the building will absorb heat from the sun instead of reflecting back into the atmosphere, which will reduce the building's contribution to the local heat island effect. Moreover, the green roof will improve the irrigation and storm water management of the building, as rain will be absorbed into the plants thus reducing storm water runoff.

Two additional sustainable initiatives in the building design include an under-floor air distribution system and demountable walls. The under-floor air distribution system contributes to the sustainability of the building through effective ventilation that increases energy efficiency and occupant thermal comfort. In addition, demountable walls provide work space flexibility that can be installed and removed easily and are available with the same materials, colors, and sound absorption characteristics as permanent walls.

B U I L D I N G

New Town Phase I is striving for LEED-NC® Gold Certification.

KEYWORDS

Integrated Team, Simulation, Commissioning, Community, Massing and Orientation Adaptable design, Lighting control and daylight harvesting, Passive solar, On-site renewable energy, Stormwater management, Efficient irrigation, Daylighting, Ventilation effectiveness, Noise control.

Johnson Space Center (JSC) Building 27 – Astronaut Quarantine Facility

OVERVIEW

- Location: Johnson Space Center, Houston, Texas
- Building type: Laboratory
- Project scope: Single building
- Suburban setting
- Awarded LEED® Certification

BACKGROUND

Due to its unique function, Building 27 at Johnson Space Center was one of the most challenging green building projects. This facility, also known as the Astronaut Quarantine Facility, adjusts the circadian rhythms of astronauts prior to flight through artificial lighting that coincides with the mission work schedule.

GREEN STRATEGIES

The ceilings of several rooms in the Astronaut Quarantine Facility are 90 percent covered by high-output fluorescent lighting. The artificial lighting necessary to complete the mission of this facility consumes substantial amounts of energy directly through the lighting and from removing heat generated by the lighting.

The energy demands of the facility are reduced through a variety of strategies, including a heat enthalpy wheel, reducing solar heat gain through windows, increasing insulation in the walls and roof, and implementing high-efficiency HVAC equipment. The enthalpy wheel exchanges heat and moisture to cool and dehumidify during summer and warm the outside air during winter. The HVAC equipment includes variable-speed motors, which operate as needed by the heating and cooling loads. In addition, the HVAC system includes variable flow control for chilled water pumps.

The facility implemented other green strategies, including:

- Native grasses and trees to minimize irrigation
- Permeable paving and a storm water retention pond to reduce storm water runoff
- Energy-efficient, highly reflective roof to reduce heat buildup and cooling load
- Recycled building materials such as structural steel and used tires in the flooring
- Purchasing 100 percent wind-generated power for the first two years of operation

BUILDING

The Astronaut Quarantine Facility was awarded LEED® Certification by the United States Green Building Council.

KEYWORDS

Commissioning, Transportation benefits, Open space preservation, Insulation levels, Recycled building materials, Local materials, C&D waste, Operations and maintenance, HVAC, Lighting control and daylight harvesting, Occupant recycling, Indigenous vegetation, Efficient irrigation, Thermal comfort, Indoor air quality monitoring, Low-emitting materials.

Johnson Space Center (JSC) – Child Care Center

OVERVIEW

- Location: Johnson Space Center, Houston, Texas
- Building type: Daycare
- Building size: 13,066 ft^2 (1,214 m^2)
- Project scope: Single building
- Suburban setting
- Energy improvements completed 2007

BACKGROUND

Renewable energy and education have been important themes for NASA throughout its history. Both of those themes are combined at the JSC Child Care Center in Houston, Texas, where renewable energy technologies are getting real world testing and analysis.

GREEN STRATEGIES

In 2007, a Multi-Platform Renewable Energy System (MPRES) was designed and installed at this facility. The MPRES provides energy through surface-based photovoltaic arrays and wind turbines, and hot water is generated by a solar thermal panel. Data from the building is continuously collected and displayed locally and online: http://www.sacredpowercorp.com/NASA_CCC.swf

The MPRES supports the Engineering Directorate at Johnson Space Center by providing an opportunity to better understand large, surface-based photovoltaic arrays necessary for lunar surface exploration. It also allows JSC to gain experience with various renewable energy technologies, to demonstrate sustainable building principles, and to assist in meeting federal energy mandates. In addition, by collocating with a facility dedicated to children, the project provides excellent educational opportunities.

