City of La Crosse

Net Zero Energy Building Guide

January 2023

Prepared By

making change personal
paleBLUEdot

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Acknowledgements

This guide was developed in conjunction with the City of La Crosse's 2022 Climate Action Plan (CAP) to assist the City of La Crosse in achieving the energy reduction goals outlined in the CAP.

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Note:
These guidelines are intended as an educational resource to assist building owners, designers, and contractors in achieving Net Zero Energy in their buildings. This document does not replace, supersede, or represent State or City codes and ordinances. Ratified building codes and ordinances shall govern in any apparent or potential conflict with any of the information provided in this guide document. Contractors, designers, and building owners should become familiar with the requirements of all relevant building codes and ordinances.

Section 01

Introduction

The City of La Crosse is committed to environmental stewardship and sustainability. In 2009, the City adopted the Strategic Plan for Sustainability, prepared by the Joint Oversight Committee on Sustainability. This plan provided the City with an overall framework for addressing a variety of sustainability initiatives.

In 2019, the City of La Crosse Common Council passed a resolution which set a goal of reaching carbon neutrality community-wide, in both energy and transportation by 2050. In December 2022, the City completed the 2022 Climate Action Plan with the goal to reduce City operations and community-wide GHG emission reduction goals are to reduce community-wide GHG emissions by 40% to 50% below 2019 levels by 2030 and achieve carbon neutrality by 2050.

This Net Zero Energy Building Guide is being issued as a tool in support of the City's Climate Action Plan goals. The purpose of this guide is to provide a tool for use by the municipality, institutions, businesses, residents, and others in the achievement of net zero energy buildings within the community. The guide can be used for new construction and existing buildings.

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Introduction

NET ZERO ENERGY GUIDE INCLUSION IN CLIMATE ACTION PLAN

This Net Zero Energy Building Guide directly supports the key strategies in the City's 2022 Climate Action Plan (CAP), including:

Strategy BE 1: Reduce community-wide residential, commercial, educational, and industrial building energy consumption by 15% by 2030 (electricity and natural gas).

Strategy BE2: Increase adoption of Net Zero construction community-wide to 10% of new residential and commercial construction annually by 2030 (estimated at 13 net zero homes and 8 net zero commercial buildings annually).

Strategy BE 3: Achieve 10% residential and commercial and industrial building "fuel switching" from on-site fossil fuel combustion to electrification by 2030.

In addition, this Net Zero Energy Building Guide is featured in detailed actions included in the City's CAP Plan, including:

Action BE 1-11: Expand the City's on-line "Energy Resources" to include tools and resources to support residents and businesses in identifying energy efficiency opportunities. Resources should include the DOE Home Energy Saver, EPA Home Energy Yardstick, ENERGY STAR Home Advisor, and the City's Net Zero Energy Guide.

Action BE 1-13: Create an on-line "one-stop shop" for building and development energy efficiency and renewable energy information and resources as an expansion to the City's existing "Energy Resources" website content. Resource should include the City's anticipated Net Zero Energy Guide and checklist, Solar Ready Guide as well as content connecting residents and businesses with resources for energy efficient products, costs, rebates, incentives, contractors, etc.

WHAT IS NET ZERO ENERGY

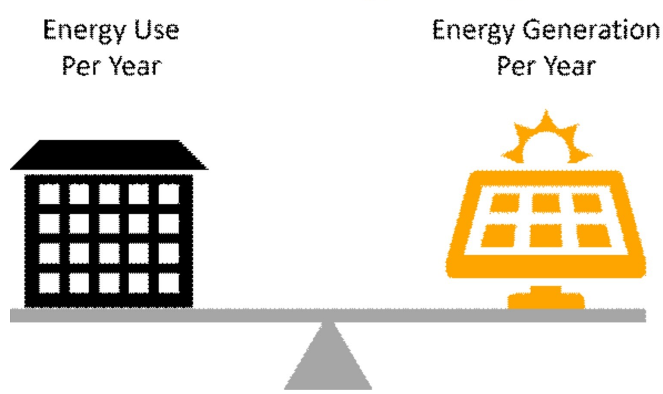
A Net Zero Energy Building (NZE) is a highly energy efficient building with zero net energy consumption. This means the building offsets all energy used in the building with renewable energy created on site, calculated on an annual basis. In other words, a Net Zero Energy building balances its energy consumption with its renewable energy generation. A Net Zero Energy building has an annual operating carbon footprint of zero.

> **While Net Zero Energy buildings may seem cutting edge, they will become status quo faster than you think.**
>
> - U.S. General Services Administration Sustainable Facilities Tool

WHAT IS NET ZERO ENERGY READY

A Net Zero Energy Ready (NZER) building is "a high-performance home so energy efficient all or most annual energy consumption can be offset with renewable energy." A building owner, designer, or builder may choose to pursue NZER instead of NZE if the building has poor renewable energy potential (I.e. Significant shading on roof and site making it a poor choice for solar pv), budget constraints requiring a lower up-front cost, or preference to wait before purchasing on-site renewable energy systems. Although not all buildings can be built to NZE standards, all buildings can be built to NZER standards.

What is a Net Zero Energy Building?



Graphic Source: Red Car Analytics

Introduction

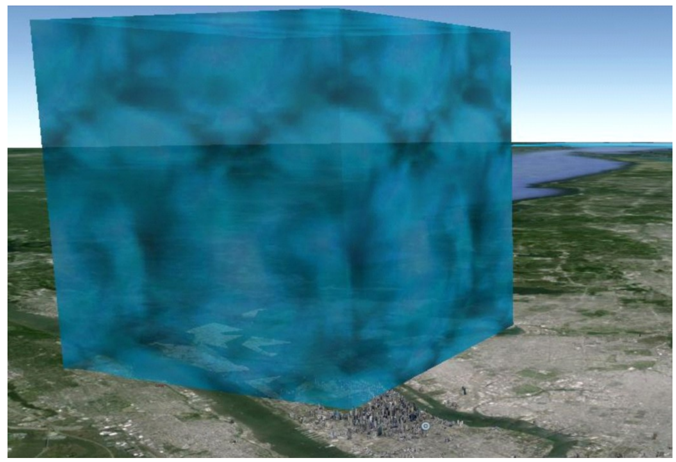
WHY NET ZERO MATTERS

The world faces significant challenges in the near future related to natural resource depletion, soil erosion, water resource depletion, and the projected impacts of climate change. According to the US EPA, Department of Energy, and Energy Information Agency, buildings account for:

- 35-40% of total energy consumption (39 quadrillion BTU)
- 80% of total electric grid load (3.3 trillion kwh)
- 39% of Greenhouse Gas Emissions (5.7 trillion pounds)
- 50-75% of all natural resources extracted (40 billion tons globally)
- 40% of total waste stream in US (164 million tons)
- 20% of total water use (14.5 trillion gallons)

It is clear that if we, as a society, are going to make meaningful progress toward global climate targets and needed resource sustainability, we need to address our buildings. They are the largest end-users of energy and natural resource extraction. Because of building's 30+ life span, how we design, construct, and occupy our buildings can be a part of the problem, or by adopting Net Zero Energy approaches, become a significant part of the solution for years to come.

The Impact of Building Greenhouse Gas Emissions

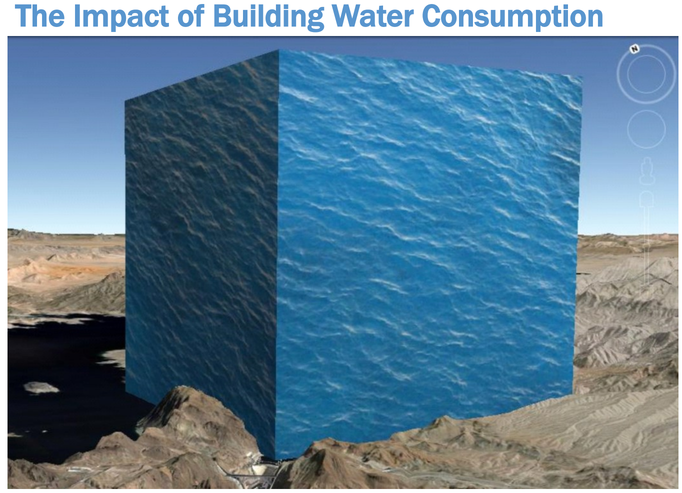


Buildings in the United States account for 39% of total greenhouse gas emissions - 5.7 trillion pounds. That's 51 trillion cubic feet annually. The graphic shows the volume of US building GHG emissions annually as seen from 40,000 feet above New York City.

The Impact of Building Construction Waste

Buildings in the United States account for 40% of total solid waste stream - 139.4 billion cubic feet annually – 16 square feet for every new sf commercial construction. The graphic shows the volume of US building construction waste shown on top of the City of Seattle.

The Impact of Building Water Consumption

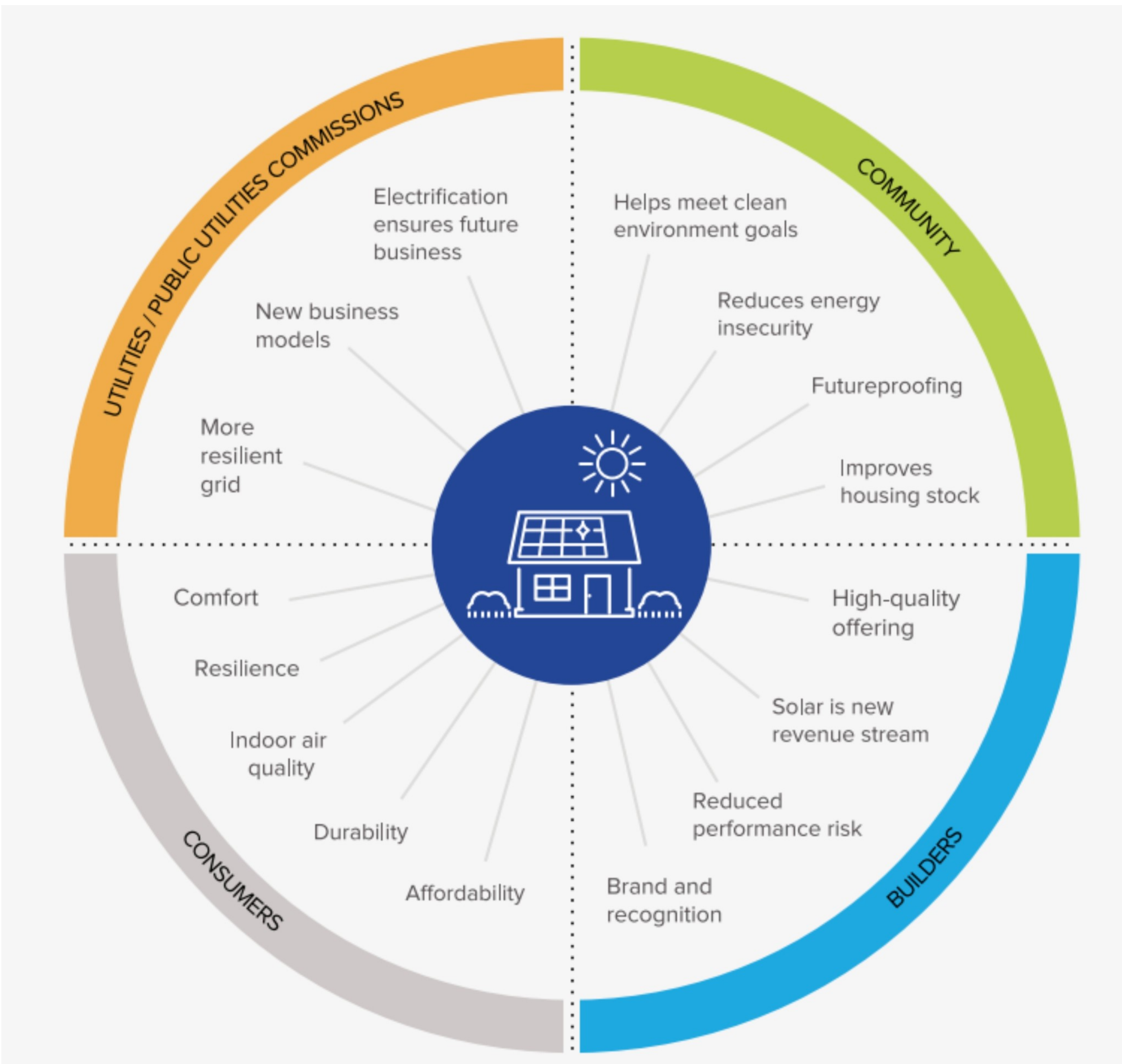


Buildings in the United States account for 20% of total water use - 14.5 trillion gallons. That's 5,953,642 acre-feet annually. The graphic shows the volume of US building water use annually….the small white object at the bottom left corner of the volume is Hoover Dam.

Introduction

BENEFITS OF NET ZERO ENERGY BUILDINGS

Studies and databases of Net Zero buildings throughout the United States illustrate a number of benefits of Net Zero Energy buildings. Their benefits touch not only the owners/consumers of the buildings but also the contractors who build them, utilities who serve them, and the broader community. The graphic below, from "Economics of Zero Energy Homes" by the Rocky Mountain Institute illustrates the range off benefits as indicated by the US Department of Energy (DOE) "Tour of Zero" online project database.



Graphic Source: "Economics of Zero Energy Homes" by the Rocky Mountain Institute

Introduction

NET ZERO ENERGY BASICS

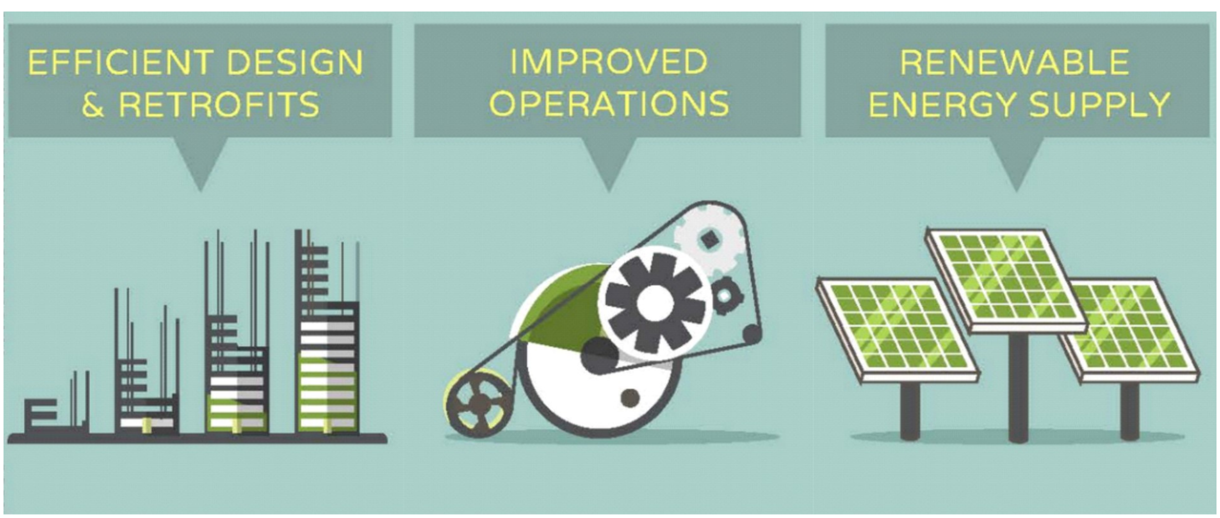
This guide details numerous strategies to help building owners, designers, and builders harness the benefits of Net Zero Energy buildings. All these strategies fit within four primary steps to designing a Net Zero Energy building. These four steps can be implemented by any knowledgeable design professional:

1. Work With Nature. This includes strategies to design the building to use the sun for passive solar heating and daylighting, minimize unwanted solar heat gain during the summer, utilize cooling breezes, or other natural design techniques that will help the building perform better. By working with nature, a Net Zero Energy building relies less and less on mechanical systems which require energy to operate. Working with nature also increases the overall resilience of a Net Zero Energy building.

2. Make A Tight Building Envelope. The "building envelope" is the exterior walls and roof of the building. By using high levels of insulation, and a well sealed and airtight construction, a Net Zero Energy building can minimize the amount of heating and cooling that is lost through the building envelope. A tight building envelop will save a significant of energy and reduce the size of mechanical systems.

3. Electrify Everything with Efficient Systems. Most of our buildings use natural gas to heat the building or to heat the water used in the building. There are now a variety of highly efficient electric systems capable of replace those gas systems. Unlike natural gas systems, efficient electrical systems are capable of having their fuel (electricity) generated on site. For every natural gas fixture that is installed in a Net Zero Energy building, the quantity of renewable electricity that is required to be generated on-site to offset energy use is increased. Use of electric systems minimizes the amount of on-site renewable energy required to balance the building's energy consumption.

4. On-Site Solar Photovoltaic Array. Photovoltaic (PV) panels create electricity from the sun. When we execute the first three steps successfully, the total energy consumption of the building will be greatly reduced - this makes the ability to meet that energy consumption on-site through a solar PV array a possibility.



Graphic Source: City of Cambridge

Introduction

NET ZERO ENERGY BUILDING COSTS
(new construction)

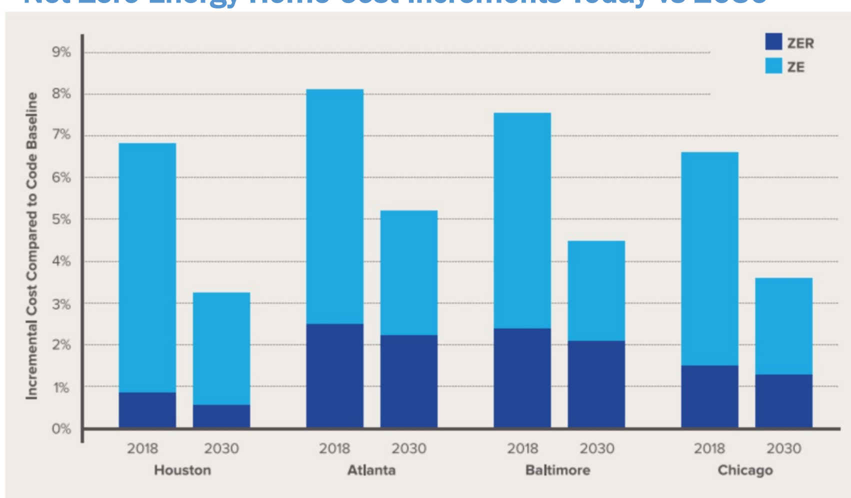
"Economics of Zero Energy Homes", a recent report by the Rocky Mountain Institute, illustrates the costs and paybacks of Net Zero homes built throughout the United States. The report demonstrates that the initial construction cost increase needed to achieve a Net Zero Energy home is 6.7% to 10%, while the initial construction costs to achieve a Net Zero Energy Ready home are as low as 0.9% to 2.5%. These initial construction costs are then offset by the on-going annual cost savings of operating a home or building that has zero energy costs due to its ability to generate renewable energy on-site equal to its energy consumption. As adoption of Net Zero Energy building technology and strategies increase, the costs of achieving Net Zero are anticipated to rapidly decrease over the next 10 years. By 2030, the cost increase associated with achieving Net Zero Energy may be nearly 50% less.

Net Zero Energy Home Cost Threshold Achievement in Cold Climates

	Bozeman (CZ6)		Duluth (CZ7)	
ZER Incremental Cost	$5,358		$6,722	
Mortgage Threshold (30 years)	✔	$13,877	✔	$19,953
Resale Threshold (12 years)	✔	$7,047	✔	$10,133
Customer Willingness to Pay Threshold (4%)	✔	$9,897	✔	$10,942
First Cost Threshold (0%)	✖	$0	✖	$0

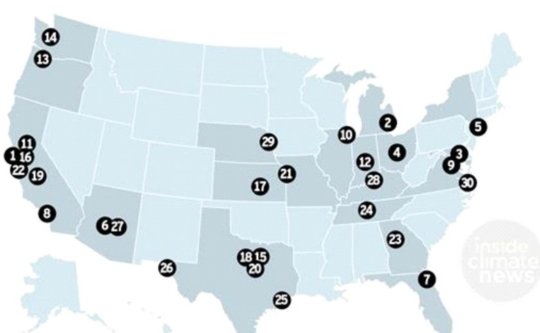
Graphic Source: "Economics of Zero Energy Homes", by Rocky Mountain Institute

Net Zero Energy Home Cost Increments Today vs 2030



Graphic Source: "Economics of Zero Energy Homes", by Rocky Mountain Institute

Return on Investment for Net Zero Energy Buildings (in years)



Graphic Source: "Economics of Zero Energy Homes" by the Rocky Mountain Institute

Cost and Energy Savings Comparison Electric vs Natural Gas

		Chicago	Bozeman	Duluth
Electric Baseline	Incremental Cost of Building to ZER	**$5,369**	$4,499	$5,029
	Annual Energy Bill Savings	**$1,052**	$985	$2,934
	Payback (years)	**5.1**	4.6	1.7
Natural Gas Baseline	Incremental Cost of Building to ZER	$3,652	**$5,358**	**$6,722**
	Annual Energy Bill Savings	$921	**$708**	**$1,018**
	Payback (years)	4.0	**7.6**	**6.6**
Moving from an Electric Baseline to Natural Gas	Change in Incremental Cost for Building ZER	-$1,717	-$859	-$1,693
	Change in Payback (years)	-1.1	+3	+4.9

Graphic Source: "Economics of Zero Energy Homes", by Rocky Mountain Institute

Introduction

WHO IS WORKING ON NET ZERO ENERGY BUILDINGS

Federal legislation has established Net Zero Energy target

Legislation

Energy Independence and Security Act of 2007, Section 433(a)	"Federal buildings must reduce fossil fuel-generated energy consumption by increasing percentages reaching 100% reduction in 2030"

State and local initiatives have established Net Zero Energy targets

State and Local Initiatives

California	The Public Utilities Commission created the "Zero Net Energy Commercial Action Plan" as part of the Long Term Energy Efficiency Strategic Plan.
Massachusetts	The Executive Office of Energy and the Environment created a plan for transforming buildings to Net Zero Energy.
Oregon	The Energy Trust of Oregon created a "Path to Net Zero" pilot program.
Seattle, Washington	Seattle created a goal of carbon neutrality by the year 2030. The Seattle 2030 District, a public-private collaborative, is working towards that goal with a high-performance building district in downtown Seattle.

Industry programs have established Net Zero Energy targets

Industry Programs

Architecture 2030	The 2030 Challenge advocates for carbon neutral buildings by the year 2030.
AIA 2030 Commitment	The American Institute of Architects (AIA) 2030 Commitment provides a framework to evaluate design options to support Net Zero Energy.
ASHRAE Vision 2020	The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Vision 2020 aims to create tools and strategies to support Net Zero Energy.
Living Building Challenge	The Living Building Challenge - Net Zero Energy Building Certification requires not only that a building achieve Net Zero Energy, but also that it does not negatively impact the ability of other buildings to achieve Net Zero Energy (i.e. by shading or urban sprawl).


DETOUR
TO ORANGE ST.
& BOOKSTORE
net
zero
energy

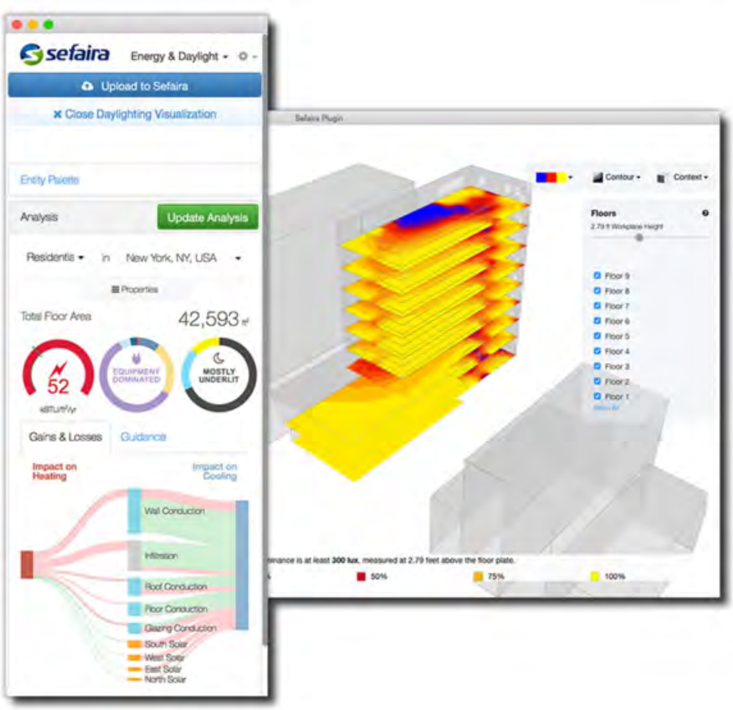
Section 02

Energy Consumption Design

Change Metrics
Change Time Periods

Metrics Summary

Metric	Sep 2017 (Energy Baseline)	Sep 2017 (Energy Current)	Change
ENERGY STAR Score (1-100)	42	42	0.00 (0.00%)
Source EUI (kBtu/ft²)	146.7	146.7	0.00 (0.00%)
Site EUI (kBtu/ft²)	91.0	91.0	0.00 (0.00%)
Energy Cost ($)	21,204.44	21,204.44	0.00 (0.00%)
Total GHG Emissions Intensity (kgCO2e/ft²)	8.1	8.1	0.00 (0.00%)



A successful Net Zero Energy building begins with understanding, and designing, the building's energy consumption. The less energy a building consumes, the easier it is to generate its energy through on-site renewable energy sources. Establishing an understanding of a building's energy consumption is a critical first step for both Net Zero Energy retrofits of existing buildings as well as for Net Zero Energy new construction projects.

The first steps for any Net Zero Energy project - or for any building owner interested in exploring achieving Net Zero Energy at their property - are:

1) Energy Benchmarking
2) Targeting Energy Use
3) Energy Modeling

With these steps, building owners, designers, and builders can guide the design or retrofit of any building towards a Net Zero Energy future. All of the strategies outlined in the sections of this report which follow should be evaluated with, and against, these three energy consumption design tools.

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Energy Consumption Design

ENERGY CONSUMPTION DESIGN

EC1 Energy Benchmarking

Benchmarking the energy performance of your buildings is a key first step to understanding and reducing energy consumption and beginning the path towards a Net Zero Energy building. Benchmarking simply consists of collecting data on a building's uses, size, and energy consumption and comparing that data against other buildings. Benchmarking will enable a building owner or designer to determine whether a building is using more or less energy than its peer facilities with similar occupancies, climates, and sizes.

There are a number of benchmarking software and program options to assist building owners, designers, or contractors, including:

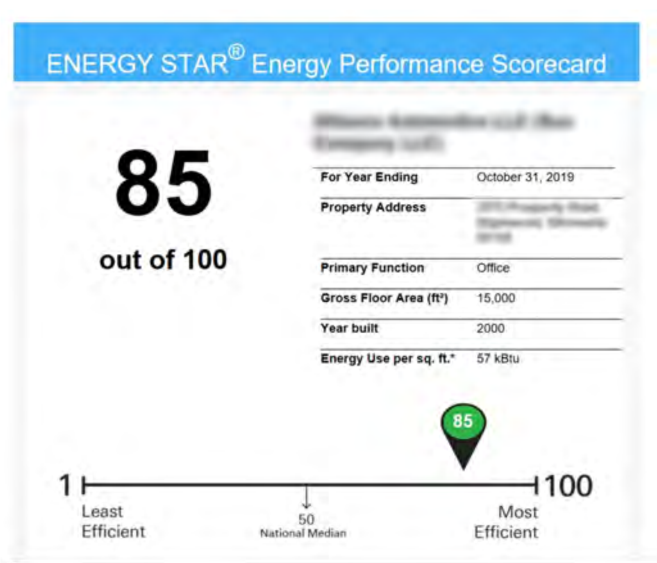
- ENERGY STAR Portfolio Manager by US EPA
- Building EQ by ASHRAE
- FirstView by New Buildings Institute

To use any of these benchmarking tools, building owners or designers will be required to collect a limited amount of data. To establish a quality benchmarking comparison, a building's total square footage, uses, and annual electrical and natural gas consumption will be required. The quality of benchmarking can be increased with a few additional operational data points as well, such as, the total number of employees using the building, number of computers, freezers and refrigerators, and number of hours the building is in use on an average week.

Once a building's energy use history is known and compared against its peer group, a building owner or designer can begin to anticipate the level of energy efficiency improvements needed - as well as the potential - for a building.

> **Energy Use Intensity:**
> **(EUI) is a building's annual energy use per unit area. It is typically measured in thousands of BTU per square foot per year (kBTU/ft2/yr) or kWh/m2/yr.**
>
> **EUI allows buildings of different sizes to compare energy use in meaningful ways by establishing the building's total energy consumption on a per square foot**

> **Buildings across the U.S. that benchmarked over a 3-year time span reduced energy consumption by an average of 2.4% annually.**
>
> - Institute for Market Transformation



Energy Consumption Design

EC2 Energy Use Targeting

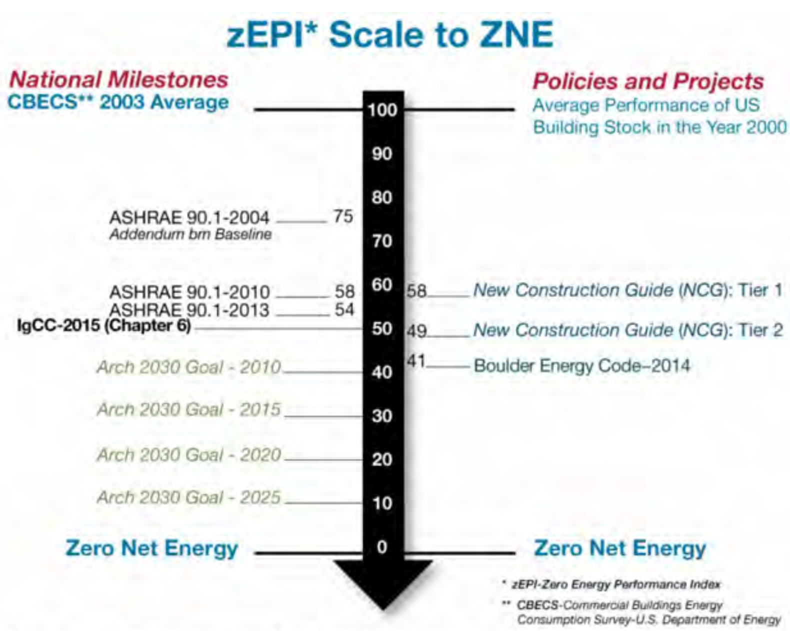
Successful Net Zero Energy retrofits and new construction projects all begin with clear energy goals early, even before design begins. These goals are, in part, established based upon the data provided in the Energy Benchmarking effort (EC1), but are refined through the use of Energy Use Targeting programs.

Net Zero Energy projects should establish an absolute energy target— a specific Energy Use Intensity (EUI) goal for the building. Energy targets appropriate for each project will vary depending on building type and climate. Understanding the project's potential for on-site energy generation is also key in establishing the project EUI target - a project with very limited on-site renewable energy generation will require an even more aggressive EUI savings in order to assure the site achieves Net Zero Energy.

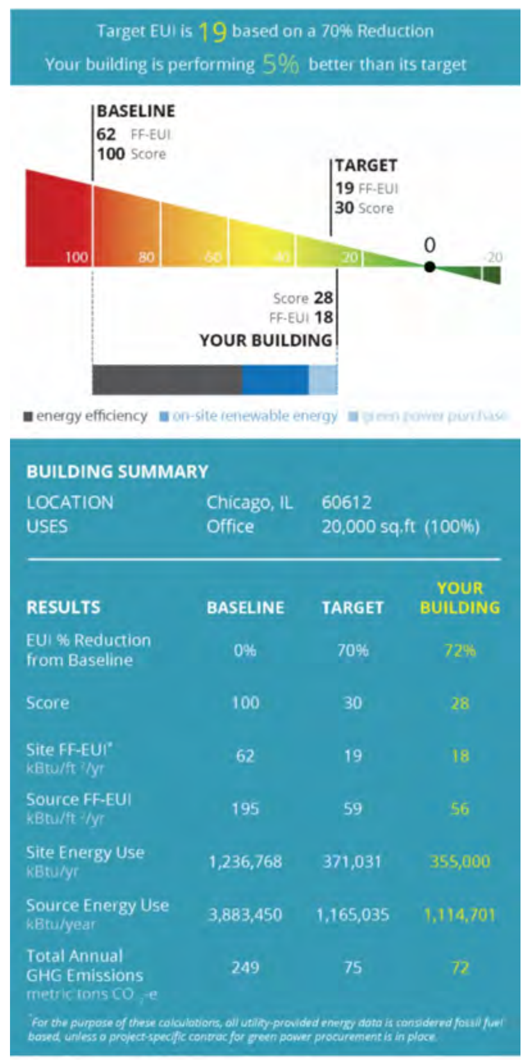
EUI targets are typically a fraction of the average building energy consumption as defined by Commercial Building Energy Consumption Survey (CBECS) or the California Energy Use Survey (CEUS). For example, CBECS 2012 suggests that an average EUI for school buildings is 53 kBtu/square foot per year while a ZNE school is about 20-24 kBtu/square foot per year.

Energy use targeting software and program options to assist building owners, designers, or contractors, include:

ENERGY STAR Portfolio Manager Target Finder by US EPA
ZeroTool by Architecture 2030
Zero Energy Performance Index (zEPI) by New Buildings Institute



Zero Energy Performance Index (zEPI) by New Buildings Institute



ZeroTool by Architecture 2030

Energy Consumption Design

Zero Energy Use performance targets by building type and climate zone. Values are site energy use (EUI) in kBtu/sf/yr

Building Type	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Primary School	26	25	26	25	27	23	21	27	24	24	28	25	24	29	26	30	39
Low-Rise Apartment	20	21	19	20	21	19	17	21	20	20	24	21	20	24	23	27	31
Medium Office	24	24	23	23	23	21	17	22	20	20	24	21	20	25	23	22	27
Small Office	19	20	18	19	18	18	16	17	18	17	18	17	16	18	18	20	24
Secondary School	29	29	26	27	26	25	22	24	26	26	25	29	23	24	24	25	35
Public Assembly	27	28	27	27	28	26	24	28	26	26	30	28	27	31	29	34	40
Standalone Retail[21]	27	30	26	28	25	26	21	25	26	26	26	28	26	27	26	29	35
Mid-Rise Apartment	22	23	21	22	23	21	19	24	22	22	26	23	23	27	25	30	34
Strip Mall[21]	30	33	31	32	33	29	25	34	29	31	39	34	33	41	37	46	60
High-Rise Apartment[21]	28	28	27	27	28	26	22	29	27	27	33	29	27	33	30	37	43
Warehouse	5	8	6	8	7	7	7	9	8	8	11	9	9	11	10	15	16
Small Hotel[21]	36	35	35	35	35	34	32	36	34	34	38	35	34	39	37	41	47
Fire Station[22]	29	30	29	29	30	28	25	30	28	28	33	30	29	33	31	36	43

EC3 Energy Modeling

Energy modeling helps determine the anticipated energy savings of each design decision made in a Net Zero Energy retrofit or new building project. Employing energy modeling in the design phase of a Net Zero Energy project is a necessity - it is the only means for a building owner or designer to understand the energy savings potential of their design decisions and is the only mechanism to understand the level of on-site renewable energy generation which will be required to meet a Net Zero Energy building's needs.

Effective energy modeling is also key in determining which energy saving features are most cost effective. Energy modeling software is an important design tool that helps building owners, designers, and builders identify the least expensive measures required to create a Net Zero Energy building. Modeling should be conducted in multiple times in conjunction with the design process - this enables the energy modeling to analyze the energy impact of different design choices and ultimately help a project team arrive at the most optimum decisions for that building.

There are a number of energy modeling tools available, both free and paid subscription. The tools typically require a degree of training to use properly so are often managed by trained professionals like architects, engineers, or a builder's technical staff. The payback on the costs of energy modeling itself is usually quite short for a Net Zero Energy building - frequently just a matter of weeks.

Energy modeling software and program options to assist building owners, designers, or contractors, include:

- Zeros by Build Equinox (free)
- OpenStudio by US DOE (free)
- EnergyPlus by US DOE (free)
- DOE-2 by Lawrence Berkeley National Laboratory (free)
- Sefaira (paid)

Energy Consumption Design

Benefits of Energy Modeling for Building Owners:
Reduced First Cost through Right-Sizing: Energy modeling allows reduction of the safety factors traditionally applied in sizing costly building systems, resulting in a corresponding reduction in initial costs.
Reduced Change Orders: Early scrutiny of, and agreement on, design parameters reduces changes during construction.
Reduced Operating Costs: Energy modeling facilitates design choices that reduce energy use and, accordingly, utility costs.
Reduced Maintenance Costs: More durable materials and more effective systems lower long-term maintenance costs.
Greater Predictability of Operating and Maintenance Costs: The dependability of performance of a well-modeled building enables more cost-effective business and financial decision-making.
Incentives: Many utilities offer financial incentives for highly energy efficient buildings. Energy modeling can quantify the financial impact of these incentives, as well as provide the evidence of anticipated energy performance the utilities require to receive these incentives.

American Institute of Architects
"An Architect's Guide to Integrating Energy Modeling in The Design Process"

Resources and Information:

ENERGY STAR Portfolio Manager:
https://www.energystar.gov/buildings/tools-and-resources/portfolio-manager-0
Building EQ by ASHRAE:
https://www.ashrae.org/technical-resources/building-eq/building-eq-portal
FirstView by New Buildings Institute:
https://newbuildings.org/resource/firstview/
ENERGY STAR Portfolio Manager Target Finder:
https://portfoliomanager.energystar.gov/pm/targetFinder?execution=e3s1
Zero Tool:
http://www.zerotool.org/
Zero Energy Performance Index (zEPI):
https://newbuildings.org/code_policy/zepi/
Zeros by Build Equinox:
https://buildequinox.com/zeros/
OpenStudio by US DOE:
https://www.openstudio.net/
EnergyPlus by US DOE:
https://energyplus.net/
DOE-2 by Lawrence Berkeley National Laboratory:
http://www.doe2.com/
Sefaira:
https://sefaira.com/

Section 03

Site + Subdivision Design Strategies

Change Metrics
Change Time Periods

Metrics Summary

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Total GHG Emissions Intensity (kgCO2e/ft²)	8.1	8.1	0.00 (0.00%)

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Site + Subdivision Design Strategies

ENERGY CONSUMPTION DESIGN

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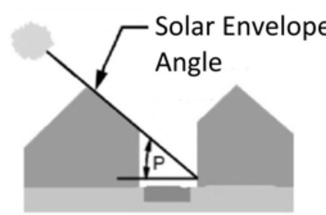
Once a building's energy use history is known and compared against its peer group, a building owner or designer can begin to anticipate the level of energy efficiency improvements needed - as well as the potential - for a building.

> **As much as 50% of the heating and cooling energy can be saved by going from the worst orientation to the best orientation, and street layout has a tremendous impact on the orientation of buildings.**
>
> - Norbert Lechner
> Architect and professor emeritus, Auburn University.

Village Homes subdivision in Davis, California - an example of urban planning for solar access.



Graphic Source: GreenVision Studio, School of Architecture, Univ. of Tennessee

SD3 Protecting Breeze Access

If the streets are not oriented properly to the prevailing winds, then not all streets will receive good ventilation. Dense connected buildings with few gaps in between push the wind up over the city, instead of allowing it to penetrate and disperse around every building. Subdivision planning should consider prevailing winds, particularly during hot periods of the year, and strive for an equitable redistribution of breezes throughout the planning area, allowing building ventilation and improving pedestrian comfort.

Recommended strategies to protect access to, and dispersing cooling breezes include:

- Creating passages for prevailing breezes through blocks and between buildings.
- Using landscaping and open space patterns to direct prevailing cooling breezes towards occupied development zones.
- Subdivision planning should consider prevailing winds (generally West to Southwest)

Site + Subdivision Design Strategies

SD4 Planning for Vegetative Cooling

Thoughtful placement of trees and vegetation between and around buildings can cool the ambient air temperature and when located to shade structures during hot periods of the year, will decrease a building's demand for air conditioning and energy usage. Trees and vegetation have multiple co-benefits for subdivisions, including:

- **Improved air quality and lower greenhouse gas emissions**: Trees and vegetation remove air pollutants and store and sequester carbon dioxide.
- **Enhanced stormwater management and water quality**: Trees and vegetation reduce stormwater runoff and soil erosion and improve water quality.
- **Reduced pavement maintenance:** Tree shade can slow deterioration of street, drive, and walkway pavement, decreasing the amount of maintenance needed.

SD5 Minimizing Heat Island

"Heat Island" is an area having higher average temperature than its surroundings owing to the greater absorption, retention, and generation of heat by its buildings, pavements, and human activities. Based on a 2006 study done by Minnesota State University and the University of Minnesota, the relationship between impervious surface percentage of a City and the corresponding degree of heat island temperature increase can be understood as a ratio. The ratios vary slightly for each season, however, for summer heat island conditions the ratio of potential heat island contribution is 0.17°F for every 1% of impervious ground cover (building roofs, streets, driveways, and sidewalks). That means that within a residential subdivision of 20% impervious surface coverage, the heat island experience could be 3.4°F hotter than the surrounding area. For a commercial district of 50% impervious surface, the temperature experience could be as much as 8.5°F hotter.

These increases, in turn, increase the demand for air conditioning and cooling in our occupied buildings. Planning strategies to minimize heat island include:

- **SD5-a Optimized street width:** minimizing total width of streets to only what is necessary for the development type and density - for a residential development this likely means streets of 25' or less.
- **SD5-b Cool Pavement:** use of cool pavement - light colored road and walkway surfaces such as concrete or cool-colored coatings reduce the total heat absorption and retention of impervious surfaces. Goals should be to achieve an average albedo of 0.3 or higher for all pavement areas.

Albedo Levels of Common Pavement Surfaces

Pavement Type	Albedo
Asphalt	0.05 – 0.10 (new) 0.10 – 0.15 (weathered)
gray portland cement concrete	0.35 – 0.40 (new) 0.20 – 0.30 (weathered)
white portland cement concrete	0.70 – 0.80 (new) 0.40 – 0.60 (weathered)

Source: American Concrete Pavement Association

- **SD5-c Permeable Pavement:** These pavements allow air, water, and water vapor into the voids of the pavement. Permeable pavement technologies include porous asphalt applications, pervious concrete applications, permeable pavers, and grid pavements. When wet, these pavements can lower temperatures through evaporative cooling. Furthermore, some permeable pavement systems contain grass or vegetation, which can increase the cooling potential of the pervious pavement system.
- **SD5-d Tree canopy:** The national average urban tree canopy is 27%. Increasing tree canopy coverage, especially in designs which provide cover to impervious surfaces or provide shading to occupied structures, can significantly decrease heat island effects.