The total first year renewable energy production from the Child Care Center was 53 megawatt-hours. The renewable production, in addition to energy-efficiency improvements has reduced total energy demand by 20 percent at the Child Care Center.

KEYWORDS

Green specifications, Commissioning, Operations and maintenance, Lighting control and daylight harvesting, On-site renewable energy, Ventilation effectiveness.

Marshall Space Flight Center (MSFC) – Building 4346 – Child Development Center

OVERVIEW

- Location: Marshall Space Flight Center, Huntsville, Alabama
- Building type: Daycare
- Building size: 15,700 ft^2 (1,460 m^2)
- Project scope: Single building
- Rural setting
- Completed May 2007
- Rating: USGBC LEED-NC Certified (v.2/v.2.1)

BACKGROUND

Stormwater management, irrigation, green transportation, and daylighting techniques are all sustainable elements implemented at Marshall Space Flight Center (MSFC) Building 4346. Additional measures include an energy efficient HVAC, as well as the use of environmentally preferred products.

GREEN STRATEGIES

Site grading, drainage, and utilities were designed for this facility using sustainable concepts such as erosion and drainage control as well as utilizing indigenous species throughout the landscaping. Indigenous species benefit water efficiency and eliminate the need for irrigation systems. The site also contains sustainable transportation techniques such as designated parking spaces for carpools and recharging stations for electric vehicles.

Inside the building, a decentralized split-system direct expansion (DX) HVAC was installed to increase energy efficiency. The equipment allows for cost-effective temperature control of classrooms, while also reducing energy demand to 20 percent below American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) baseline standards. The HVAC system includes an air-to-air heat exchanger to pre-condition outdoor air.

Sustainable building materials used to construct this facility include low-emitting materials such as interior finishes, adhesives, caulking and sealants. Recyclable content was also used in the construction of this building including concrete that contains fly-ash. In addition, an ENERGY STAR® roof was installed.

BUILDING

A total of 31 percent of the building materials was manufactured using recycled materials.

KEYWORDS

Commissioning, Performance measurement and verification, Indigenous vegetation, Drought-tolerant landscaping, Glazing, Recycled materials, Local materials, Connection to outdoors, Daylighting, Ventilation effectiveness.

Marshall Space Flight Center (MSFC) – Building 4600 – Office Building

OVERVIEW

- Location: Huntsville, Alabama
- Building type(s): Commercial office
- New construction
- Building size: 139,000 ft^2 (12,900 m^2)
- Project scope: Single building
- Rural setting
- Completed November 2005

BACKGROUND

Renewable energy, irrigation, as well as utilizing recycled and low-emitting products are all sustainable practices implemented at the Marshall Space Flight Center (MSFC) Building 4600. When combined, these, and other sustainable practices, have allowed MSFC Building 4600 to achieve LEED-NC v2 Silver Certification.

GREEN STRATEGIES

Building 4600 was designed to maximize energy and water efficiency. The site orientation of the building maximizes daylighting, which reduces the demand for artificial lighting as well as the heating load. In addition, the solar exposure benefits the 34.65 kW roof-top photovoltaic system.

The landscape is irrigated with blow-down water from the chilled water plant and with rainwater collected in a membrane-lined retention pond. The water reductions from irrigation as well as other indoor water conservation measures achieves total building consumption that is 3.6 million fewer gallons of potable water per year than a conventional building.

Over 15 percent of the material used in the building is recycled content. Concrete used for foundations and floor slabs were specified to contain 20 percent fly ash, replacing Portland cement. In addition, environmentally preferred products, certified wood, as well as locally manufactured and harvested materials were incorporated into the facility. During the construction process, over 83 percent of the construction waste was reused or recycled, thus diverting the material from landfills.