Site + Subdivision Design Strategies

SD6 Establish a Net Zero Covenant

Subdivisions frequently have covenant agreements establishing standards such as material and color aesthetics. The covenant agreement structure can be a powerful tool, when combined with appropriate subdivision design strategies, to advance the adoption of high performance and Net Zero construction. Subdivision developers and owner's associations should establish covenant language which establishes an expectation that each property is to self-generate sufficient electricity to offset the property's total annual electrical consumption by means of on-site solar PV systems (or wind turbine where appropriate). An example of this covenant structure can be found at the Red Fox Crossing development in New Berlin, WI (http://neumanndevelopments.com/redfoxcrossing.html)

SD7 Microgrid Energy Resilience

A microgrid is a small network of electricity users with a local source of supply that is usually attached to a centralized national grid but is able to function independently. When applied to the scale of a subdivision, a microgrid can interconnect multiple distributed solar PV arrays and battery systems within the community, providing an opportunity to share energy resources and increase energy resilience for all of the properties. Beyond increased energy reliability, microgrids can also optimize on-site energy generation by maximizing electrical generation in portions of the subdivision with ideal solar exposure and providing a renewable energy boost to those portions of the subdivision with less than ideal conditions due to solar obstructions from buildings or trees.

SD8 Establish a 2030 District

2030 Districts bring property owners and managers together with local governments, businesses, and community stakeholders to provide a business model for urban sustainability through collaboration, leveraged financing, and shared resources. 2030 Districts establish building energy benchmarking and disclosure standards, share best practices for energy efficiency and verification methods for measuring progress towards a common goal: achieving a Carbon Neutral built environment by 2030. Properties within 2030 districts are also able to leverage group purchasing potential to reduce equipment and construction costs for energy efficiency upgrades, appliances, and renewable energy installations. https://www.2030districts.org/

What is passive design?

Passive design is a building design approach that utilizes architectural features and construction practices to allow a building to remain comfortable while requiring very little energy for heating and cooling over the course of a year.

Typical features of passive architecture include large amounts of thermal mass, upgraded insulation, smaller window to wall ratios, canopies or other shade structures, controlled natural ventilation, and improved roof designs. Passive designs seek to greatly reduce, or eliminate the need for mechanical heating and cooling systems and are ultimately highly cost effective design approaches - particularly when viewed as a life-cycle cost.

Site + Subdivision Design Strategies

SITE DESIGN STRATEGIES

S1 Site Analysis for Net Zero

Site analysis evaluates the unique characteristics of a property to evaluate what elements will support or hinder the building goals. Designers can utilize solar access, natural shading, air movement, available water, soil conditions, etc. to optimize the building location, orientation, massing, and consider other green building elements that could support energy and water performance. Decisions about passive heating, cooling, and ventilation solutions must occur early in design to minimize design time.

The interrelationships between the building and its systems, surroundings, and occupants should make efficient and effective use of resources by considering climate as a resource. During the conceptual and schematic design phases, evaluate the major climatic variables that impact the energy performance of buildings including temperature, wind patterns and orientation, solar exposure, and humidity. Assess local topography or adjacent properties that would impact access to sunlight and passive solar heating. Characterize the local climate using annual seasonal metrics such as annual solar radiation, cooling degree days (CDD), heating degree days (HDD), dew-point design temperature and design wet-bulb temperature.

S2 Understanding Site Solar Access

Shade cast from surrounding trees and buildings can reduce solar access, minimizing available on-site energy production potential from photovoltaics. Conduct an analysis of the climactic (solar path, etc) and biologic (tree stands, etc) current and future conditions to select the best array location, keeping in mind that new and future buildings or design elements such as awnings, cooling towers, and other architectural and mechanical elements that could hinder the future production of energy. When siting options are limited, or an existing building shades the roof area, ground or vertically mounted PV arrays may be the best opportunity before researching to offsite generation.

S3 Understand Future Development

Future regional development can change how adjacent buildings and sites effect one another. These effects can impact building energy consumption and maintenance requirements. Consider how the future development or expansion of surrounding sites will impact solar access, exposure to natural elements, wind, rainfall amounts, and stormwater runoff patterns and concerns.

S4 Understand Site's Microclimate

Microclimates are local zones that differ from a surrounding area. A microclimate can be as large as several square miles or as small as a few square feet. Your building's microclimate can vary from your neighbor's microclimate just a few blocks away. Microclimates are often created by changes in elevation, slope, aspect or surface. For instance a cooler microclimate can exist near a body of water such as a river or pond. Knowing your building and property's microclimates can be very helpful when designing your landscape as well as building orientation considerations.

S5 Landscaping for Energy Savings

According to the Arbor Day Foundation "Planting the right tree in the right place is key to maximizing the energy-saving benefits that trees provide. When planted properly, a single tree can save a homeowner up to 20% on energy costs." Trees which help buildings reduce their energy consumption based on their location are known as energy-affecting trees. Strategies for energy-affecting trees in the La Crosse area include:

Site + Subdivision Design Strategies

S5-a Plant for Sun and Shade: Plant deciduous trees on the south and west side of the building to maximize sun in the winter and shade in the summer. To plant for shade effectively, you need to know the size, shape and location of the shadow at different seasons and different times of the day. In most cases, if you plant a 6-8 foot deciduous tree near a 1 story building, it will start shading your windows in the first year, and the second floor (or roof in 5-10 year)s. Vines, shrubs and bushes can also effectively shade walls and windows and may be enough in certain conditions.

S5-b Plant to Deflect Winter: Deflect winter winds by planting windbreak appropriate trees and shrubs on the north and northwest sides of the building. When planted properly, a good windbreak can reduce the wind speed for a distance of as much as 30 times the windbreak's height. The best windbreaks block wind close to the ground by using trees or shrubs that are dense throughout the height of the plant. You can also use a combination of trees, shrubs, bushes and berms to create an effective windbreak. Windbreaks also help reduce noise, sights or smells as well as create wildlife habitat.

S5-c Plant For Ventilation: Attract summer breezes towards the building by knowing where the summer cooling breezes come from and landscaping to channel them towards the building.

S6 Landscaping for Solar Power

For all the reasons that trees help shelter our buildings from energy demands, they can also deprive our buildings and sites of quality solar power potential and weaken solar access for Solar Photovoltaics (PV) or Solar Thermal systems. Determine the portions of the site which will require maintenance of solar access to assure solar benefits are preserved for on-site solar PV or solar thermal systems and designate that a Solar Access Landscape Zone. All landscaping that occurs in the Solar Access Landscape Zone must be carefully selected to provide the various benefits desired by the landscaping while assuring solar access to the anticipated solar PV or solar thermal locations are not shaded.

Use of ground covers, shrubs, dwarf tree varieties are can all enable landscaping close to the building while not infringing upon rooftop solar arrays. See the City of La Crosse Solar Ready Guidelines, Section 2 Site Planning for more information.

Landscaping for Solar Power:

Surrounding trees, buildings, or geological features to Southeast, South, or Southwest should be no more than 6' higher than lowest edge of roof for every 12' in distance from roof edge they are. Selection of dwarf or limited growth tree varieties can provide shade for the occupied spaces of a building while retaining solar access.

S7 Climate Adaptive Landscaping

The La Crosse region has already seen some climate change impacts over the last few decades. In fact, the region has changed from a USDA Hardiness zone of 4 to 5. These changes can be anticipated to continue, even as the community works to reduce its carbon emissions. Consequently, one of the impacts building owners and designers should anticipate is a change in the performance and hardiness of certain landscaping materials – particularly tree species. Using climate adaptive tree species in support of the S5 and S6 strategies above can help a site's long-term climate adaptive capacity. See Appendix for Climate Adaptive tree species for the region.

Resources and Information:

US Department of Energy Microgrid Portfolio of Activities:
https://www.energy.gov/oe/services/technology-development/smart-grid/role-microgrids-helping-advance-nation-s-energy-syst-0
US EPA Heat Island Compendium - "Heat Island Basics":
https://www.epa.gov/sites/production/files/2017-05/documents/reducing_urban_heat_islands_ch_1.pdf
US EPA Heat Island Compendium - "Cool Pavements":
https://www.epa.gov/sites/production/files/2017-05/documents/reducing_urban_heat_islands_ch_5.pdf
US EPA Permeable Pavement Resources:
https://www.epa.gov/soakuptherain/soak-rain-permeable-pavement
Connecticut Department of Energy and Environmtal Protection, A Resident's Guide to Pervious Pavement:
https://www.ct.gov/deep/lib/deep/water/watershed_management/wm_plans/lid/what_is_permeable_pavement.pdf
Wisconsin Department of Natural Resources, Permeable Pavement Technical Standard
https://dnr.wisconsin.gov/sites/default/files/topic/Stormwater/1008_PermeablePavement_06-2021.pdf
Minnesota Pollution Control Agency Construction Specifications for Pervious Pavement
https://stormwater.pca.state.mn.us/index.php/Construction_specifications_for_permeable_pavement
2030 District:
https://www.2030districts.org/
Midwest Gardening, Small Ornamental Trees for rooftop solar compatibility:
https://www.midwestgardentips.com/trees-index-1/small-ornamental-trees
Climate Change Field Guide for Northern Wisconsin Forests: Site-level considerations and adaptation:

Section 04

Building Massing + Building Orientation

Center for Sustainable Landscapes
The Design Alliance Architects
Pittsburgh, Pennsylvania, United States
Credit: Denmarsh Photography, Inc.

Building massing - its basic form - and orientation are two of the most important strategies for reducing energy consumption, improving thermal comfort for occupants, and achieving a Net Zero Energy building. These two aspects are the most crucial for harnessing passive energies for heating, cooling, and daylight. They affect the amount of sun falling on surfaces and direction of winds.

For new construction, building massing and orientation are the most important strategies to get "right" because they are one-time interventions. Once constructed, a building's orientation and massing will likely never change.

In general, the underlying goal of building massing and orientation for Net Zero Energy is to maximize the amount of solar energy impacting the building in the winter while minimizing the impact in the summer…and leveraging the value of natural daylight throughout the year. Orientation also plays an important role with regard to the wind by minimizing wind exposure in the winter and maximizing cooling breeze capture in the summer.

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Building Massing + Building Orientation

Early-phase design decisions have a profound impact on future building energy usage. With timely analysis and integrated planning, project teams can radically alter the trajectory for building energy usage by making smart and informed decisions that establish a solid frame-work for subsequent decisions and conservation measures.

During the early design phases, practitioners should employ a climate-responsive design approach that strives to design for efficiency while simultaneously satisfying or enabling the achievement of all project goals. The optimization process uses energy modeling and other tools to iterate design solutions and reconcile competing

> **Proper building massing can improve a building's energy efficiency by 10% or more while increasing a building's on-site renewable energy generation potential by up to 20%.**
>
> - Demba Ndiaye, "The impact of building massing on net-zero achievability for office buildings".

Cantine Ferrari, Alberto Cecchetto
Mezzocorona, Italy, Credit: Rossano Albatici

BUILDING MASSING STRATEGIES

B1 Consolidate functions to reduce the building footprint

A net zero energy building can reduce energy use by consolidating functions and reducing the building footprint. Although this strategy might increase the energy use per square foot of the building, it can reduce total building energy use by reducing overall building square footage. Consolidating building functions requires the building operators and planners to coordinate to understand the occupant workspace needs and the timing of those needs with the needs and to identify all matches which can enable shared space functions resulting in a more efficient building program and space plan.

B2 Effective Surface Area to Volume Ratio

The basic shape of the building has a fundamental impact on the daylighting potential, energy transfer characteristics, and overall energy usage of a building. In general, the more building mass, the more materials (and higher initial construction cost) and the more energy the building will require. Building mass can be measured by the ratio of surface area (envelope) to volume, also known as the thermal shape factor A/V (exterior surface area to total building volume). The efficiency can also be measured by the ratio of surface area to floor area, known as shape factor A/A (area to area). Studies have shown that the differences in shape factor between buildings can have a large impact and accounted for 10%-20% of their final energy demand.

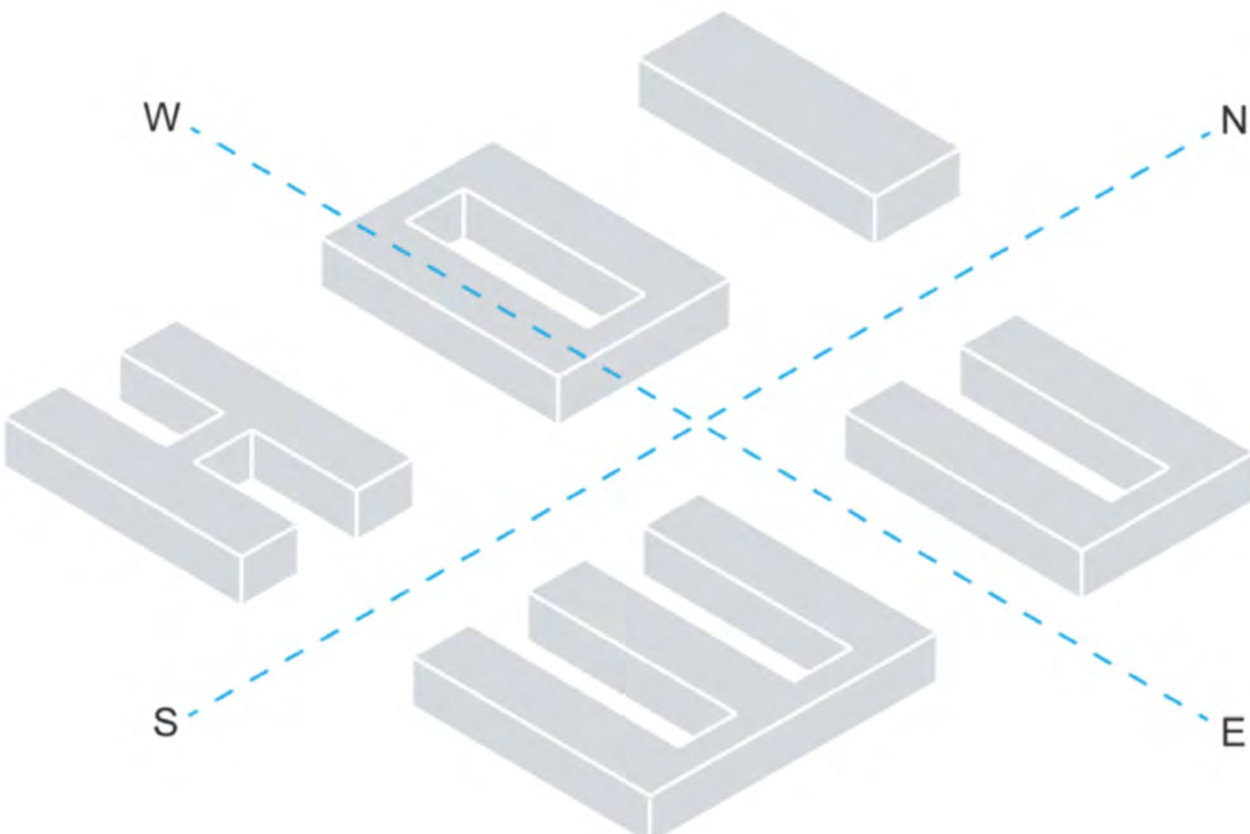
In this strategy, the efficiency of the building mass (a cube has the smallest ratio and would minimize thermal losses through the building envelope) must be carefully balanced against the passive conditioning considerations (smaller area to volume ratio increases potential for natural ventilation and passive cooling and heating).

Building Massing + Building Orientation

Buildings which have all occupied spaces capable of being daylit and served by natural ventilation (i.e. operable windows with shading controls) and within 20-30 feet of the exterior wall should be designed to maximize the exterior surface area to total building volume (higher A/V ratio). For larger buildings meeting these functional considerations, using elongated shapes with floorplates of 30 to 60' wide may be best. These larger surface area building shapes need to be oriented properly, typically 20° plus or minus of east/west for the elongated axis in order to maximize beneficial natural daylighting. Building forms that are sometimes referred to as "Letter Building Shapes" are examples of building massing meeting these parameters.

All other buildings should be designed to minimize the exterior surface area to total building volume (lower A/V ratio)*. See also, L1 Building Configuration for Natural Daylighting.

*Based on a study by Tongji University http://ibpsa.org/proceedings/asim2014/160_AsimC5-29-293.pdf



LETTER BUILDING SHAPES

Source: ASHRAE Special Project 140 Funded by DOE through NREL

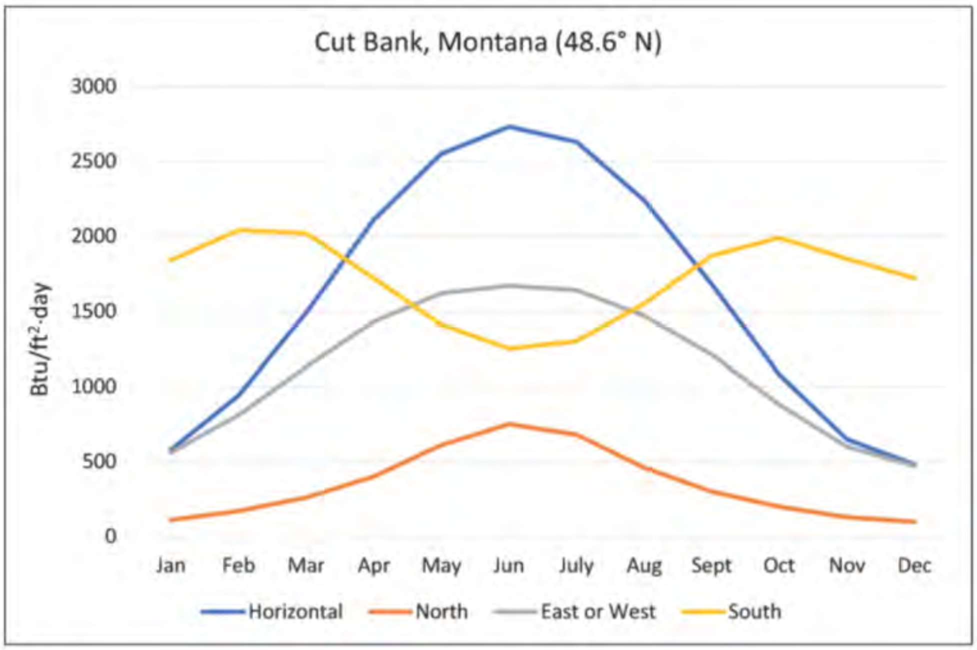
Building Massing + Building Orientation

BUILDING ORIENTATION STRATEGIES

B3 Maximize Orientation for Solar Responsive Design

The nature of natural daylight available from each direction varies significantly and has implications on the quality of daylighting and passive heating characteristics to the responding zones of the building. Building performance can be optimized by designing each facade based on its sun exposure. Minimize surfaces receiving direct solar radiation during the cooling season, prioritizing the reduction of direct sun on glass because of the heat gain this sunlight creates in the space.

The goal in this strategy, ultimately, is to select the building site and orient the building massing to maximize passive solar advantages, to optimize shading benefits, and allow for on-site renewable energy generation. In the La Crosse area, orientations which maximize Southern exposures and minimize Eastern and Western exposures will typically provide the greatest passive solar harvesting and solar control opportunities.



Source: ASHRAE Special Project 140 Funded by DOE through NREL

This graph shows hourly average solar radiation by orientation for Cut Bank Montana, a community at a similar latitude and solar exposure to our area. This illustrates that for most uses in the region, maximizing Southern exposure while minimizing East/west orientation and minimizing heat gain through horizontal (roof) orientation is the most advantageous building orientation.

B4 Consider Prevailing Breezes

Considering wind direction when determining building orientation can allow the building to take advantage of summer breezes for cooling and to be shielded from adverse winds in winter. Cold winds in the La Crosse area generally originate from the north and west. If the site has a unique microclimate, the orientation should take that into consideration, specifically wind directions per season.

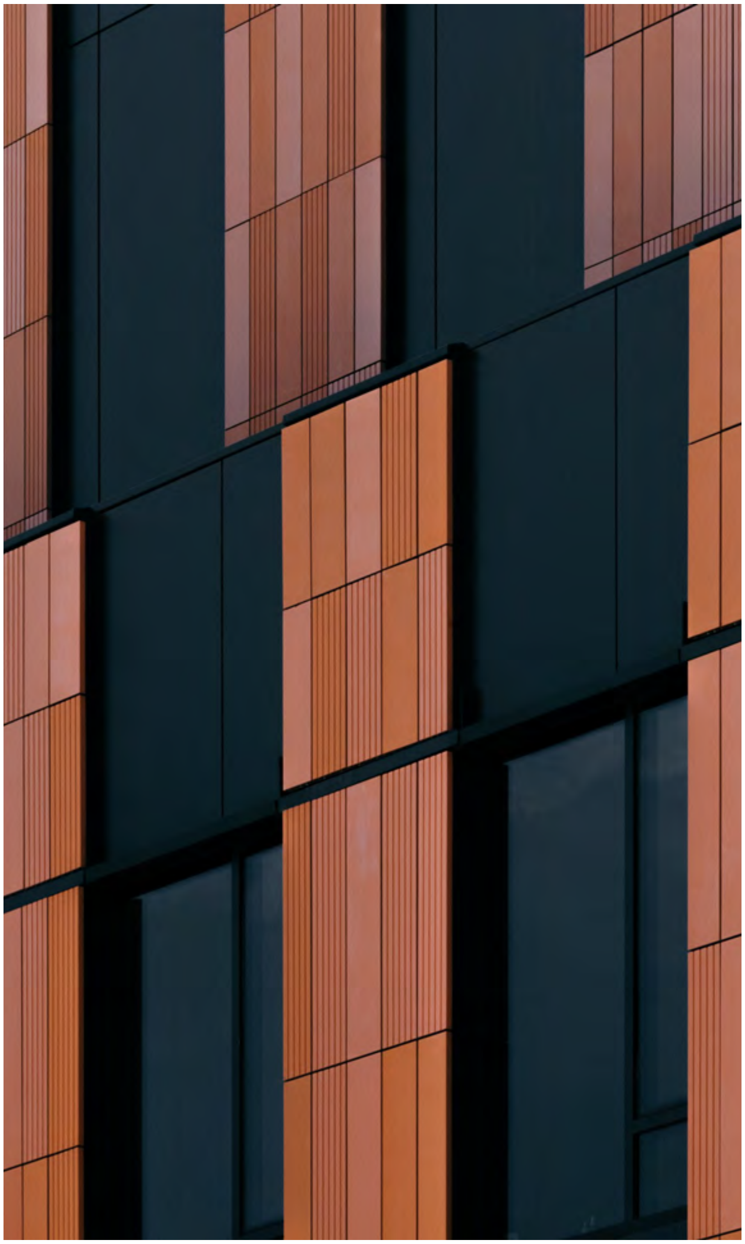
Building Massing + Building Orientation

Resources and Information:

Passive Design Toolkit, City of Vancouver:
https://vancouver.ca/files/cov/passive-home-design.pdf
US Department of Energy, Passive Solar Home Design:
https://www.energy.gov/energysaver/energy-efficient-home-design/passive-solar-home-design
US Department of Energy, Passive Solar Design Factsheet:
https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/29236.pdf
Sun Angle Calculator:
https://susdesign.com/sunangle/index.php
Window Heat Gain Calculator:
https://susdesign.com/windowheatgain/index.php

Gazebo House, AR + C >br/> Cecopamba Road, Guayllabamba, Equador
Credit; LorenaDS Architectural Photography

Section 05



General Building Design

The overall building design of a Net Zero Energy Buliding supports a reduced operational energy budget. Designing a Net Zero Energy building begins with facility programming and conceptual design with a focus on mindful placement of spaces in order to take advantage of the site's natural resources and energy.

Thoughtful Net Zero Energy building design focuses on efficiencies that can be leveraged through the space planning of the building uses. Strategies like locating spaces occupied at different times of the day within different quadrants of the building to leverage natural daylighting, or grouping spaces with similar heating and cooling demands in order to maximize mechanical system zoning efficiency will make significant differences in the energy demands of a Net Zero Energy Building.

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General Building Design

GENERAL BUILDING DESIGN STRATEGIES

D1 Programming for Low Energy Use

During the space programming phase of a zero energy building, include aspects which will have a direct impact on the building's energy use in the programming discussions and in the final program document. Things which should be established within the program should include:

- Lighting Power Density (LPD) targets for all spaces (the lowest level that meets function is best)
- Daylighting goals and requirements for all spaces (the highest level that meets function is best)
- Plug Load Power Density (PPD) targets for all spaces (the lowest level that meets function is best)
- Occupancy Density and internal heat gain values for all spaces
- Indoor Air Temperature allowable thresholds for all spaces (lowest warming threshold and highest cooling threshold that meets function is best)
- Natural Ventilation goals and requirements for all spaces (highest level that meets function is best)

Typical Internal Heat Gains for Office Spaces

Room Type	Occupancy Density, ft^2/person*	Equivalent People Sensible Btu/h/ft^2†	Lighting, Btu/h/ft^2 (W/ft^2)**	Plug Load, Btu/h/ft^2 (W/ft^2)‡
Office: light computer usage	200	1.22	3.75 (1.1)	1.7 (0.5)
Office: medium computer usage	200	1.22	3.75 (1.1)	3.4 (1)
Office: heavy computer usage	200	1.22	3.75 (1.1)	6.8 (2)
Conference room	20	12.25	4.4 (1.3)	1.7 (0.5)
Lobby	100	2.45	4.4 (1.3)	0.8 (0.25)
Corridor	—	—	1.7 (0.5)	0.8 (0.25)
Kitchenette/break room	20	12.25	4.1 (1.2)	1.7 (0.5)

*ASHRAE 2010a, Table 6-1.
†ASHRAE 2009b, Chapter 18, Table 1, applying "Seated, very light work" 245 Btu/h sensible.
**ASHRAE 2007a, Table 9.6.1.
‡ASHRAE 2009b, Chapter 18, Table 11.

Source: ASHRAE Advanced Energy Design Guide for Small to Medium Office Buildings.

D2 Planning for Low Energy Use.

Early space planning for heating and cooling considerations can reduce energy use and improve thermal comfort. Establishing PPD and LPD reduction goals for each space can reduce energy for lighting and plug loads and will also reduce internal heat gains and cooling loads for each space (see Programming for Low Energy Use). In addition, establishing internal heat gain values in combination with heating and cooling load targets for each space allows for energy-saving potential to be found in planning for space adjacencies and the development of the building envelope design. For example, spaces with high internal gains may be best served located in portions of the building that are not subject to high solar heat gains. Also, spaces with similar internal heat gains can be grouped together for efficient air conditioning zoning. Another example would be for spaces with low internal heat gains or with a flexible range of allowable temperatures which could be good candidates for natural ventilation to be planned for locations in the building with access to natural ventilation.

Other planning considerations that can reduce energy use include:

D2-a Optimizing Floor-to-Floor heights: Higher floor-to-floor heights increase a building's envelope and exposure to heating and cooling demands, while increased ceiling heights can improve natural daylighting and ventilation. Designers should carefully coordinate and model the demands of structural and mechanical systems in balance with the natural daylighting, ventilation, and heat loading impacts they have and select the most balanced concept for the buildings' function.

General Building Design

D2-b Openings between floors: when appropriate by function, allowed by code, and well located and designed, openings between floors can maximize natural daylighting and ventilation throughout a building.

D2-c Space planning for shared natural daylight: where enclosed spaces such as offices are required, locating them to facilitate natural daylighting to other spaces as well as considering use of internal windows will maximize shared natural daylighting of spaces.

D2-d Interior design for lighting efficiency: surfaces and materials which are light in color or reflective, when placed appropriately, can improve the effectiveness of natural and electric lighting. Generally, lighter materials placed on surfaces well positioned to redirect natural daylight deeply into the building as well as on ceilings can be effective. A 2017 study showed that light and reflective wall surfaces have the most impact on improving electric light distribution, followed by the ceiling and floor surfaces. (Makaremi, Nastaran & Schiavoni, Samuele & Pisello, Anna Laura & Asdrubali, Francesco & Cotana, F.. 2017. "Quantifying the effects of interior surface reflectance on indoor lighting." Energy Procedia. 134. 306-316. 10.1016/j.egypro.2017.09.531.)

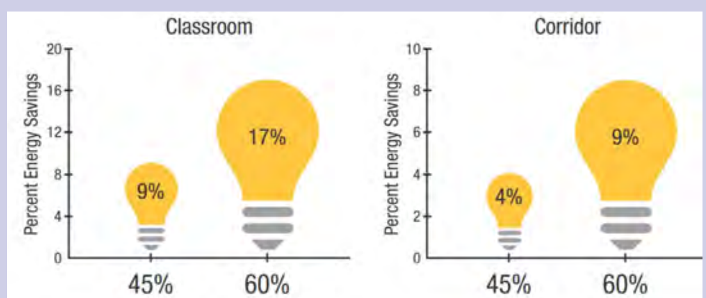
Consider the following minimum reflectance as a guide for interior surface considerations

Location	Minimum Reflectance
Wall segment above 7 ft	70%
Ceiling	70% (preferably 80% to 90%)
Light well or window well	80% to 90%
Floor	20%
Furniture	50%
Walls segment below 7 ft	50%

Source: ASHRAE Special Project 140 Funded by DOE through NREL

Example Light Savings From Reflectance - Classrooms
Comparing spaces with 80% reflectant ceilings with 45% and 60% reflectant walls.

- Source: Armstrong "Daylighting and Flooring: Don't Overlook the Issue of Reflectivity"



D2-e Design for flexibility: Consider potential changes over time for the requirements of the functions of the building. Consider, also, how spaces might be designed and related in order to maximize accommodation of potential future alternative uses with minimum building modifications. Designing for flexibility will enable the building to efficiently adapt to changing demands overtime and increase its overall effective life-span.

General Building Design

D2-f Consider interior-exterior relationships: when locating building functions consider the specific conditions of the site and the possible interior-exterior relationships. Locate spaces with heavy morning use where Eastern morning light can be an advantage, or late-day use functions where Western afternoon light can be put to use. Consider exterior viewsheds and exterior physical attributes that can be taken advantage of by interior spaces such as public sidewalks, access, and greenspaces.

D2-g Plan for heating and cooling zones: consider the allowable thresholds for temperature and the heating and cooling demands of the planned spaces. When configuring the building, look to group spaces with similar heating and cooling demands so that the building's HVAC zones can be as efficient as possible. Consider variations in hours of use so that spaces which are occupied late at night can be served by as few HVAC zones as possible, allowing shut-down for as many mechanical units as possible.

D2-h Create climate buffers: when possible, locate unoccupied spaces, or spaces with less sensitive heating and cooling demands in locations where they can serve as climate buffers for the building. As an example, spaces which can withstand cooler temperatures may serve well located on the Northwest corner of the building if the site is susceptible to cold wintertime prevailing winds from that area.

D2-i Use vestibules: entrances should be provided with vestibules or designed with an "air-lock" to minimize uncontrolled exchange of exterior air with the interior. Vestibules that are 10 ft or more in clear inside depth are recommended. Deeper vestibules help to limit the instances of simultaneous openings of inner and outer doors during use.

D3 Planning for Daylighting and Views.
Occupant access to daylight and views is a cornerstone of a healthy, zero energy office. The programming and space planning for a zero energy office should prioritize the location of regularly occupied spaces so they are within 30 ft of exterior walls with windows (See Daylighting and Electric Lighting for more). When enclosed offices and rooms are located on the perimeter they can constrict access to daylight and views for adjacent spaces. It is best practice to locate open spaces, such as open office areas, on the perimeter of an office floor plate, with the enclosed spaces and core spaces toward the center to maximize daylighting and views for all occupants. Though this is best practice, there are many creative ways to design and space-plan an office to optimize daylight and views for all occupants.

General Building Design

Resources and Information:

InstaHub Residential Plug Load Waste Calculator:
https://www.getinstahub.com/plugLoadWaste#buttonContainer
US GSA Sustainable Facilities Tool, Plug Loads:
https://sftool.gov/learn/about/426/plug-loads
US GSA Plug Load Reduction Checklist:
https://www.gsa.gov/cdnstatic/PlugLoad_Checklist_Form_Fields_508.pdf
2030 Palette:
http://www.2030palette.org/

Section 06

Building Envelope

Center for Design Research
Studio 804
Lawrence, Kansas, United States
Credit: Studio 804

A “building envelope” is the physical separator between the conditioned and unconditioned environment of a building including the resistance to air, water, heat, light, and noise transfer. This includes the walls, windows, doors, and the roof of a building.

A Net Zero Energy building is it’s envelope. The building envelope is key to reducing energy use and saving money. In the design and construction of a Net Zero Energy building, careful consideration, detailing, and installation of the building’s envelope is essential in order to achieve a high-performance structure.

A high-performance building envelope reduces heat movement in both directions, both into and out of the building. This lowers the workload on space heating equipment during winter, and air conditioning systems during summer. In Net Zero Energy construction, to paraphrase Benjamin Franklin, a kilowatt saved is a kilowatt earned!

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Building Envelope

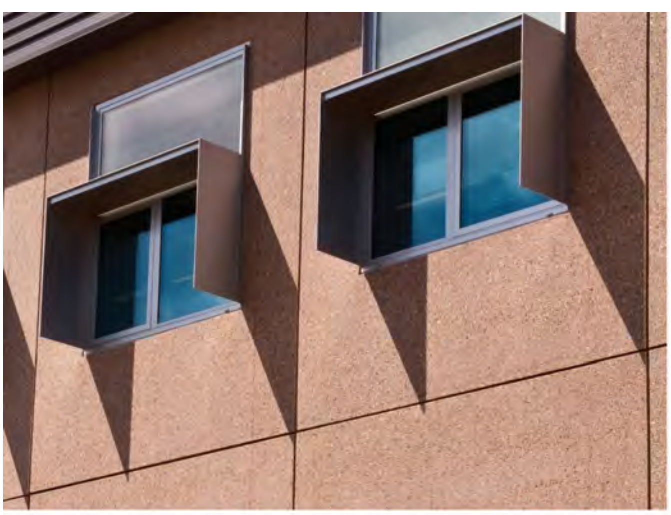
BUILDING ENVELOPE STRATEGIES

E1 Orientation Responsive Envelope Design

East and West facing facades have low angle direct sunlight which can cause glare and poorly controlled natural daylight year-round. South facing facades have high angle direct sunlight during summer months which can be kept from entering the building with modest overhangs and sun screens while still allowing the beneficial lower angle winter South sun entry into the space.

Building performance can be optimized by designing each facade based on its sun exposure. Minimize surfaces receiving direct solar radiation during the cooling season, prioritizing the reduction of direct sun on glass because of the heat gain this sunlight creates in the space. Prioritize the control and reduction of orientations that receive the highest solar gains during the cooling season. East and West facing facades receive the most solar radiation during the summer, compared to south or north orientations, consequently, a good solar control strategy is to eliminate or significantly reduce the direct sunlight which enters the building through the East and West building faces. Where possible, place 50% to 60% of the window area facing south. Most of the common occupied areas should be on the south side where they receive maximum natural light and winter heat from the sun. Unless shaded in some way, windows facing east and west tend to gain too much heat when it isn't wanted.

According to ASHRE "There are a variety of ways to provide shading for glazing and other envelope components including overhangs, shade structures, screens, double-skins, exterior blinds, and landscaping. Exterior shading strategies are more effective at reducing solar heat gain than interior mounted solutions, because they prevent solar radiation from entering through the glazing."



Eastern/Western orientation response:
National Renewable Energy Laboratory
RNL
Golden, Colorado, United States
Credit: Dennis Shroeder / NREL

Southern orientation response:
Orokonui Ecosanctuary Visitor Centre
Architectural Ecology Limited
Dunedin, New Zealand
Credit: Patrick Reynolds

Building Envelope

E2 Optimize the Building for Natural Ventilation

When appropriate, design building massing to make beneficial use of the wind for natural ventilation. In La Crosse's climate there are significant time periods during which natural ventilation can play a role in cooling and bringing fresh air to offices and other spaces. Research has shown that in naturally ventilated buildings, occupants more readily adapt to a wider range of indoor temperatures, based on the outdoor air temperature. Buildings should be designed in careful collaboration to optimize use of operable windows for natural ventilation and fixed windows:

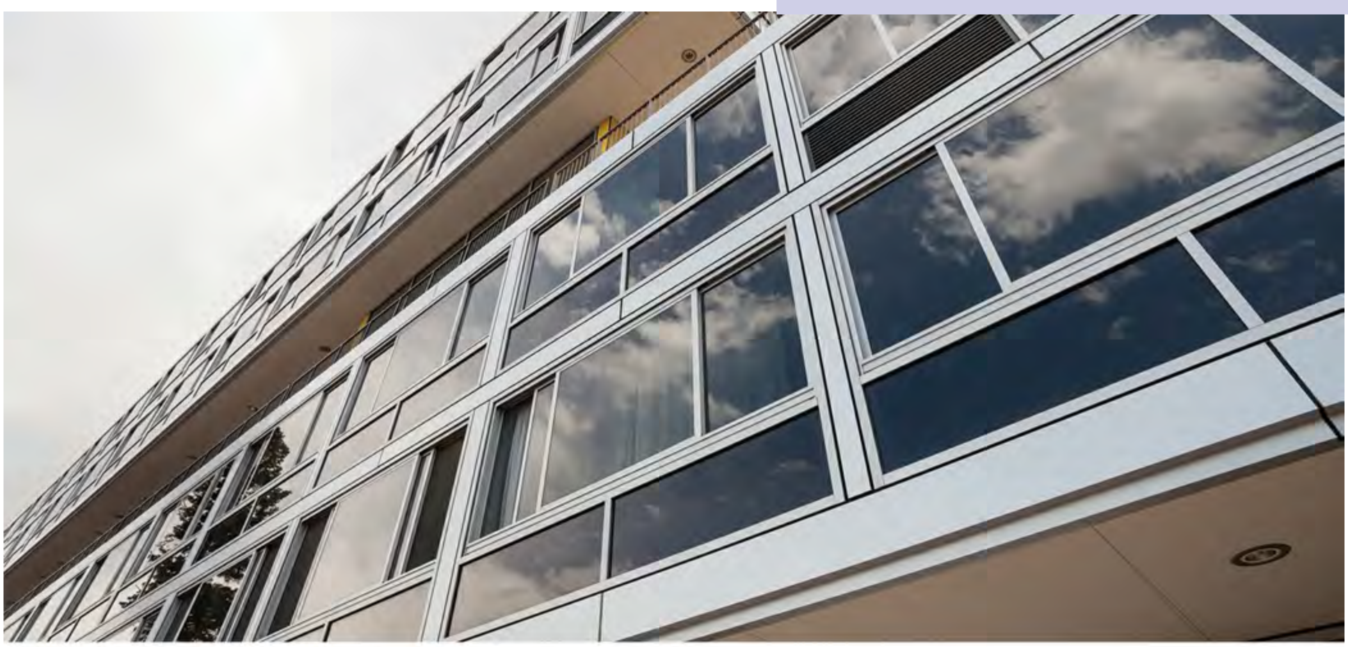
Operable Windows

Operable windows can be strategically placed to allow for optimal summer cross ventilation, which will reduce the summer cooling load. Make use of the "stack effect" to ventilate and cool the building, by placing operable windows near high points to allow warmer air to escape and near low points to draw cooler air in. All operable windows should be casement or awning where possible because they seal better than sliders or single-hung windows.

Fixed Window

Select fixed windows for locations not specifically designed for natural ventilation. Fixed windows, followed by casement and awning windows, are the most airtight, and have better U-value compared to similar sliding or single hung windows. Fixed windows also cost less than casement.

> **Operable windows can be a part of an effective natural ventilation strategy, when applied using the recommendations in the Carbon Trust Good Practices Guide 237 and ASHRAE 62.1-2004**
>
> - Steve Fronek, Vice President of Technical Services, Wausau Window and Wall Systems



Fixed and Operable Window Application:
Credit: Kawneer, An Arconic Company

Building Envelope

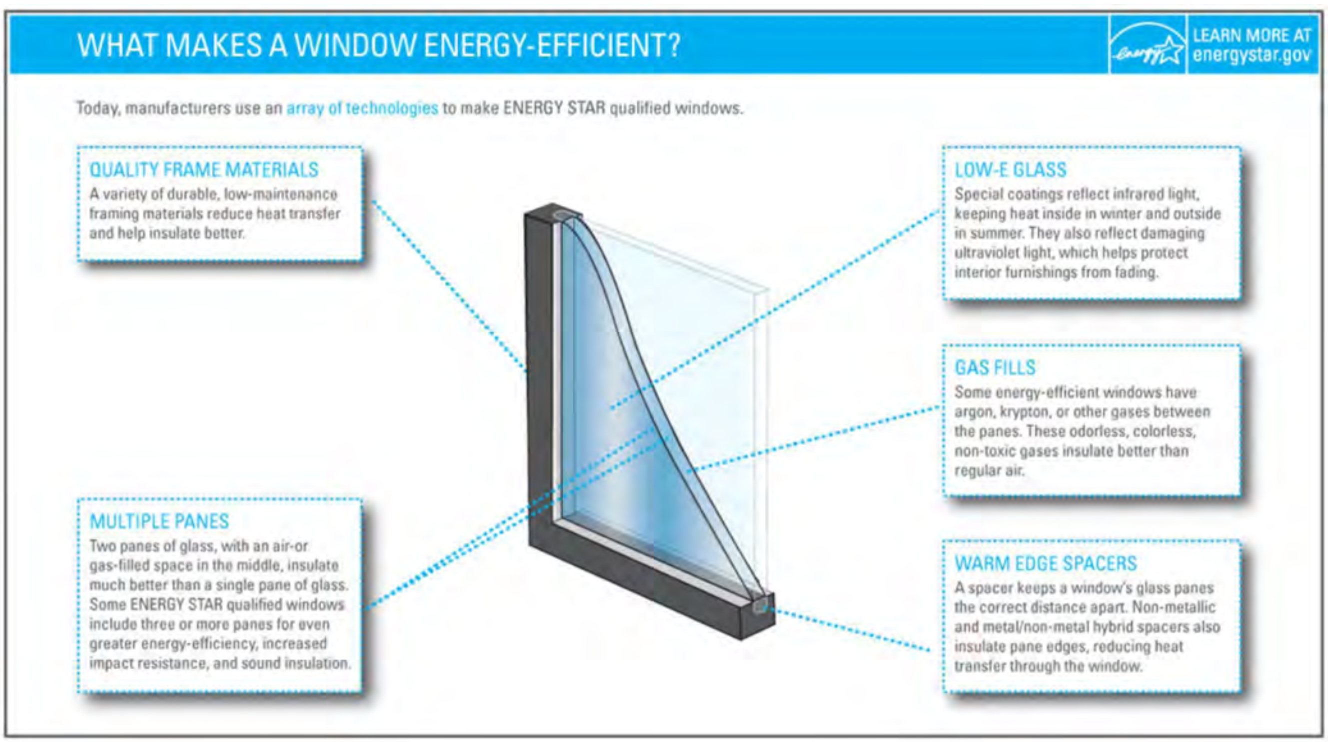
E3 Energy Efficient Windows

Windows represent a significant potential source of unwanted heat loss, occupant discomfort, and condensation issues. In recent years, driven in part by the US EPA ENERGY STAR program, windows have undergone a technological revolution. High-performance, energy-efficient window and glazing systems are now available that can dramatically cut energy consumption and pollution sources.