Low-emitting paints, carpets, and adhesives were used throughout the building. Furniture with low levels of volatile organic compounds (VOCs) was specified to be used in the building, and all workstations and seating are Greenguard certified.

In 2006, the building operated at 47 percent of the electrical consumption of comparable structures throughout MSFC.

KEYWORDS

Commissioning, Contracting, Open space preservation, Glazing, Recycled materials, Local materials, Performance measurement and verification, Passive solar, HVAC, Lighting control and daylight harvesting, Efficient lighting, On-site renewable energy, Occupant recycling, Certified wood, Efficient irrigation, Daylighting, Thermal comfort indoor air quality monitoring, Low-emitting materials.

Wallops Flight Facility (WFF) Building E-109 – Engineering Building

OVERVIEW

- Location: Wallops Flight Facility, Chincoteague, Virginia
- Building type: Commercial Office and Laboratory
- Building size: 53,378 ft^2 (4,959 m^2)
- Project scope: Single building
- Rural setting

BACKGROUND

Building E-109 is a two-story engineering building constructed in 2007 providing office, lab, and machine shop space for several departments at Wallops Flight Facility. The facility is centrally located on the Main Base, just west of Runway 4-22 and south of Building E-002. Approximately half of the site comprises an asphalt parking lot and the other half comprises the building footprint, sidewalks, grass, and a small area of landscaping wrapped around the building.

GREEN STRATEGIES

Completed in 2007, the design of Building E-109 included several green design elements not found in traditional building designs, including daylighting, a landscaped interior courtyard, as well as thermal comfort and lighting controls around the building. In addition, the site consumes no water for irrigation by utilizing water-efficient landscaping strategies.

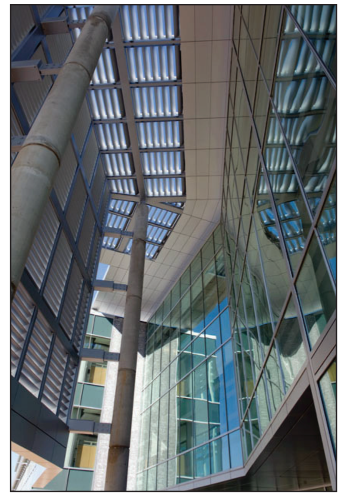
Building E-109 includes a variety of energy and water efficient technologies and equipment. Since construction, the facility has added aerators on most faucets and is currently planning to replace the existing fluorescent bulbs with higher efficiency lighting systems. The building is metered for both electricity and potable water to track consumption over time.

Building E-109 is registered under the LEED® for Existing Buildings: Operations & Maintenance credit system.

KEYWORDS

Recycled materials, C&D waste, Performance measurement and verification, Lighting control and daylight harvesting, Efficient irrigation, Ventilation effectiveness.

Johnson Space Center (JSC) – Building 20 – Office Building



OVERVIEW

- Location: Houston, Texas
- Building Type(s): Commercial office
- New construction
- Building size: 83,000 ft^2 (7,500 m^2)
- Project scope: Single building
- Rural setting
- Completed: January 2010

BACKGROUND

Recycled materials, a cool roof, solar water heating system, daylighting, and low water consumption are just some of the sustainable elements incorporated in to Johnson Space Center's (JSC) Building 20. Through incorporation of these and other sustainable features, JSC Building 20 is NASA's first building to achieve a LEED Platinum rating under the LEED-NC® v2.1 criteria.

GREEN STRATEGIES

Building 20 was designed to maximize energy and water efficiency. Based on the energy modeling completed during design, the building is 57.8 percent more efficient than ASHRAE Standard 90.1-1999 and potable water use is 40.25 percent lower than the calculated baseline. The facility is equipped with a solar hot water system that provides potable hot water for the building. In addition, 100 percent of the electricity supplied to the building comes from Green-e Certified renewable energy.

The surrounding site conforms to EPA stormwater management guidelines. The native landscaping is watered with condensate from the building's air conditioning system. The roof and non-roof impervious surfaces are highly reflective to reduce the heat island effect.

Indoor environmental quality was enhanced by using low emitting paints, carpets, and adhesives. Demand controlled ventilation (CO_2 based) is used to improve indoor air quality along with MERV 13 filters and GREENGUARD certified workstations. After construction, the building interior air was flushed for two weeks, and the building meets ASHRAE Standard 62 and ASHRAE Standard 55.

B U I L D I N G

96 percent of all the construction waste from Building 20 was recycled.

KEYWORDS

Commissioning, Recycled materials, Local materials, Lighting control and daylight harvesting, On-site renewable electricity, Occupant recycling, Certified wood, Low-emitting materials, Transportation benefits, C&D waste management, Indigenous vegetation, Efficient irrigation, Thermal comfort, Indoor air quality monitoring.

Jet Propulsion Laboratory (JPL) – Building 321 – Flight Projects Center

OVERVIEW

- Location: Oak Grove, California
- Building type(s): Offices
- New Construction
- Building size: 190,000 ft^2 (17,700 m^2)
- Project scope: Single building
- Suburban setting
- Construction completed: September 2009

BACKGROUND

The Flight Projects Center, or Building 321, is a five story office building providing space for 600 occupants that includes office space, a 400-seat auditorium, meeting rooms, and support facilities. The Flight Projects Center brought together personnel from three demolished buildings that housed personnel supporting Flight Program and Project Management. The project diverted from the landfill. 94 percent of construction waste generated on-site.

GREEN STRATEGIES

Building 321 is located on a site that has been defined as a brownfield. Remediation to the brownfield was completed prior to construction of the building. Stormwater runoff from 90 percent of the average annual rainfall is captured or treated such that 80 percent of the average annual post-development Total Suspended Solids (TSS) is removed. Sixty-one percent of the non-roof impervious surfaces have been paved with non-colored concrete, reducing the heat island effect. The roof is constructed with a combination of reflective roofing material and a vegetative roof. The incorporation of dual-flush water closets and low-flush faucets reduce water use by 43 percent. MERV 8 filters were used during construction and replaced prior to occupancy. Finally, a thermal comfort survey was provided to occupants within 12 months of occupancy.

The facility implemented other energy efficiency measures including:

- Improved thermal shell
- Reduced lighting power density
- Lighting occupancy sensors
- High efficiency elevators, chiller, and boilers
- Demand-controlled ventilation
- ENERGY STAR office equipment
- Enhanced building commissioning

BUILDING

The Flight Projects Center became NASA's first building to achieve a LEED® Gold rating.

KEYWORDS

Brownfield redevelopment, Commissioning, Ventilation effectiveness, Thermal comfort, Efficient fixtures and appliances, Stormwater management, C&D waste management, Efficient lighting, Lighting control and daylight harvesting, Insulation levels, Ventilation effectiveness.

Stennis Space Center (SSC) – Building 8000 – Emergency Operations Center (EOC)

OVERVIEW

- Location: Bay St. Louis, Mississippi
- Building type(s): Commercial office, Public order & safety
- New Construction
- Building size: 79,000 ft^2 (7,350 m^2)
- Project scope: Single building
- Suburban setting
- Construction completed: May 2009

BACKGROUND

Building 8000 is a mixed use two-story building that houses the Stennis Space Center (SSC) Fire Station, Security Offices, the Energy Management and Control System (EMCS), Emergency Operations Center (EOC), severe weather warning system, and a medical clinic. Lessons learned from Hurricane Katrina identified the need for an operations building to provide a safe haven for emergency response and recovery personnel during a major hurricane. Specifically, it was determined that a centrally located area was needed to minimize response times, prevent existing interferences, and to provide a more cohesive environment for emergency personnel that is essential during emergency situations.

GREEN STRATEGIES

Some of the features that contribute to Building 8000's USGBC LEED® Gold status include: 70 percent of the non-roof impervious surfaces have been paved with open grid paving; reduced potable water use by 52 percent through the installation of waterless urinals, dual-flush toilets, low-flow showerheads, and low-flow faucets; enhanced building commissioning elements; development and implementation of a measurement and verification plan consistent with Option D of the IPMVP; installation and use of recycled building materials totaling 18 percent by value; and 64 percent of the total building materials were manufactured within 500 miles of the project site.