Select the most cost-effective windows with a heat loss rate of U-0.27 at a minimum (ENERGY STAR minimum qualification for Northern climates), or ideally a U-0.25 or lower. In some window assemblies this may be achieved through advanced double-glazed windows, while others may require triple-glazed assemblies to achieve the goal. Low U-values are achieved through three window assembly considerations:

- Low-emissivity (Low-E) coatings are microscopically thin layers of metal applied to the inner surfaces of the glass or on layers of clear film suspended between the glass panes. They limit the amount of heat that jumps from one glazing layer to the other.
- Spacers that hold the panes apart are typically made of aluminum and conduct heat rapidly. High performance glazing units use thermally improved plastic spacers or a plastic “thermal break” in the spacer to reduce heat loss around the edges.
- Consider triple pane, inert gas-filled windows with approximately 0.27 U-value or lower, such as Harvey Tribute, Thermotech, Atrium Northwest, Cascade, Solar View, Intus, Milgard or Alpen. Some double-pane windows such as Milgard, which use i89 glazing, are achieving U-values close to 0.22 and could be considered.

For renovations of existing buildings where costs are a constraint, a less expensive alternative to replacement windows may be to add storm windows on top of the existing ones, creating an air barrier that serves as additional insulation. This option, however, may not be appropriate for all architectural applications.



Building Envelope

E4 Optimize Window Area

Even with high performance energy efficient windows, a window will lose heat up to seven times faster than walls. As such, managing window area is a key factor in overall heat loss. A common way to understand window area relative to the size of a commercial building is by calculating the ratio of window-to-wall area (WWA).

It should be noted that although assuring quality natural daylighting, tests have shown that highly-glazed buildings (WWR>40%) in cold climates *do not* save more daylighting energy than they lose in heat energy. Large swaths of south-facing windows also rarely collect more useful free heat during the day than they lose at night. As the chart on page 6-6 shows, for high performance commercial buildings, the target maximum window-to-wall ratio should be between 20% to 40%, with a window U-Factor of 0.25 or greater. It is good practice to reduce WWR on the east and west elevations compared to the north and south elevations. It is difficult to control solar gains and glare on the east and west façades, and northern latitudes, like La Crosse's, have higher incident solar radiation striking these façades during the summer.

For residential construction, the common way to understand window area relative to the size of the home is by calculating the ratio of window-to-floor area (WFA). The average WFA is about 18% to 22% in production homes and 30% to 40% in custom homes. Based on energy modeling, reducing the window-to-floor ratio to the 14% to 16% range for homes is about optimum for minimizing heat loss.

E5 Insulate for High Performance Efficiency

Appropriate insulation levels are one of the key considerations for achieving high energy performance and cost effective Net Zero Energy buildings. Reducing energy demands while maintaining occupant comfort requires a much more significant attention to effective insulation than standard construction. Insulation values of materials and assemblies are measured in "R-Value", meaning the ability to resist conductive heat transfer. The higher the R-Value the higher the ability to resist heat transfer.

An important concept in high performance building insulation is "continuous insulation" (c.i.). Continuous insulation design focuses on the elimination of thermal bridging, elements within the assembly's construction which create opportunities for heat transfer around the assembly's insulation – an example is wood framing in a typical residential wood framed wall. On the following page are the current State of Minnesota minimum insulation requirements as well as the recommended insultation levels for minimum high performance as well as for passive net zero levels. Buildings seeking too be Net Zero Energy or Net Zero ready should achieve the minimum high performance levels or greater.

Building Envelope

	State of Minnesota Energy Code Insulation Requirements	Net Zero Construction Recommended Range: Minimum High Performance Insulation Recommendtions	Net Zero Construction Recommended Range: Passive Net Zero Insulation Recommendations
Windows	0.32 U-Factor	0.35 U-Factor	0.12 U-Factor
Skylights	0.55 U-Factor	0.50 U-Factor	0.12 U-Factor
Slabs-on-grade	R-10, 4 ft	R-20 to 4' from perimeter	R-20 to 4' from perimeter
Basement Walls	R-15/19	R-15 c.i	R-20 to 4' from perimeter
Floor	R-38	R-38	R-38
Wall - Mass	R-19/21	R-19 c.i.	R-40
Wall - Wood Frame	R-20 + 5 c.i.	R-13.0 + R-12.5 c.i.	R-40
Wall - Steel Frame	R-20 + 5 c.i.	R-13.0 + R-18.8 c.i.	R-40
Ceiling/Attic	R-49	R-49	R-60

Note: c.i. refers to "Continusous Insulation" assemblies without thermal bridging through insulation
Wall parapets should be continuously insulated to the same R-Value as the main wall

Insulation R-Values	
Type of Insulation	R-Value
Fiberglass	3.5 per inch
Cotton Batts	3.5 per inch
Cellulose	3.5 per inch
Closed-cell Foam	6 per inch
Open-cell Foam	3.5 per inch
Note: These numbers are estimates and the final R-value depends on density and installation.	

Building Envelope

E6 Wall Openings

Window transitions in walls should align the insulated glazing unit, the window frame's thermal break, and the continuous exterior insulation to minimize thermal pathways around the frame. Further, the exterior insulation should extend to the window frame at the head, sill, and jamb. This requires special coordination with the building designers and window manufacturer for the connection of the window in the window opening.

Door transitions in walls require details similar to those outlined above for windows. In the same way, insulated exterior doors or thermally broken framed doors with glass need to fall entirely within the exterior building insulation plane to maintain proper continuous thermal separation.

Window Unit Thermal Break Examples
Source: Glo Windows

Building Envelope

E7 Air Sealing to Eliminate Air Infiltration

Air leakage is a significant driver of energy use in all buildings, in residential construction, it is typically the largest single driver and can be 30%-70% of wasted heating and cooling energy use. Air leakage is typically the cause behind air drafts from the exterior and can be a major contributor to cold/hot spots in the occupied space. Air leakage is also the most significant contributor to moisture problems, especially mold and mildew formation.

With these considerations in mind, it is clear to see why one of the most cost effective measures of achieving a high performance net zero ready building involves air sealing the building envelope. Effective air sealing will focus on eliminating air leaks from the building structure itself and from around windows, doors, electrical outlets, plumbing fixtures and all other building penetrations. Air leakage through the envelope must be controlled to a determined maximum rate of 0.25 cfm/ft2 (or less) of total envelope surface area at 75 Pa for La Crosse's climate zone. The air barrier system must be continuous over all surfaces of the building envelope, including at the lowest floor, exterior walls, and the roof, separating controlled interior environments from exterior and semi-conditioned or unconditioned spaces.

Air sealing includes a continuous sheet applied air barrier, or solid wall and roof sheathing throughout the exterior envelope as well as caulking compounds, foam, gasketing, weather-stripping, or otherwise sealing all joints, penetrations and other openings through that continuous air barrier to limit air leakage.

What are some of examples of what must be sealed?

- Exterior joints around window and door frames, including doors between the house and garage, between interior HVAC closets and conditioned space, between attic accesses and conditioned space, between wall sole plates and the exterior floor panels;
- Exterior wall air barrier at the top and bottom plates;
- Openings for plumbing, electricity, and gas lines in exterior walls, ceilings and floors;
- Openings in the attic floor, including where ceiling panels meet interior and exterior walls and masonry fireplaces;
- Openings around exhaust ducts such as those for clothes dryers;
- Field-fabricated operable windows and doors must have weather stripping;
- And all other such openings in the building envelope.

Building Envelope

E8 Cool Roofs and Warm Roofs

A cool roof is a roof constructed of materials which literally stay cooler than other roofing materials. Cool roofs reduce the temperatures of roofs and can therefore reduce the urban heat island effect and reduce the cooling loads of buildings. To be considered a cool roof, a product must demonstrate a solar reflectance index (SRI) of 78 or higher. The Cool Roof Rating Council (CRRC) measures the SRI and other properties for roofing products and publishes the results on an online directory allowing building owners, designers, and contractors to compare the rated values of various product types and brands. The CRRC Directory can be found here: https://coolroofs.org/directory.

An overview of the additional benefits of a cool roof can be found here: https://coolroofs.org/documents/IndirectBenefitsofCoolRoofs-WhyCRareWayCool_000.pdf
In addition to the CRRC Directory, look for ENERGY STAR Certified high reflectance and high emissivity roofing products. (https://www.energystar.gov/products/building_products/roof_products)

E9 Green Roofs

Green roofs are roofs with a vegetative layer and soil and plants. Green roofs provide similar benefits as cool roofs, referenced in E8. The EPA estimates that green-roof temperatures can be 30°F to 40°F lower than those of conventional non-cool roofs. Though they are more expensive than conventional roofs, green roofs offer unique advantages in addition to reduced heat island effect. These advantages include improved storm-water management, sound insulation, improved air quality, biodiversity, biophilia, and aesthetics.

Green Roof Benefits Include:

- Reduction of stormwater runoff rate from a roof by up to 65%.
- Make roof surfaces 30-40% cooler.
- Reduce heat flux from roof to building by up to 72%.
- Last 40 years or more.
- Attract such wildlife as birds, bees and spiders.

U.S. General Services Administration

Building Envelope

E10 Roof Penetrations

Roof drains and the substantial connecting pipes are a source of thermal energy loss (and internal building condensation) at the roofing assembly. To minimize the impact of roof drain penetrations, the inboard side of the drain assembly should be thoroughly insulated where it penetrates the thermal envelope. Where metal rain leaders are used, the leaders should be insulated inside the building to the point where they penetrate the floor below.

Generic penetrations of the roof, such as plumbing vents, can also be thermal bridges. These penetrations should be sealed, with all gaps around the penetration filled. When metal pipe is used, the pipe should be insulated to the top of the vent before being flashed. On the interior side, metal pipe should be insulated for a minimum of 10 ft.

E11 Roof Hatches

Roof hatches are another substantial source of unintended energy loss. Roof hatches can vary greatly by manufacturer and have conventionally been significantly underinsulated. Recent innovations have included thermally broken hatches that decouple the exposed outer portions of the unit from the base mounting. During design, consider roof access that does not require roof hatches. If roof hatches are required, select the units which have integrated thermal breaks with the maximum R-Value available – units with an R-value of 18 are commonly available.

Tips for Existing Home Owners

Insulation:

A great place for existing home owners to begin is to focus on fixing areas of insufficient insulation in their home. Some of the most common areas of poor or failing insulation in homes are:

- Attic and roof assemblies.
- Kitchen cabinet bulkheads at exterior walls.
- Behind light switch and electrical outlet boxes in exterior wall construction.
- Improper, aged, or missing sealing around windows, doors and rough openings.

Windows:

If your windows are in good condition and it is not yet time to replace them, there are still steps you can take to improve their efficiency. Improving your existing window efficiency may be one of the most cost effective options to increase the comfort of your home and save money on energy costs. There are several things you can do to improve the efficiency of your existing windows:

- Check existing windows for air leaks.
- Caulk and weatherstrip. See the Department of Energy's DIY weatherstripping page: https://www.energy.gov/energysaver/services/do-it-yourself-energy-savings-projects/savings-project-how-weatherstrip-double
- Add window treatments and coverings.
- Add storm windows or panels.
- Add solar control film.
- Add exterior shading, such as awnings, exterior blinds, or overhangs.

Building Envelope

Tips for Existing Commercial Building Owners

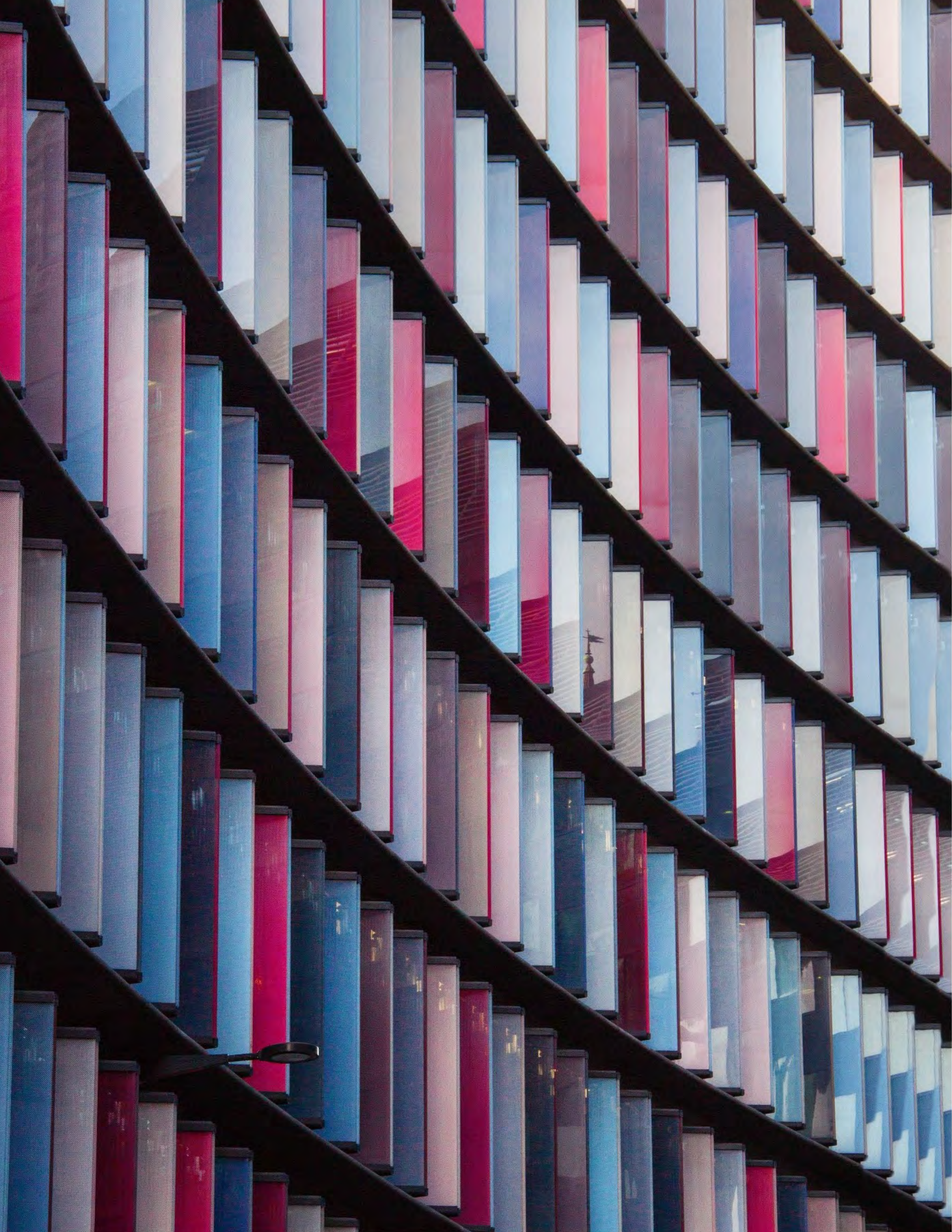
As a commercial building owner, the best place to begin to improve the energy efficiency of your building's envelope is to conduct a building energy audit. Start by assessing your energy bills, and maintenance records on heating and cooling equipment (see Section 2 Energy Benchmarking). Compare your energy use with similar facilities through ENERGY STAR Portfolio Manager as well as comparing your building's energy use over time (year over year use).

Visually inspect your building's walls, windows, doors, floor, and roof. Look for damaged areas of these assemblies or missing sections of window sealant, caulk, etc. Also look for sections of the wall with staining or increased dirt collection - that can sometimes be an indicator of areas of poor insulation.

You can also hire an architect or energy audit consultant to review your building. Have the consultant perform a building envelope assessment including measurements of effective R-Value performance and thermographic imagery to identify areas of potential concern and recommend corrective measures.

Resources and Information:

US Department of Energy "Where to Insulate a Home"
https://www.energy.gov/energysaver/weatherize/insulation/where-insulate-home
US EPA Heat Island Compendium - "Green Roofs":
https://www.epa.gov/sites/production/files/2017-05/documents/reducing_urban_heat_islands_ch_3.pdf
US EPA Heat Island Compendium - "Cool Roofs":
https://www.epa.gov/sites/production/files/2017-05/documents/reducing_urban_heat_islands_ch_4.pdf
Window Overhang Design Tool:
https://susdesign.com/overhang/index.php
Window Overhang Annual Analysis Tool:
https://susdesign.com/overhang_annual/index.php
Daylight Penetration Calculation and Visualization Tool:
https://susdesign.com/light_penetration/index.php
Window Exterior Louver Shading Calculator:
https://susdesign.com/louver_shading/index.php
Window Exterior Vertical Fin Shading Calculator (East/West exposures):
https://susdesign.com/vertical_fins/index.php
Window Heat Gain Calculator:
https://susdesign.com/windowheatgain/index.php
Cellulose Insulation Manufacturers Association, Insulation Savings Calculator:
https://cellulose.org/Cellulose-Insulation-2nd.php?pagename=CalculateSavings&dirname=HomeOwners
Whole Building Design Guide, Residential Building Enclosure:
https://www.wbdg.org/resources/residential-building-enclosure



Section 07

Daylight + Electric Lighting

Center for Design Research
Studio 804
Lawrence, Kansas, United States
Credit: Studio 804

Daylighting is an occupant well-being, building resiliency, and energy-efficiency design measure. Considering occupant well-being, daylighting provides people with a connection to the outdoors through high-quality views, intensity variation over space and time, and access to a full range of visible wavelengths.

In the context of building resilience, daylighting provides an integral aspect to the lighting system that can be used to support energy load reductions and wayfinding during prolonged grid outages. For Net Zero Energy building energy efficiency, daylighting can lower the electric lighting EUI by about 25% by reducing lighting power in response to useful daylight.

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Daylighting + Electric Lighting

DAYLIGHTING STRATEGIES

L1 Building Configuration for Natural Daylighting

As indicated in strategy B2 Effective Surface Area to Volume Ratio, occupied spaces within 20-30 feet of the exterior wall can be effectively daylit and served by natural ventilation. To achieve this, building configurations can be elongated, curved, or organized into many shapes. Buildings elongated in the east-west direction expose the longer north and south sides for controlled daylighting, and high ceilings and windows allow for greater interior daylight penetration. Buildings with large floor plates can introduce daylight through clerestories, skylights, atriums and courtyards.

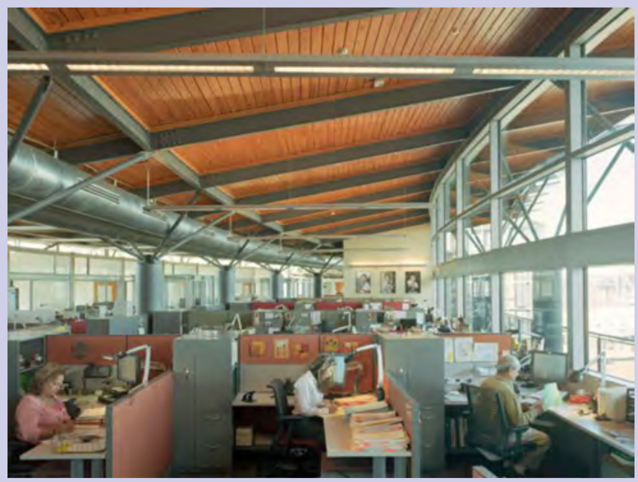
To configure the building for optimum natural daylight, elongate the building in the East-West direction with the longer faces oriented within 15 degrees of South and North. Use the 15/ 30 foot rule-of-thumb for developing building shapes and floor plates that include a 15 foot perimeter zone depth for task daylighting and an adjacent 15 foot zone with ambient daylighting.

When developing a building shape, consider how best to admit daylight into the building.

Use the 4.5 / 9 meter (15 / 30 foot) rule-of-thumb for developing building shapes and floor plates with:

- A 4.5 meter (15 foot) perimeter zone depth for task daylighting; and
- An adjacent 4.5 meter (15 foot) zone with ambient daylighting.

- Architecture 2030



L2 Optimize Window Orientation for Daylight and Heat Gain Balance

As noted in E1 Orientation Responsive Envelope Design, the qualities of sunlight and heat gain characteristics vary for each of the cardinal directions. These orientations have different qualities and considerations for the design of natural daylight and quantity of windows appropriate:

> North-facing windows are the most advantageous for quality daylighting as they admit an even wash of cool natural light, producing little glare and almost no unwanted summer heat gain. High north-facing clerestory windows are an effective and energy efficient means of admitting quality light.

South-facing windows are also an excellent source of natural lighting, and useful for moderating seasonal temperatures. They allow most winter sunlight into the home but little direct sun during the summer – provided that they are properly shaded. Generally, south-facing glazing should be sheltered from the summer sun with exterior overhanging eaves or sun-screens.

Daylighting + Electric Lighting

East- and west-facing windows are not desirable for natural lighting – they should be limited. They may cause glare, admit a lot of unwanted heat during the summer months, and contribute little to no solar heating during the winter. If East-West facing windows are a must for other reasons, they should be heavily shaded with vertical louvers, specially designed external sun control devices, or vegetation.

L3 Provide Balanced Daylighting

Daylighting spaces from multiple sides provides more even lighting and produces less glare around people and objects, supporting more effective use of natural day light. Spaces daylit from one side may contain excessive spatial differences in brightness, high brightness areas behind objects in the field of vision, and uncomfortable glare conditions – particularly with East and West orientations in the summer and South orientations in the Winter. In these instances, the change in day light intensity from the window to the interior of a space is steep, so the area furthest from the glazing may appear uncomfortably dark and the area towards the window will appear significantly brighter and produce glare.