Indoor environmental quality features include: MERV 8 filter media in the air handling equipment during construction which were replaced with MERV 13 filters prior to occupancy; a two-week interior air flush-out prior to occupancy; and the installation of a permanent temperature and humidity monitoring system providing control of the building zones as defined in ASHRAE 55-1992, Addenda 1995.

BUILDING

70 percent of non-roof impervious surfaces have been paved with open grid paving.

KEYWORDS

Stormwater management, Efficient fixtures and appliances, Commissioning, Performance measurement & verification, Recycled materials, Ventilation effectiveness, Local materials, Thermal comfort, Indoor air quality monitoring.

Goddard Space Flight Center (GSFC) – Building 34 – Exploration Sciences Building

OVERVIEW

- Location: Greenbelt, Maryland
- Building type(s): Mixed Use, Offices and Labs
- New Construction
- Building size: 200,000 ft^2 (18,580 m^2)
- Project scope: Single building
- Suburban setting
- Construction completed: September 2009

BACKGROUND

The Exploration Sciences Building, also known as Building 34, is a mixed-use building including office and laboratory space. The building was designed to maximize flexibility and capability in laboratory space; lab spaces can be manipulated to create one, two, or three separate areas, and each area has its own lab racks, lighting, and air ventilation. A formal multiple-day design charrette developed the optimal features for users while providing easily accessible utility corridors for operations and maintenance staff. In addition to standard drawing submittals, the A/E contractor was required to provide a three dimensional constructability model. To complete this model, subcontractors created 3D models to generate automated material take-offs and estimates, which avoided costly errors and omissions. The general contractor merged the subcontractor 3D models into an overall constructability model to eliminate design and construction phasing problems.

GREEN STRATEGIES

Some of the features that contribute to the Exploration Sciences Building USGBC LEED® Gold building status include: large reflective paving areas to reduce heat island effect; site lighting designed to reduce light pollution; efficient plumbing fixtures to reduce water usage; no ozone depleting compounds used in the building, such as CFCs, HCFCs, and Halons; reduced energy usage; a proactive stormwater management system; areas for recyclables; chemical use areas and copy rooms are separated, vented, and kept at a negative pressure; and a manifold exhaust system that allows hazardous and non-hazardous lab exhaust to be separated and to recirculate non-hazardous lab exhaust, thereby reducing energy costs.

The building was also designed to foster teamwork and cooperation among scientists, so collaboration areas are located on each floor near a centralized staircase. A large skylight above the centralized staircase allows natural light to spill throughout the top two floors of the collaboration area.

BUILDING

The Exploration Sciences Building attained a LEED® Gold rating.

KEYWORDS

Design charrette, Simulation, Adaptable design, Daylighting, Efficient fixtures and fittings, Occupant recycling, Ventilation effectiveness, Stormwater management.