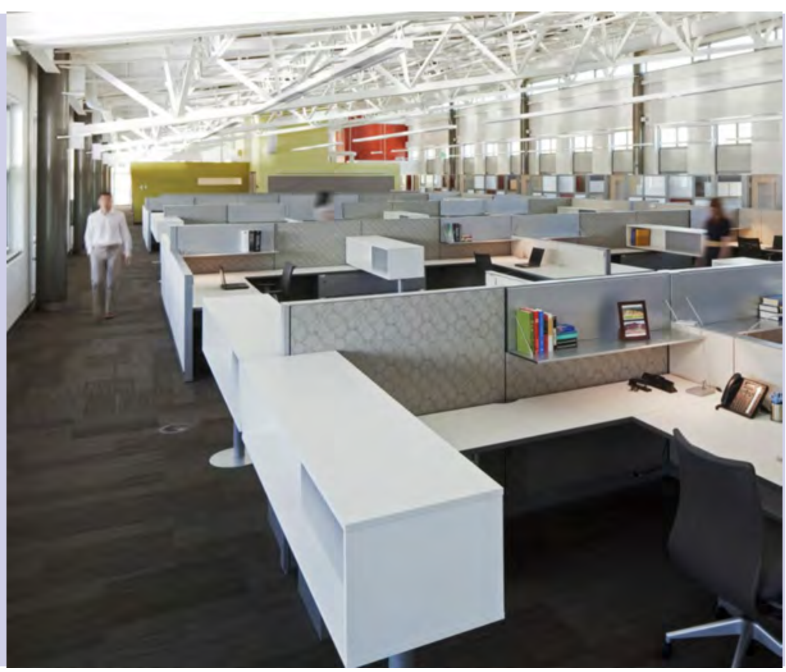
To provide balanced daylighting in occupied spaces, focus on providing daylight from multiple sides. Strategies to achieve this include providing windows on adjacent and/or opposite walls and providing a combination of wall and skylight or clerestory glazing. When it is not possible to provide daylighting from multiple sides, make walls and ceilings white in color and incorporate high ceilings and windows with light shelves to direct sunlight deeper into a space.

To achieve sufficient natural daylighting of occupied spaces, size the window area as a percentage of the floor area to be daylit with 10-15% minimum for basic daylighting levels and 15-25% for task oriented daylight levels.

Daylighting Facts:

- Annual U.S. lighting expenditures top $60 billion
- Lighting costs can be reduced by 20 to 80% through daylighting
- Integration of daylighting strategies can reduce total energy costs by up to 30%

Solatube International



Daylighting + Electric Lighting

L4 Daylight With Clerestories and Skylights

This approach is appropriate for increased privacy, shading of the solar façade, heating deep spaces and spaces located along other facades, avoiding direct sunlight on people and furniture, and to avoid glare. The following are clerestory and skylight design strategies:

Clerestory/Sloped Skylight – to supply heat down into a space, locate a clerestory or skylight 1 to 1.5 times its height above the floor in front of an interior wall.

Sawtooth Clerestory – make the clerestory roof angle equal to, or less than, the angle of the sun at noon on the winter solstice.

Horizontal Skylight – use a solar facing reflector with skylights to increase winter solar gain.

Make the ceilings of clerestories and sloped skylights a light color, and shade roof glazing in summer.

WTC Transportation Hub designed by Santiago Calatrava, New York City

Daylighting + Electric Lighting

L5 Effective Daylight Control

Direct sunlight on critical task areas (e.g., work areas, desk, TV or computer screens, reading areas, etc.), and the presence of high brightness in the field of view, causes a high degree of contrast between surfaces or uncomfortable glare. In addition, external shading devices can reduce solar heat gain through glazing by up to 80%. By designing shading devices according to the sun's seasonal path, both summer shading and winter solar gain can be achieved in the La Crosse area's climate of significant seasonal variations. The following strategies are recommended:

East/West Facing: vertical louvers (external ideal).

South Facing: Horizontal overhangs, light shelves or horizontal louvers (internal or external).

North Facing: vertical louvers if needed.

Make louvers a light color to reflect daylight into a space. An exterior *louvered* overhang above South facing windows, when properly designed, allows more daylight into a space while also blocking unwanted summer sun. Additional shading strategies include recessing glazed openings, and incorporating porches, balconies, and mature vegetation to shade east and west walls as well as outdoor areas.

L6 Light Shelves for Deep Daylighting

A Light shelf is a horizontal light-reflecting overhang that allows daylight to penetrate deep into a building. It is placed above eye-level and has a high reflectance upper surface. It can also shade near the windows and help reduce window glare. A light shelf added to a glazed opening will reflect daylight deeper into a space, and can increase the daylight depth to 2.5 times the height of the glazed opening. Light shelves should be used on South facing facades and the ceiling of the space receiving a light shelf should be light colored to reflect the incoming daylight.

Light Shelves…

- Enhance daylight quality.
- Reduce the need for artificial lighting and so reduce energy consumption.
- Reduce cooling loads.
- Increase occupant comfort and productivity.

Daylighting + Electric Lighting

ELECTRIC LIGHTING STRATEGIES

L7 Lighting Options for Occupants

With daylight providing basic lighting levels, aim to build in layers of additional electric lighting options to ensure that occupants gain the lighting they need for the varieties of tasks they perform. Provide occupants with options for additional lighting, examples include:

Provide task lighting at individual workstations and desks. LED lamps and fixtures with movable arms provide even greater energy savings and positive ergonomics.

Use vacancy sensors (manual on, automatic off) instead of occupancy sensors (automatic on, automatic off). In other words, turn lights off automatically when not in use but require occupants to opt in for more light as needed, by flipping a switch.

Divide the space into fine-grained electric lighting zones to direct lighting where it is most needed and allow for appropriate variations within the workspace. Provide intuitive control displays that are easy and convenient for occupants to use.

> **Task lighting and individual controls have been shown to increase employee satisfaction and engagement by giving them control over their space.**
>
> - 1000Bulbs.com

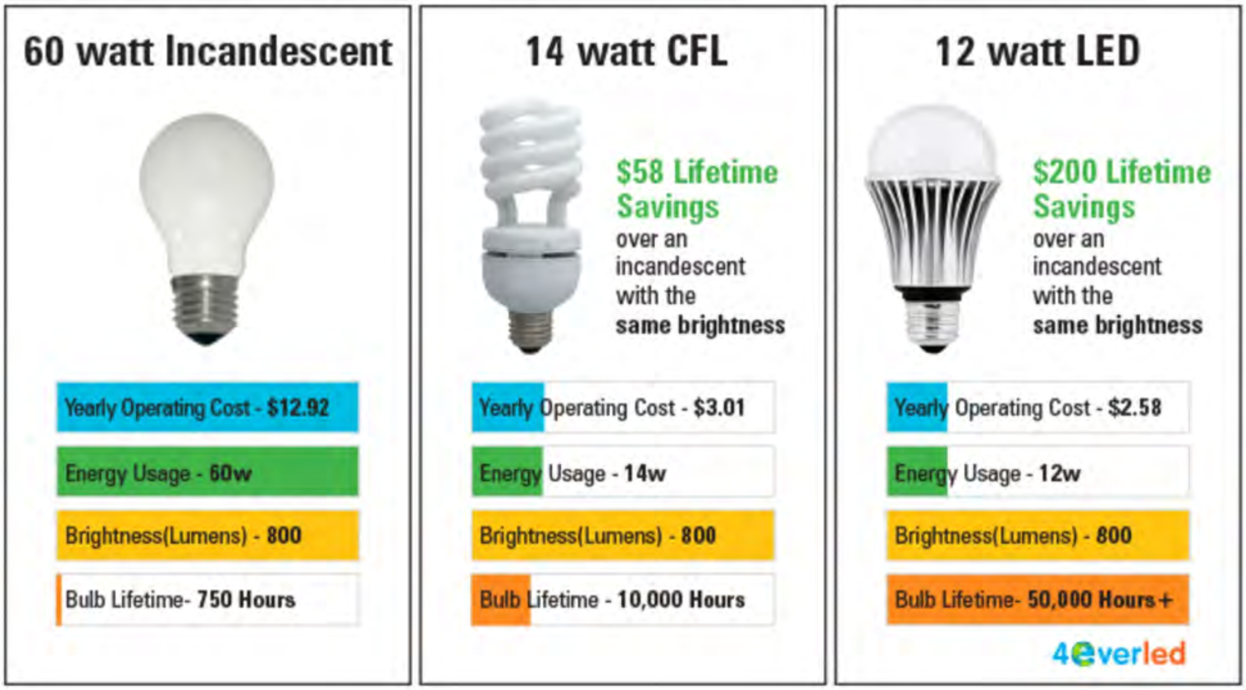
L8 Electric Light Integration

Integrate the lighting design and fixture selection with the anticipated natural daylighting characteristics and functions of the space. Fixtures with an indirect lighting component, for instance, more closely matches the lighting effects as daylighting and can be well integrated to maintain quality lighting through variations of daylighting quality. Well integrated light fixtures can also assure the right quality of lighting needed for the variations of tasks and functions within a space or building while minimizing the total quantity of electric light output.

L9 Use only Energy Efficient Lighting Fixtures (Interior, Building Exterior, and Site)

Upgrade electric lighting fixtures to more efficient fixtures. Use LED lighting wherever possible. Alternatively, high efficiency fluorescent and CFL lighting can also be used, though the energy efficiency and longevity of these fixtures are frequently not quite as high as LED counterparts. These new technologies emit more light per watt than conventional fixtures, enabling you to maintain light levels while meeting a lower Lighting Power Density (LPD) goal and thereby saving energy and money without impacting performance.

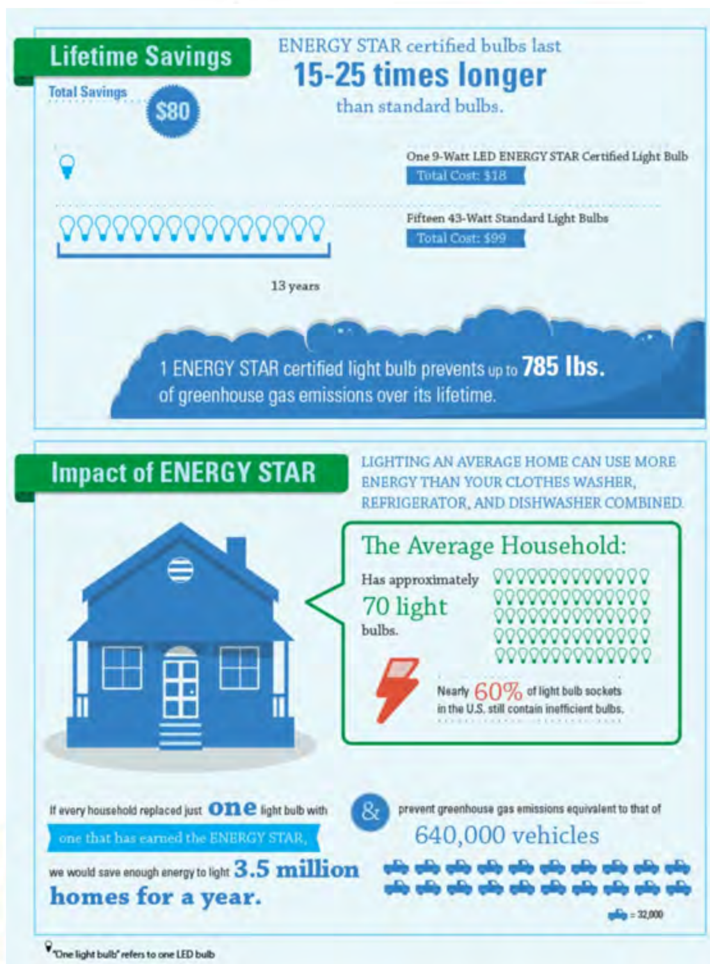
Daylighting + Electric Lighting



L10 Use ENERGY STAR Certified Fixtures

ENERGY STAR is a program of the US Department of Energy with the mission of providing simple, credible, and unbiased information for advancing energy efficiency for businesses and residents. The ENERGY STAR Certification program was created to provide comparative data and certification of high energy performing products.

Search the ENERGY STAR database here: https://www.energystar.gov/products/lighting_fans



ENERGY STAR

Daylighting + Electric Lighting

L11 Use Integrated Lighting Controls

Zero energy buildings aim to meet a variety of human well-being, environmental, and cost-effectiveness goals. In a high-performance building, the primary objectives for lighting control and sensor systems are to contribute to a comfortable and productive environment while achieving significant energy and operational cost savings. To do so, the lighting control system for a net zero building should integrate occupant use, daylighting, and equipment performance patterns in order to optimize use of artificial lighting.

Controls such as vacancy sensors, timers and photocells save electricity by turning lights off when not in needed. Dimmers, when controlled to provide only the level of lighting needed can save electricity. Maximize the efficiency of electric lighting systems through control systems that ensure that electric lighting is used only for the time, location, and quantity needed by occupants for a typical task. Options for lighting controls for high performance and energy efficiency include:

Vacancy Sensors: A control that requires the user to manually turn the lights on but will automatically turn the lights off after all users have left the space (preferred over Occupancy Sensors).

Occupancy Sensors: An automatic control that turns the lights on when users enter the space and off after all users have left the space (preferred over Time Scheduling)

Time Scheduling: Using a time switch to automatically turn the lights on or off at predetermined times.

Daylight Sensors: Automatic control that adjusts the lighting in response to available daylighting in the space.

Task Tuning: Dimming lights in building spaces so that the average light level is appropriate for the activities occurring in that space.

Networked Lighting Control: Control system integrating all of the above options with network interface of all devices combined together to act as a complete system.

See also: **D2-d Interior design for lighting efficiency**

Daylighting + Electric Lighting

Resources and Information:

National Institute of Building Sciences, Whole Building Design Guide, Daylighting:
https://www.wbdg.org/resources/daylighting
Window Heat Gain Calculator:
https://susdesign.com/windowheatgain/
Window Overhang Design Tool:
https://susdesign.com/overhang/index.php
Window Overhang Annual Analysis Tool:
https://susdesign.com/overhang_annual/index.php
Daylight Penetration Calculation and Visualization Tool:
https://susdesign.com/light_penetration/index.php
Window Exterior Louver Shading Calculator:
https://susdesign.com/louver_shading/index.php
Window Esterior Vertical Fin Shading Calculator (East/West exposures):
https://susdesign.com/vertical_fins/index.php
Window Heat Gain Calculator:
https://susdesign.com/windowheatgain/index.php
Velux SunTunnel Skylight Daylight Estimate Tool:
https://www.veluxusa.com/professional/tools/daylight-estimator
Velux Daylight Visualizer:
https://www.velux.com/article/2016/daylight-visualizer
University of Bath, Room Interactive Learning - Daylight Factor:
https://people.bath.ac.uk/zw305/ROOM/daylightfactortab.php
Efficient Windows Collaborative, Windows for High Performance Buildings:
https://www.commercialwindows.org/
Minnesota B3, Daylight Factor Calculation Tool:
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwiguYaw_6HnAhXJZc0KHThwBeEQFjAAegQIARAC&url=https%3A%2F%2Fwww.b3mn.org%2Fguidelines2-2%2Fdownloads_v2_2%2F5IEQ_App-I-9_V2-2.xls&usg=AOvVaw0sqXw0M7yB7vzhC-7Bwiue
Bulbs.com, Light Bulb Energy Savings Calculator:
https://www.bulbs.com/learning/energycalc.aspx
ENERGY STAR Certified Lighting Products Database:
https://www.energystar.gov/products/lighting_fans
National Institute of Building Sciences, Whole Building Design Guide - Electric Lighting Controls:
https://www.wbdg.org/resources/electric-lighting-controls
New Building Institute, Daylighting Pattern Guide:
https://newbuildings.org/resource/daylighting-pattern-guide/

Section 08

Equipment, Appliances, and Plug Loads

Plug loads are energy used by equipment, appliances, and products that are powered by means of an ordinary electrical outlet. Plug loads are not related to the building's HVAC, water heating, or general lighting. According to "Office Plug Load Field Monitoring Report" by Ecos Consulting:

> "Computers and monitors accounted for 66% of all [plug load] devices; office electronics (printers, faxes, multifunction devices and computer speakers) accounted for 17% of all devices; miscellaneous devices (portable lighting, telephones, and coffee makers) accounted for the remaining 17% of all plug load devices."

Until recently, it was uncommon to plan and strategize for control of plug loads in a building. They were not considered important, and no one had the responsibility to track or manage them. But, that is changing. As buildings become more energy efficient, the significant impact of plug loads becomes more apparent. In high efficiency buildings, plug loads may account for more than 50% of the total energy consumption

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Equipment, Appliances, and Plug Loads

EQUIPMENT, APPLIANCE, AND PLUG LOAD MANAGEMENT STRATEGIES

P1 Purchase ENERGY STAR products

These products are the most energy efficient in their class. ENERGY STAR creates a minimum standard and qualified products are the most efficient in their class. Many products are certified by ENERGY STAR, meaning that they meet a minimum energy efficiency standard. Alternatively, the Energy Guide labels can be used to select products that are near the lower end of the energy scale (less kWh). The list of ENERGY STAR-certified products is a good starting point for finding efficient plug load equipment. For computer and related hardware, the ENERGY STAR settings must be enabled. See http://www.energystar.gov/products/certified-products

P2 Purchase products with auto off

Equipment should automatically turn off to a near zero state after a period of nonuse. This is similar to computers with ENERGY STAR options enabled, where the computer will turn off after a period of nonuse. Charging stations should be specified to have minimum parasitic loads after charging is completed. Some small appliances, such as coffee makers, can be purchased to automatically turn off after a specified amount of time.

ENERGY STAR Product Facts

In 2017, ENERGY STAR certified products helped consumers save 170 billion kilowatt-hours of electricity, avoid $18 billion in energy costs, and achieve 130 million metric tons of greenhouse gas reductions.

Americans purchased more than 300 million ENERGY STAR certified products and more than 300 million ENERGY STAR certified light bulbs in 2017, for cumulative totals exceeding 6 billion products and more than 4 billion light bulbs, respectively.

The estimated annual market value of ENERGY STAR product sales is more than $100 billion.

EPA sets definitions of efficiency leadership for more than 75 residential and commercial product categories. Currently more than 60,000 product models have earned the ENERGY STAR based on these rigorous criteria.

More than 2,800 product models from more than 170 manufacturers were recognized as "ENERGY STAR Most Efficient" in 2018.

By choosing ENERGY STAR, a typical household can save about $575 on their energy bills and still enjoy the quality and performance they expect.

About three-fourths of U.S. households report the ENERGY STAR label as influential in their purchasing decisions.

80% of purchasers would recommend ENERGY STAR products to a friend.

- U.S. EPA ENERGY STAR

Equipment, Appliances, and Plug Loads

P3 Incorporate Power Strip Plug Load Management Strategies

One or more of the following strategies can help reduce plug loads at work stations and equipment locations in businesses and residents:

P3-a Use Motion Activated Switch or Power Strip

Motion Activated Switch or Power Strip. The key to reducing plug loads is to turn products off when they are not being used. One strategy is to use an activity monitor power strip (a type of advanced power trip) or a motion controlled wall switch that turns outlets off. When no activity is detected, the circuits are de-energized. These should be used only if automatic on is critical for success, such as in a retail display area. These require a small parasitic load to remain activated, which means that a small amount of power is required for each controller to operate.

P3-b Use remote switch power strips

These require a user to push a switch to activate the load and are appropriate for office environments. They can be either wall-mounted switches with controlled outlets or power strips. Timer power strips and vacancy timers will turn off after a set time without motion. You should specify units that have zero parasitic loads when off.

P3-c Use master-controlled power strips

This type of plug strip has a master outlet where an appliance is plugged in. The plug strip senses the current in this outlet, and when there is no current, the rest of the plug strip turns off. An example would be an office where the computer is the master and the other office plug loads, including lamps and printers, are the slaves. This APS strategy used a foot-pedal switch with an internal timer connected to the APS. The foot-pedal allows for convenient manual off/on operation.

P3-d Advanced power strip with occupancy sensor (APS-o)

This advanced power strip (APS) strategy uses an occupancy sensor attached to an otherwise standard power strip. The strategy uses an Advanced Power Strip (APS) connected to an occupancy sensor in lieu of a standard power strip at each workstation. The occupancy sensor should have a cord long enough so that the APS can be placed on the floor while the occupancy sensor is mounted in an effective location such as under the front edge of a desk or to the underside of a monitor. The occupancy sensor should also allow for a variable time-to-off setting, with a recommended setting of 10 minutes. This strategy can include both controlled and non-controlled outlets; with all devices plugged into controlled outlets except for desktop computers and laptop docking stations. This strategy should be combined with the Computer Power Management strategy below.

P3-e Advanced power strip with timer and foot-pedal (APS-p)

The APS uses the same controlled/uncontrolled outlet configuration as the previous strategy. For participants willing to actively manage their energy use, the foot pedal can easily be pressed to turn off power to all controlled devices whenever they leave their workstation; even for a short break. For those less willing to actively manage their energy use, the foot pedal could simply be pressed once when occupant arrives at the workstation for the day. The internal timer can then limit the power strip to 4, 8, or 10 hours of power. This strategy should be combined with the Computer Power Management strategy below.