APPENDIX I. FEASIBILITY MATRIX

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Best Management Practice	Cost Impact	Cost Effectiveness	Savings Potential	Retrofit Applicability	Implementation Timeline	Comments
Chapter 1 - Employ Integrated Principles						
Integrated Project Team	$	%%%	Varies	High	Immediate	Incurs soft cost - from in-house labor and/or consultants
Performance Design Goals	$	%%%	Varies	High	Short	Incurs soft cost - from in-house labor and/or consultants
OMB Capital Asset / Business Case Summary	$	%%	Varies	Medium	Short	Incurs soft cost - from in-house labor and/or consultants; may already be covered by NASA Policy Directive 8820.2C, which requires a business case analysis
Incorporate Sustainable O&M Practices Within an EMS	$ to $$	%%	Varies	High	Intermediate	Also incurs soft cost to maintain EMS data records
Condition & Operational Procedure Assessment	$ to $$	%%	Varies	High	Immediate	No additional cost - already Implemented by other federal requirements, DMA, RPI, etc.
Operational Performance Goals	$	%%%	Varies	High	Short	Incurs soft cost - from in-house labor and/or consultants
Incorporate a Building Management Plan	$	%%	Low	High	Short	Incurs soft cost - from in-house labor and/or consultants
Augment O&M with Occupant Satisfaction Survey	$	%%	Low	Medium	Intermediate	Incurs soft cost - from in-house labor and/or consultants
Whole Building Commissioning	$	%%%	Varies	Medium	Immediate	No additional cost may be incurred as NASA Procedural Requirements 8820.2F already requires total building commissioning as defined by USGBC for all new construction and major renovation, and used in conjunction with NASA Reliability Centered Building and Acceptance Guide 2004 and supplemented by criteria and standards published by ASHRAE
Chapter 2 - Optimize Energy Performance						
Reduce Energy Consumption	$ to $$$	Varies	Varies	High	Intermediate to Long	Other load reduction strategies such as better glazing, more insulation, more efficient lighting can offset, in full or in part, reductions in size of HVAC
On-Site Renewable Energy	$$ to $$$	% to %%	Medium to High	Medium	Long-term	Only a few alternatives may be practical to NASA needs, e.g. wind power, photovoltaic or geothermal, and may require application study on a project/site basis. Energy conservation measures are typically less costly than renewable power, so measures to reduce building energy use first then size renewable system accordingly
Solar Hot Water Heating	$ to $$	%%	Medium	High	Intermediate	NASA standards do not explicitly address
Utility Meters (Electricity)	$$	%%%	High	Medium	Short to Intermediate	Also incurs soft cost for measurement and verification activities; NASA Procedural Requirement 8831.2E furnishes guidance for utilities management through building automation systems and environmental management control systems
Building Performance Target	$	%%	High	Medium	Immediate	No additional cost for new construction as NASA Procedural Requirements 8820.2F already includes this element; for major renovations, policy requires reduction of energy cost budget by 20 percent from pre-renovations 2003 baseline. For both new construction and renovation, performance target is to design to earn the ENERGY STAR targets where applicable.
Meet or Exceed Design Target	$ to $$$	Varies	Medium to High	High	Short to Intermediate	Also incurs soft cost for measurement and verification activities

Best Management Practice	Cost Impact	Cost Effectiveness	Savings Potential	Retrofit Applicability	Implementation Timeline	Comments
Chapter 3 - Protect and Conserve Water						
Planning	$	%%%	Low	High	Immediate	Incurs soft cost - from in-house labor and/or consultants; NASA Procedural Requirement 8750.1 refers to DOE Best Management Practices
Water Audit & Leak Detection	$ to $$	%%%	High	High	Short	NASA Procedural Requirement 8750.1 refers to DOE Best Management Practices
Water Metering	$$	%%	High	High	Short to Intermediate	Also incurs soft cost for measurement and verification activities; NASA Procedural Requirement 8831.2E furnishes guidance for utilities management through building automation systems and environmental management control systems
Potable Water Reduction (Indoor)	$ to $$	% to %%	Low to Medium	Low to Medium	Immediate	Automatically earn 20 percent reduction with requirements of NASA Procedural Requirements 8820.2F. Typically, difficult to meet the LEED® credit for 30 percent without cost impact and likely cost prohibitive to achieve 50 percent reduction
Alternative Water Sources	$$ to $$$	% to %%	Low to Medium	Low	Long-term	NASA Procedural Requirement 8570.1 and 8820.2F require considering water reuse and recycling
Irrigation	$	%%%	High	High	Short	Could be achieved at no cost or reduced cost with water efficient landscaping and/or capturing rain or recycled water; NASA Procedural Requirements 8820.2F calls for 50 percent reduction through use of water efficient landscaping
Stormwater Runoff	$ to $$	%%	Low to Medium	Medium	Short-term	Can be automatically earned using existing NASA, federal and/or local water quality and quantity permit requirements; could potentially have cost savings if quantities requiring treatment can be reduced
Process Water	$$	%%	Medium	Medium	Intermediate	NASA standards do not explicitly address
Chapter 4 - Enhance Indoor Environmental Quality						
Ventilation	$ to $$$	% to %%	Low to Medium	Low to Medium	Intermediate	NASA Procedural Requirements 8820.2F may already comply, and refers to ASHRAE standard; soft costs may be incurred for performing and documenting ADPI calculations which are not part of typical HVAC system design
Thermal Comfort	$ to $$$	% to %%	Low to Medium	Low to Medium	Intermediate	NASA Procedural Requirements 8820.2F identifies requirements per ASHRAE Standards
Moisture Control	$ to $$	%%	Low to Medium	Low to Medium	Intermediate	NASA Procedural Requirements 8820.2F calls for moisture control strategy
Daylighting	$ to $$	% to %%	Low	Low	Intermediate	Occupant comfort and performance; NASA Procedural Requirement 8820.2F directs a minimum of 2 percent daylight factor in 75 percent of spaces occupied for critical visual tasks.
Low-Emitting Materials	$ to $$$	%%	Low	Medium	Varies	Low-VOC materials are widely available for carpet, adhesives, sealants and paints with no construction premium. Additional soft costs may be incurred for additional specifications language, submittals reviews, tracking VOC budget etc. Availability is not the same case for composite woods. NASA Procedural Requirement 8820.2F calls for the use of low-emissions materials and products.
Protect Air Quality During Construction	$	%%%	Low	High	Immediate	Portions of IAQ management may already be part of contractors construction management practice. NASA Procedural Requirement 8820.2F refers to Sheet Metal and Air Conditioning Contractors National Association Guidelines for Construction of Occupied Buildings. May incur additional soft costs to develop and manage the IAQ plan
Environmental Tobacco Control	$	%%	Low	Medium	Varies	NASA design standard does not set explicit distance for non-smoking building policy
Integrated Pest Management	$	%	Low	High	Immediate	NASA standards do not explicitly address