Equipment, Appliances, and Plug Loads

> **A low– to no–cost approach can be the first energy savings action to reduce office plug loads by 19-40 percent, even at buildings already employing green and energy efficient strategies…the absolute savings would be significantly more at office buildings with less efficient equipment or higher densities.**
>
> \- Ecos PIER Plug Load Savings Assessment, December 2011

P4 Computer Power Management (CPM)

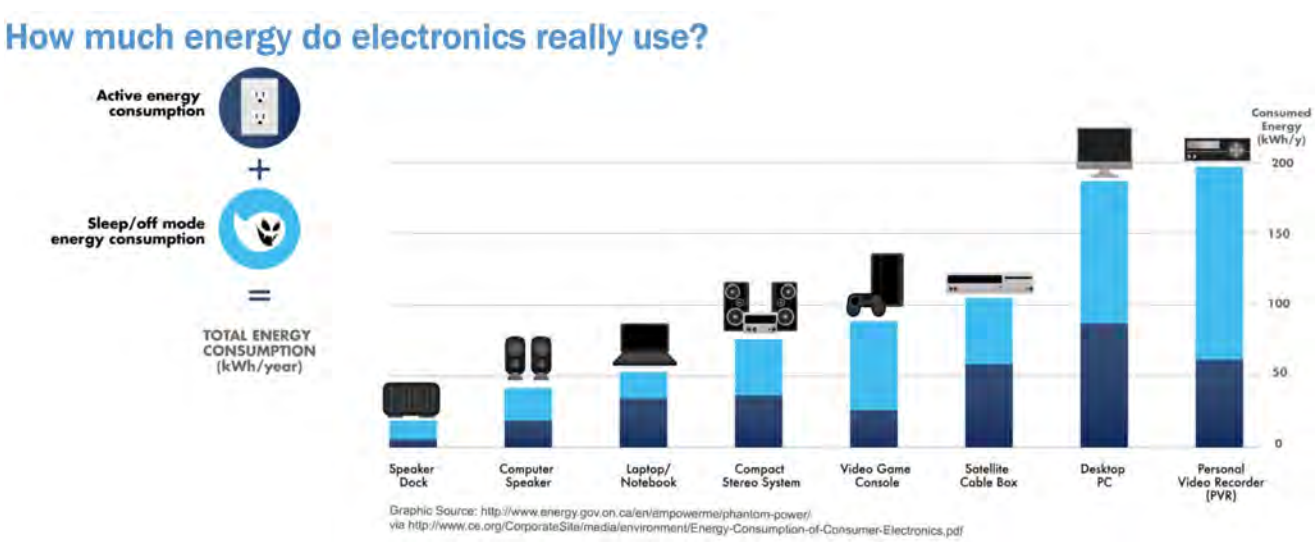
CPM settings control energy used by monitors and computers, by activating sleep and hibernation functions when the computer is not actively in use. Recommended CPM measures include setting computer default power settings to turn off monitors after 15 minutes of inactivity, enable sleep mode in all computer types after 30 minutes, and stop hard disks after 5 minutes. Operators will need to work closely with their IT departments or consultants. Office operators may also contact ENERGY STAR for no-cost support.

P5 Use Laptops In Lieu of Desktop Computers

Where computer functionality can be supported through laptop computers, switching from desktop to laptop computers can save up to 70% per machine. (Source: https://www.nrdc.org/sites/default/files/slashing-energy-use-computers-monitors-ib.pdf)

P6 Timers for common area equipment

The potential strategies for reducing energy usage of devices in common areas differ from those in workstations for several reasons. Because there are a large number of people that share use of these devices each day, options such as occupancy sensors are often not a feasible strategy for equipment located in areas of the office where a sensor would be triggered nearly continually whether the devices are being used or not. This strategy employs a simple timer power strip that can be set to disable all power to the common area equipment at times when the building or space is largely unoccupied.



Equipment, Appliances, and Plug Loads

P7 Energy Efficient Coffee Service

Replacing standard traditional drip coffee maker where the pot is kept warm on a burner can increase energy efficiency. Alternatives include using a larger thermal carafe well-enough insulated to not need to be kept warm on a burner or the use of a single cup coffeemaker, providing on-demand coffee when needed, without the need for a warming burner.

P8 Optimize Printer Locations

By eliminating unnecessary printers, buildings can reduce not only energy use but also equipment purchase and maintenance costs. The National Renewable Energy Lab (NREL) recommends that most offices can function well with just one printer for every 60 employees.

P9 Timers for Common Use Rooms

Rooms such as break rooms and work rooms often have multiple pieces of equipment which are left "on" indefinitely, causing significant unnecessary electric use. By placing equipment on timers in these rooms, buildings can reduce the plug load of these spaces by up to 40%-50% (source: Plug-Load Control and Behavioral Change Research in GSA Office Buildings. NREL/TP-7A40-55780. National Renewable Energy Laboratory)

P10 Eliminate Unnecessary Equipment

Building owners and designers should engage end users in a discussion to determine whether there are pieces of equipment that are not fundamental to the core function of the office building and business. For example, large flat-screen TV arrays in lobby areas can be eliminated or at minimum placed on timers, and mechanically cooled drinking water can be replaced with filtered tap water.

P11 Efficient Conference Room Equipment

To ensure that equipment in conference rooms is not drawing power when the rooms are vacant, controls should be installed to turn off the equipment when the space is unoccupied or when the equipment is not needed for a meeting. Occupancy sensors are an option for controlling the rooms during operating hours and for tying the room equipment to an overall building controls system to allow it to be shut off outside of operating hours.

> **Miscellaneous electric loads are likely to be the biggest impediment to achieving high efficiency / net zero energy buildings.**
>
> - American Council for an Energy Efficiency Economy (ACEEE)

Equipment, Appliances, and Plug Loads

P12 Energy Efficient Refrigerators

Use larger, solid-door refrigerators in lieu of multiple mini fridges. All refrigerators should be ENERGY STAR certified and operated at their suggested temperature settings, not at the highest cooling settings, in order to reduce energy use. Ice trays, rather than automatic ice makers, will also save energy.

P13 Induction Cooktop

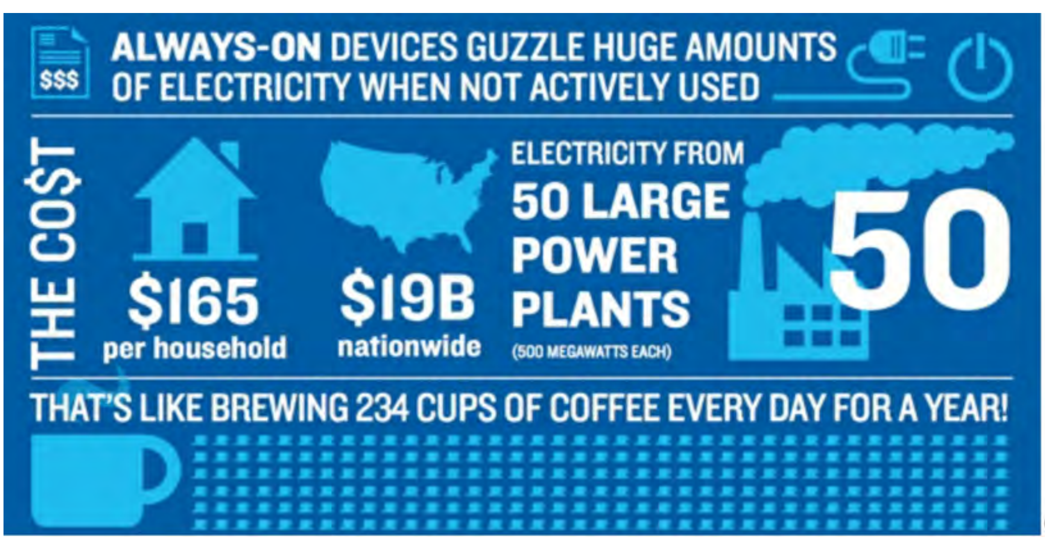
Use all electric induction cooktops. All cooktops should be ENERGY STAR certified and operated at their suggested settings. Research by the U.S. Department of Energy indicates an induction cooker is 84% efficient at energy transfer, versus 74% for a smooth-top electric unit, giving it a heating performance comparable to a gas element. More significantly, induction is 90% efficient with its power use, using 2.8 kW to deliver 2.52 kW. This is a substantial improvement over electric coils, which use 2.0 kW to deliver 1.1 kW (a 55% efficiency), and over gas, which uses 3.5 kW to generate 1.75 kW (a 50% efficiency). (Source: http://www.bestinductioncooktopguide.com).

P14 Eliminate Vending Machines

When possible, eliminate use of vending machines. If vending machines are a functional necessity, they should be ENERGY STAR Certified and equipped with occupancy sensor control for lighting and for cooling operations.

P15 Electrification of Appliances and Equipment

Electricity is the quickest and most realistic path to CO2 emission free energy. Perhaps the biggest challenge for Net Zero Energy buildings is addressing the energy consumption of appliances and equipment which use natural gas or other fuels beyond electricity. Stovetops, ovens, water heaters, and many other common appliances in homes and businesses are now readily available in energy efficient electric models. Electric, ENERGY STAR certified appliance options can be found on the ENERGY STAR database, select "electric" to see all electric options: https://www.energystar.gov/products



Graphic Source: Techlicious.com

Equipment, Appliances, and Plug Loads

Resources and Information:

US Department of Energy, Estimating Appliance and Home Electronic Energy Use:
https://www.energy.gov/energysaver/save-electricity-and-fuel/appliances-and-electronics/estimating-appliance-and-home

ENERGY STAR Certified Appliance Database:
https://www.energystar.gov/products

New Buildings Institute, Plug Load Best Practices Guide:
https://newbuildings.org/resource/plug-load-best-practices-guide/

Better Buildings Institute, Plug and Process Loads:
https://betterbuildingssolutioncenter.energy.gov/alliance/technology-solution/plug-process-loads

NREL, A Tool for Reducing Plug Loads in Commercial Buildings:
https://www.nrel.gov/docs/fy15osti/63736.pdf

NREL, Selecting a Control Strategy for Plug and Process Loads:
https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/selecting_control_strategy_plug_process_loads_0.pdf

NREL, How To Use Advanced Power Strips in an Office Setting:
https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/how_to_use_advanced_power_strips.pdf

Oregon Department of Administrative Services & Department of Energy, Plug Load Strategy:
https://www.oregon.gov/energy/Get-Involved/Documents/2018-BEEWG-Plug-Load-Strategy.pdf

North Carolina, Plug Load Calculator:
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwi6p5L5kaLnAhWDKs0KHSUDAJcQFjAAegQIAxAC&url=https%3A%2F%2Ffiles.nc.gov%2Fncdeq%2FEnvironmental%2520Assistance%2520and%2520Customer%2520Service%2FUtility%2520Savings%2520Initiative%2FPlug%2520Load%2520Calculator.xlsx&usg=AOvVaw1gybkjihnu01RDgKC4d-ZO

ENERGY STAR Top 10 Computer Power Management Myths...and Realities:
https://www.energystar.gov/products/low_carbon_it_campaign/put_your_computers_sleep/myths_realities

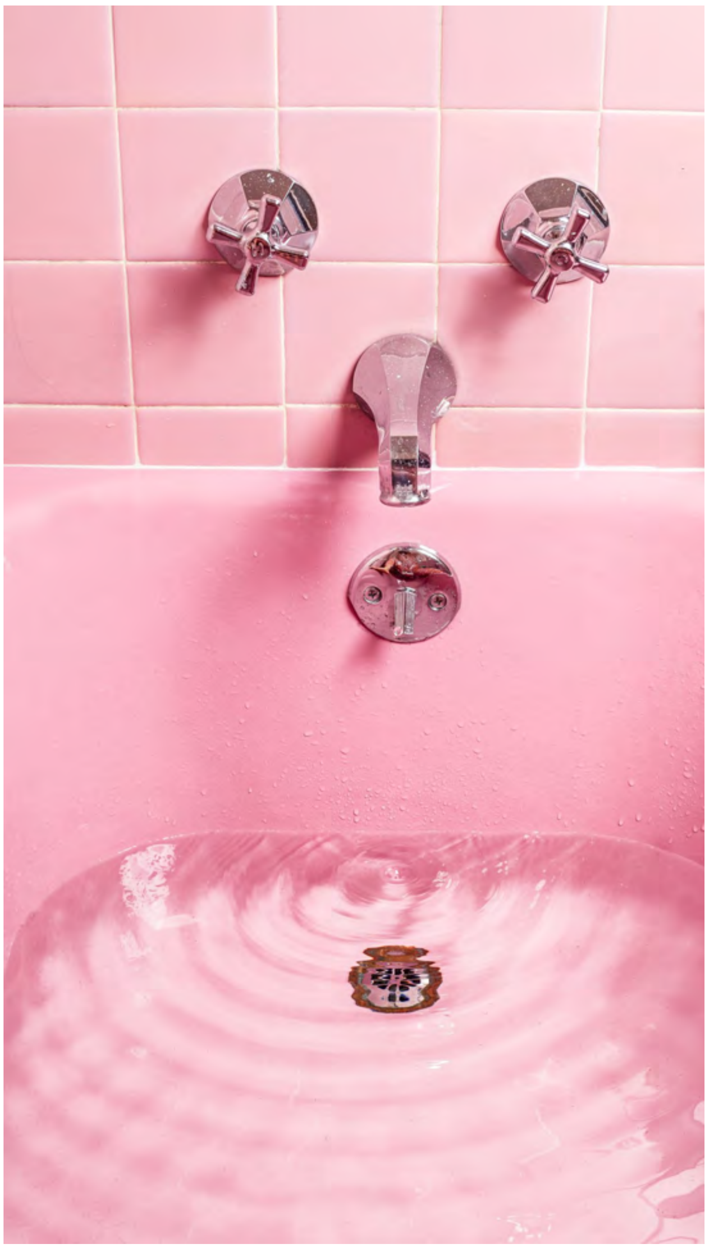
BC Hydro, Energy saving campaign toolkits for business:
https://www.bchydro.com/powersmart/business/programs/workplace-conservation/campaign-kits.html

US Department of Energy, Purchasing Energy-Efficient Computers:
https://www.energy.gov/eere/femp/purchasing-energy-efficient-computers


I'M NOT BOSSY

Section 09

Water Conservation



Although building water use does not significantly effect on-site energy use for most building types, water conservation strategies are still an important consideration. Water conservation is important because fresh clean water is a limited resource, as well as an operational expense for all buildings.

At the community level, the delivery of clean water is a significant consumer of energy, so water conservation translates into community level energy conservation. Conserving water provides an operational cost benefit as well as a community-wide environmental benefit.

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Water Conservation

EQUIPMENT, APPLIANCE, AND PLUG LOAD MANAGEMENT STRATEGIES

W1 Reduce Demand In Plumbing Fixtures

Use high efficiency, low-flow plumbing fixtures which are EPA WaterSense labeled. Select the most efficient equipment available, consider non-water-using fixtures such as composting toilets and non-water urinals, ensure that proper operation and maintenance practices are established.

W2 Aerator Use

Use lavatory faucet aerators at all faucet locations.

W3 Low-Flow Sensors

Use low-flow electronic sensor faucets in all sink locations.

W4 Reduce Demand In Kitchens

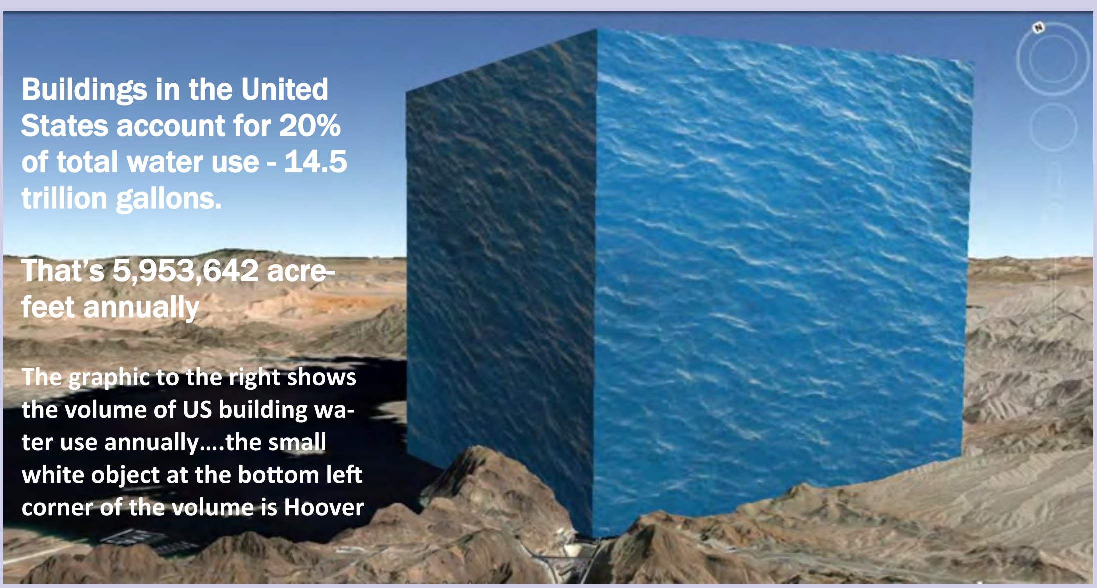
Use high efficiency kitchen fixtures which are EPA WaterSense labeled. Specify the most-efficient equipment available, and use dishwashers that recycle water.

W5 Reduce Demand In Cooling and Heating Systems

When applicable, reduce or eliminate water used for cooling and heating by using passive systems that use the power of the sun and natural convection cycles. Select mechanical systems equipment with high water efficiency levels.

W6 Efficient Water Heaters

Select high efficiency, ENERGY STAR Certified water heaters, sized for optimal service for the building's hot water demand.



Water Conservation

W7 Water Efficient Landscaping
Incorporate water efficiency principles with native plantings that require no supplemental irrigation into the landscape design.

W8 Harvest Rainwater
Precipitation that is collected from a roof and stored for use can be used for exterior irrigation with minimal treatment.

W9 Harvest Stormwater
Precipitation that is collected from hardscape on the building's grounds and stored for use. Additional treatment is likely needed compared to rooftop rainwater because stormwater picks up contaminants from the hardscape, however, stormwater can be an important water resource for an energy efficient building site.

Equipment, Appliances, and Plug Loads

Tips for Existing Home Owners

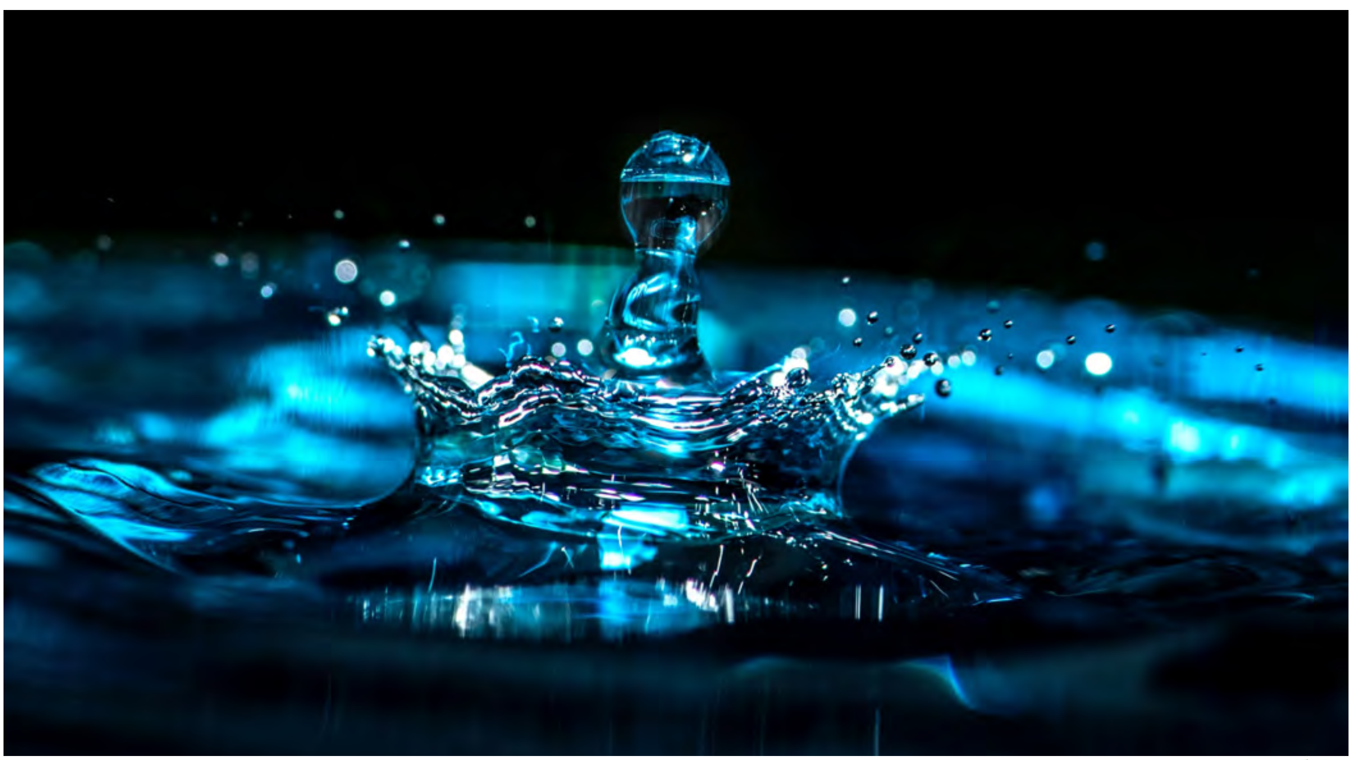
In addition to the equipment recommendations outlined in this section, home owners can advance water efficiency by implementing changes in how they use water as well:

1) Turn off the taps - Don't let your water consumption run out of control. Save 1.5 gallons of water a minute by turning off your tap while you brush your teeth.
2) Dishwashers and clothes washers - Try to use these appliances only with full loads. Even short-cycle options are generally less water-efficient than running full loads.

If you must water outside - water your garden at night or as early in the morning as possible. This will prevent the water from evaporating as quickly and result in the need for less watering in general.

Resources and Information:

Eartheasy, 45+ Ways to Conserve Water in the Home and Yard:
https://learn.eartheasy.com/guides/45-ways-to-conserve-water-in-the-home-and-yard/
National Institute of Building Sciences, Whole Building Design Guide, Water:
https://www.wbdg.org/design-objectives/sustainable/protect-conserve-water
US Department of Energy, Water-Efficient Technology Opportunities:
https://www.energy.gov/eere/femp/water-efficient-technology-opportunities
US Department of Energy, Rainwater Harvesting Tool:
https://www.energy.gov/eere/femp/downloads/rainwater-harvesting-tool
AquaScape, Rainwater Harvesting Calculator:
https://www.aquascapeinc.com/rainwater-harvesting-calculator



Section 10

HVAC Systems

"HVAC" is an acronym for "heating, ventilation, and air conditioning." HVAC systems are used to provide heating and cooling services to buildings. HVAC systems are responsible for the largest share of energy use in residential and commercial buildings. Creating the most efficient possible HVAC system is an important core consideration in the implementation of net-zero energy buildings.