Best Management Practice	Cost Impact	Cost Effectiveness	Savings Potential	Retrofit Applicability	Implementation Timeline	Comments
Chapter 5 - Reduce Environmental Impact of Materials						
Waste & Materials Management	$ to $$	Varies	Varies	Varies	Immediate	Dependent on the project scope, size, available site area, haul distances, recycling vs. landfill tipping fees, and local waste recycling laws; NASA Procedural Requirements 8820.2F directs designers to incorporate into constructions documents that salvages or recycles 50 percent of construction, demolition and land clearing waste where market opportunities exists.
Building Materials	$ to $$	Varies	Medium to High	Medium	Short	Could achieve at no or higher cost options, but materials must be reviewed early in design process to confirm product does not conflict with project requirements and for competitive bidding material should be available from more than one source.
Procurement Materials	$	Varies	Varies	Medium	Intermediate	Could be achieved at no additional cost depending on NASA standards; NASA Procedural Requirements 8530.1A mandates the purchase of environmentally preferred products and services to the extent practicable and allows for review/revision of specifications to eliminate barriers to the preference of recovered materials
Ozone Depleting Compounds	$	%%	Low to Medium	High	Short	NASA Policy Directive 8820.2F calls for the use of non-ozone depleting compounds consistent with either the Montreal Protocol or the Clean Air Act Amendments 1990. It should be noted, however, that use of non-ozone depleting equipment may affect a building's overall energy efficiency and should be assessed project-by-project.

Cost Impact	*$*	*Less than $50,000*	*Retrofit Applicability*	*Low*	*Challenging installation, expensive, can be resisted*
	$$	*$50,000 - $150,000*		*Medium*	*Needs new procedure, major effort, can be difficult*
	$$$	*Greater than $150,000*		*High*	*Easy or routine, minimal effort*
Cost Effectiveness	*%*	*Less than 30%*	*Implementation Timeline*	*Short*	*Less than 6 months*
(Return Rate)	*%%*	*30 to 100%*		*Intermediate*	*6 months to 3 years*
	%%%	*Over 100%*		*Long-term*	*More than 3 years*
Savings Potential	*Low*	*Less than 1%*			
(% of Facility Total Unit Cost)	*Medium*	*1 to 5%*			
	High	*Over 5%*			

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