Specific heating, ventilation, and air conditioning systems appropriate for each building will vary significantly based on the building size, functions, and owner operating and maintenance capacities. High-performance commercial buildings and homes require finely-tuned HVAC design strategies that go well beyond code-level buildings and homes. Designers and HVAC contractors who work with high-performance, Net Zero Energy buildings can't use the same strategies that work for mainstream buildings and must be prepared for an iterative design process that carefully models energy performance levels of multiple system models in order to select a system that is truly optimized for the specific building requirements.

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HVAC Systems

HVAC SYSTEMS STRATEGIES

H1 "Right Size" HVAC systems to ensure efficient operation

Safety factors for HVAC systems allow for uncertainties in the final design, construction and use of the building, but should be used reasonably. Greatly oversized equipment operates less efficiently and costs more than properly sized equipment. For example, oversized cooling systems may not dehumidify the air properly, resulting in cool but "clammy" spaces. It is unreasonable and expensive to assume a simultaneous worst-case scenario for all load components (occupancy, lighting, shading devices, weather) and then to apply the highest safety factors for sizing. Strategies for "right sizing" include:

Accept the HVAC safety factors and pick-up load allowance stated in ANSI/ASHRAE/IES 90.1 as minimum acceptable performance, not target performance levels.

Apply safety factors to a reasonable baseline. It is unreasonable to assume that on the hottest clear day if no shades are drawn and all lights are on that each room is occupied by the maximum number of people allowed by fire codes (thus, far in excess of the maximum number of people that can be expected in the building), and then apply safety factors. Safety factors should be applied to a baseline that was created using reasonable assumptions.

Take advantage of the new generation of dependable computerized analysis tools, such as DOE 2.1E, to reduce uncertainty and eliminate excess oversizing. Hour-by-hour computer simulations can anticipate how building design and operation affect peak loads. Issues such as diversity, pick-up requirements, and self-shading due to building geometry can be quantified. As uncertainties are reduced, oversizing factors can also be reduced or at least can be applied to a more realistic baseline.

H2 Expansion Efficiency

A change in building use or the incorporation of new technologies can lead to an increased demand for cooling. But, it is wasteful to provide excess capacity now—the capacity may never be used or the equipment could be obsolete by the time it is needed. It is better to plan equipment and space so that future expansion is possible. For example, adequately size mechanical rooms and consider the use of modular equipment.

System designs should avoid having more capacity than currently required. This concept extends to accommodating for planned expansion. Don't provide excess capacity today for a future load that may never exist, instead:

- Provide the physical space required for additional equipment: boilers, chillers, pumps, cooling towers.

Design distribution systems that can easily accept additional equipment, and can be expanded to provide for the requirements of the future expansion.

HVAC Systems

H3 Optimize For Part-Load Performance

Part-load performance of equipment is a critical consideration for HVAC sizing. Most heating and cooling equipment only operate at their rated, peak efficiency when fully loaded (that is, working near their maximum output). However, HVAC systems are sized to meet design heating and cooling conditions that historically occur only 1% to 2.5% of the time. Thus, HVAC systems are intentionally oversized at least 97.5% to 99% of the time. In addition, most equipment is further oversized to handle pick-up loads and to provide a factor of safety. Therefore, systems almost never operate at full load. In fact, most systems operate at 50% or less of their capacity. Example systems that can operate efficiently at part-load include:

- Variable volume fan systems and variable speed drive controls for fan motors;
- Variable capacity boiler plants (e.g., step-fired (hi/lo) boilers, modular boiler plants, modulating flame boilers);
- Condensing boilers operate more efficiently (95%–96%) as the part-load decreases to the minimum turn-down ratio;
- Variable capacity cooling plants (e.g., modular chiller plants, multiple compressor equipment, and variable speed chillers);
- Variable capacity cooling towers (e.g., multiple cell towers with variable speed or two speed fans, reset controls);
- Variable capacity pump systems (e.g., primary/secondary pump loops, variable speed pump motors); and,
- Temperature reset controls for hot water, chilled water, and supply air.

HVAC Systems

H4 Load Shifting and Shaving

Many electric utilities offer lower rates during off-peak periods that typically occur at night. Whenever possible, design systems to take advantage of this situation. For example, energy management systems can shed non-critical loads at peak periods to prevent short duration electrical demands from affecting energy bills for the entire year. Or, off-peak thermal ice storage systems can be designed to run chillers at night to make ice that can be used for cooling the building during the next afternoon when rates are higher. Strategies for shifting and shaving loads include:

- Investigate the utility company's rate structure; negotiate for a favorable rate structure.
- Take advantage of the on-peak and off-peak rate differences.
- Use energy management controls systems to avoid unnecessary peak demand charges (peak shaving and demand limiting).
- Explore thermal storage systems (e.g., thermal ice storage).
- Examine alternate fuel sources for heating and cooling systems (e.g., district steam vs. natural gas vs. fuel oil; steam or natural gas chillers; dual fuel boilers).
- Add energy storage (batteries).

H5 Commission the HVAC systems

Commercial HVAC systems do not always work as expected. Problems can be caused by the design of the HVAC system or because equipment and controls are improperly connected or installed. A part of commissioning involves testing the HVAC systems under all aspects of operation, revealing and correcting problems, and ensuring that everything works as intended. A comprehensive commissioning program will also ensure that O&M personnel are properly trained in the functioning of all systems.

H6 Energy Efficient Ductwork

In high-performance commercial buildings and homes, all ductwork should be located inside the conditioned space. Any time ductwork is situated outside of conditioned space, there is excess energy use and the risk of condensation in or around the ductwork increases. All ducts should be fully sealed to eliminate leakage and improve the performance of the distribution system. Supply air ducts should be fully insulated.

H7 Use High Efficiency Fans

As heating and cooling solutions are being created in net-zero-energy buildings, one of the solutions is high-volume, low-speed cooling fans also known as HVLS fans. The fans create a light breeze in the building, no harder than three mph, which produces a cooling effect. Ultimately, this effect reduces the area temperature from seven to 11 degrees Fahrenheit. Utilizing these types of fans can allow major savings on energy cost in buildings that are high performance.

HVAC Systems

H8 Use ENERGY STAR Equipment

Use ENERGY STAR Certified equipment, whenever possible, for all components of the selected HVAC system. Select the highest efficiency rating available for equipment functionality desried. ENERGY STAR Certified equipment can be found here: https://www.energystar.gov/products/heating_cooling

H9 Optimize HVAC System Selection

Select inherently efficient system types. Using refrigerant or water instead of air to transport heating and cooling energy, as in a Variable Capacity Heat Pump system, is inherently a more efficient distribution strategy. System design and modeling should explore efficiency of decoupling heating and cooling from ventilation. HVAC design process should be integrated with the design of the whole building, with an iterative approach exploring multiple options such as those reviewed in this section. System options should be modeled for energy performance to identify greatest efficiency options. Use Lifecycle Cost Analysis (LCCA) to evaluate system repair and replacement costs when evaluating costs and benefits at the system type level.

HVAC SYSTEM RETROFIT STRATEGIES (commercial)

HR1 Implement a Retro-Commissioning package

This is done to optimize systems to meet new operational needs through testing and adjusting. Retro-commissioning is used in older buildings that have never been through the commissioning process. Retro-commissioning should be considered if building systems are old, expensive to operate, and have frequent equipment failures.

HR2 Revise air filtration system

Many large built-up air handling systems include both pre-filters and final filters for cleaning the air before it is supplied to the zones. The pre-filters are installed to extend the life of the final filters, yet typically they do not achieve this since it's easy for dust to pass through and around the pre-filters. In addition, the pre-filters impose significant additional pressure drop, resulting in higher fan energy use and maintenance costs. Extended surface area filters are now available that can replace both the pre-filter and final filter. These extended surface filters have a long life (high dust holding capacity) and low pressure drop characteristics. Both maintenance (labor) and energy savings can be achieved by using these types of filters.

HVAC Systems

HR3 Calibrate Air-Sensors

HVAC systems rely on input from sensors to determine how to operate. However, these sensors can drift out of calibration over time. Sensors found in typical HVAC systems can include, but aren't limited to, temperature, pressure, and flow sensors. If these sensors are not calibrated - i.e., if the value being reported by the sensor does not match the actual condition – this could negatively impact equipment performance and occupant comfort, and could result in energy waste due to simultaneous heating and cooling. Calibrated sensors are necessary for automatic control sequences to operate properly, and for accurate diagnoses of system performance.

This measure requires developing and implementing a sensor calibration plan. In general, sensor calibration consists of comparing reported sensor readings (e.g., at the building automation system) with readings from a calibrated device, and taking corrective action where there's a significant difference between the two readings. Corrective action might include simple offsets or multipoint calibrations to align the readings. If the sensor is significantly out of calibration, replacement may be necessary. For example, if the supply air temperature setpoint is reset based on outside air temperature, it's important to ensure that the outside air temperature sensor is calibrated and located in a representative location.

HR4 Supply Air Temperature Setpoint

For multi-zone air systems, whether CAV or VAV, automatically changing the supply air temperature setpoint to better match the needs of the zones can result in lower reheat energy use due to reduced amount of zone reheat (simultaneous heating and cooling). The supply air temperature setpoint is typically reset based on either outside air temperature or an indication of zone demand - e.g., average difference between zone temperature and zone temperature setpoint.

Care should be taken when implementing this measure to verify that internal zones receive enough cooling at higher supply air temperatures. While significant reheat energy can be saved by implementing this measure, there is usually a slight increase in fan energy usage due to internal zones requesting more airflow at the higher supply air temperatures to maintain space conditions. This fan energy penalty should be weighed against the reheat energy savings.

HR5 Reduce Economizer Damper Leakage

An airside economizer cycle utilizes outside air for cooling a facility when the outside conditions are cooler than inside conditions. Economizer cycles reduce the amount of mechanical cooling energy necessary for cooling a facility. During integrated airside economizer cycle operation, when the outside temperature is cooler than the indoor temperature yet warmer than the supply air temperature necessary for cooling the space, the outside air dampers are fully open and the return air dampers are fully closed.

If the return dampers are leaky, meaning if they don't have blade and jamb seals and/or they are not adjusted to close fully when commanded to do so, the effectiveness of the economizer cycle is reduced and more mechanical cooling is required than would be necessary if the dampers leaked less.

HVAC Systems

Some HVAC systems include a morning warm-up/cool-down cycle. During this cycle, the space is cooled or heated to address the heat gained or lost during the night (unoccupied period). Typically this cycle occurs prior to the start of the occupied period, and the minimum outside air dampers remain closed during this period. If these dampers are leaky, more outside air would be drawn in than is necessary, adding an unnecessary load on the HVAC system.

Minimizing the air leakage through closed outside and return air dampers can reduce HVAC system energy use during integrated economizer operation and morning warm-up/cool-down cycles.

HR6 Calibrate Water Sensors

HVAC systems rely on input from sensors to determine how to operate. However, these sensors often drift out of calibration over time. Typical waterside sensors can include temperature, pressure, and flow sensors, to name a few. If these sensors are not calibrated – i.e., if the value being reported by the sensor does not match the actual condition – this could negatively impact equipment performance and occupant comfort, and could result in energy waste due to simultaneous heating and cooling.

This measure consists of developing and implementing a sensor calibration plan. In general, sensor calibration consists of comparing reported sensor readings (e.g., at the building automation system) with readings from a calibrated device, and taking corrective action where there's a significant difference between the two readings. For example, if chillers are staged based on measured chilled water flow, then it's especially important to regularly calibrate the chilled water flow sensor to maintain performance, equipment reliability, and energy efficient operations.

HR7 Optimize Cooling Plant Runtime

Facilities often run their cooling plants continuously during occupied periods of the cooling season. This includes the chiller, cooling tower, and related pumps. However, there may be periods during the cooling season when the plant does not need to run, especially when airside economizer cooling is used at the air handlers. If there is a space that requires continuous cooling, even after hours, it may be more efficient to install a small cooling system to serve this space, and turn off the larger plant. Automatic controls can be added to turn off the entire cooling plant when cooling is not needed in the facility during occupied hours. Two common automatic methods include:

> Outside air temperature or enthalpy-based lockout. These controls would turn off the cooling plant when the temperature or enthalpy drops below a certain value.

Enable plant based on the cooling demand. These controls would turn off the cooling plant when there is no cooling demand (e.g., all air handler cooling coil valves are closed). Adequate time lags and proper trigger points need to be programmed with this strategy to prevent the plant from cycling on and off excessively.

HR7 Optimize Cooling Plant Runtime (continued)

Before this measure is implemented, the retro-commissioning team should ensure that the cooling plant is not operating after hours. Turning the cooling plant off during unoccupied hours is typically easier to implement than cooling plant shutdown during occupied hours, due to greater building operator buy-in.

For facilities with multiple chillers, the chiller staging strategy can have a large impact on the energy consumption of the plant. It's often beneficial to shut off chillers at low load, to reduce pumping energy consumption and increase chiller efficiency. Each facility is different, and will have its own optimal chiller staging strategy. BAS software overlays are available that will continually optimize the performance of a chilled water plant.

In addition to energy savings, this measure should result in increased equipment life due to less run hours for the cooling plant. This measure may not apply to smaller buildings, which typically do not have a cooling plant.

HR8 Optimize HVAC Runtime

The maximum energy savings related to an HVAC system can be achieved by shutting the system off when not in use to minimize run time. This measure reduces the scheduled operating hours of the HVAC system, including fans, pumps, chillers and boilers, to more closely match the occupancy of the building.

In addition, many HVAC fan systems operate with the outside air damper open whenever the fans are operating, even during morning warm-up and cool-down periods, prior to the occupied period. Since ventilation is only required during occupied hours, the outside air dampers can be closed during non-economizer operation in unoccupied hours. This feature eliminates the energy associated with cooling and heating outside air when ventilation is not required.

HR9 Shut Down Heating Plant When Load is Absent

Facilities often run their heating plants throughout the year, even on warm days. This is often done to satisfy year-round reheat loads that are inherent in multi-zone VAV systems commonly used in large office building. Summertime reheat loads can occur in zones that require ventilation yet have relatively low cooling requirements. Reheat is provided to prevent overcooling these zones, which are typically interior zones. In humid climates, reheat may also be required at the air handler level to reheat the air after dehumidification.

If the reheat load can be reduced, then there is less need for heating plant operation and energy can be saved. If the reheat load can be eliminated altogether, greater savings can be achieved by shutting off the entire heating plant (boilers and pumps) to reduce standby and distribution losses, and to reduce auxiliary equipment operation.

HVAC Systems

HR10 Lower VAV Setpoints

For HVAC systems with variable air volume (VAV) systems, reducing the zone supply airflow during periods of low cooling and heating load will result in measurable energy savings at the central equipment (e.g., boilers, chillers, air handlers). Specific zone control energy conservation modifications will vary by HVAC system type and the specific needs and capabilities of each facility. It's important to integrate the controls of both the central equipment and the distribution system for maximum energy efficiency and occupant comfort.

HR11 Widen Zone Temperature Deadband

Deadband is the difference between the zone heating and cooling temperature setpoints. Widening the zone temperature deadband of the HVAC distribution system (e.g., piping, ductwork, terminal units) will result in measurable energy savings at the HVAC central equipment (e.g., boilers, chillers, air handlers). Putting the HVAC system in standby mode for zones that are unoccupied will also result in energy savings. Specific zone control energy conservation modifications will vary by HVAC system type and the specific needs and capabilities of each facility. In general, for centralized HVAC systems, it's important to integrate the controls of both the central equipment and the distribution system for maximum energy efficiency and occupant comfort.

HR12 Upgrade Fan Motor and Variable Frequency Drive

This measure involves replacing a facility's supply fan motors and VFDs with premium efficiency motors and VFDs with current technology. Standard motor efficiencies have steadily increased over the last few decades due to improvements in motor design and manufacturing, and VFD efficiencies have increased greatly over the past 10 years. Minimum motor efficiencies prescribed in building energy codes and federal regulations are frequently increased to keep pace with these improved efficiencies.

HR13 Install an Energy Management and Information System

Energy management and information systems are software tools that interface with a building to manage and control energy use. In addition to benchmarking and utility tracking (like Energy Star's Portfolio Manager), building automation systems (BAS) are a common form of EMIS. A BAS is a computer based tool that allows the facility manager to control everything from HVAC to lighting to security systems. The Department of Energy has extensive information on EMISs through the Better Buildings Program.

HR14 Optimize Economizer Damper Control

Airside economizers are used to increase the amount of outside air drawn into a building when outside conditions are cool and the system requires cooling. They reduce the amount of energy required for mechanical cooling.

For most commercial buildings, outdoor climate and indoor climate needs are the main factors in determining whether or not to use an airside economizer cycle, and which type of control to use. Ongoing maintenance costs can also be a factor in choosing which type of control to use.

HR14 Optimize Economizer Damper Control (continued)
For the La Crosse area's climate, many economizer control options exist, including single point dry bulb temperature (OA), differential dry bulb temperature (OA & RA), single point enthalpy (OA), and differential enthalpy (OA & RA). This measure consists of upgrading the economizer controls for more energy efficient operation and reduced maintenance costs.

While enthalpy-based economizer control may be more energy efficient than temperature-based control in some climates, especially humid climates, enthalpy sensors are often inaccurate due to the typical high level of error related to relative humidity sensors, even in new sensors. It is often more cost-effective to use temperature-based economizer control when sensor error and maintenance costs are factored in.

HVAC SYSTEMS Review

The following is a brief review of potential HVAC systems for consideration during the design process. Building owners, designers, and contractors should engage a licensed Professional Engineer PE) at the beginning of the schematic design effort. The PE should have experience and expertise in energy efficient and high performance HVAC systems.

Heating and Cooling

Variable Capacity Heat Pump
Variable speed compressors with multiple-capacity control VCHP systems achieve high efficiencies by varying the amount of refrigerant provided to each zone as loads fluctuate. This system is best suited to buildings in temperate climates and those with a wide variety of conditioning needs but it not well suited to those with 100% outside air applications. VCHP systems are particularly suitable for buildings with diverse loads, where some spaces might need heating while others need cooling. Buildings with high hot water loads, such as kitchens and housing, can integrate VCHP systems with hot water systems. Utilizing the heat rejected by the space cooling function for water heating results in higher combined energy savings. For buildings with low floor-to-floor heights, as in many existing buildings, the small refrigerant piping is convenient.

Ground Source Heat Pumps
Ground source heat pumps, also called geo-exchange systems, use the ground itself as a heat sink or a heat source to increase the thermal conversion efficiency of the refrigerant loop. A water/glycol mix flows through tubes, either drilled vertically down into the earth or laid down horizontally in loops and buried, to pull heat from the ground in winter or pump heat to the ground in summer. GSHPs are a relatively common strategy in ZNE new construction but are rarely used in existing buildings due to cost, access, and land use concerns. Consider whether the site characteristics and plans will allow for horizontal tubing: more space is required, but the installation cost can be significantly lower for horizontal tubing. When evaluating whether to install a GSHP sys-

Ground Source Heat Pumps (continued)

Closed-Loop Heat Pump:

Closed-loop geothermal heat pumps circulate an antifreeze solution through a closed loop -- usually made of plastic tubing -- that is buried in the ground or submerged in water. There are three common versions:

Horizontal - loops are installed horizontally in the ground, typically at a depth of 4 to 6 feet. This approach is often used for residential scale applications.

Vertical - loops are installed vertically in ground, commonly 20 feet apart and up to hundreds of feet deep. The vertical loops are then connected with horizontal pipes placed in trenches. This approach is often used for commercial scale applications

Pond/Lake - If the site has a water body meeting minimum volume, depth, and quality criteria it may act as the geothermal field.

Closed-Loop Heat Pump:

This type of system uses water from wells or surface bodies of water as the heat exchange fluid circulating directly through the heat pump system. After circulation, the water is returned to the well or body of water, to a recharge well, or discharged on the surface. This option requires all local codes and regulations regarding groundwater discharge are met.

Air Source Heat Pumps

An air-source heat pump can provide efficient heating and cooling for your home. When properly installed, an air-source heat pump can deliver one-and-a-half to three times more heat energy to a home than the electrical energy it consumes. This is possible because a heat pump moves heat rather than converting it from a fuel like combustion heating systems do.

Air-source heat pumps have been used for many years in nearly all parts of the United States, but until recently they have not been used in areas that experienced extended periods of subfreezing temperatures. However, in recent years, air-source heat pump technology has advanced so that it now offers a legitimate space heating alternative in colder regions. Common types of air source heat pumps are:

Ductless - distribution occurs through minimal through-wall opening, minimizing construction. Ductless systems are often installed in additions.

Ducted - air distribution occurs through ventilation ductwork reaching all conditioned spaces.

Short-run Ducted - often these installations have multiple units, each serving just a section of the building through short-run duct configurations.

Split Systems - Most heat pumps are split-systems, meaning they have a coil inside and a outside. Ductless and short-run ducted split systems are also known as “mini-split” systems. In ducted systems, supply and return ducts connect to the indoor central fan.

Packaged Systems - These systems have both coils and the fan outdoors. Conditioned air is delivered to the interior from ductwork that passes through a wall or roof.

Dual Fuel Heat Pumps

A dual-fuel system is a home comfort system that pairs an electric heat pump with a gas furnace and alternates between the two fuel sources to maximize comfort and efficiency. A dual-fuel heat pump works in conjunction with a furnace. During the summer months, the heat pump works like a high-efficiency central air conditioner. In mild spring and fall weather, it provides cost- effective and efficient heat. As the temperatures drop in the winter months, the pump shuts off and lets your furnace take over. Note - a dual fuel heat pump, though more energy efficient than many other systems will use fossil fuel combustion (either natural gas or fuel oil).

HVAC Systems

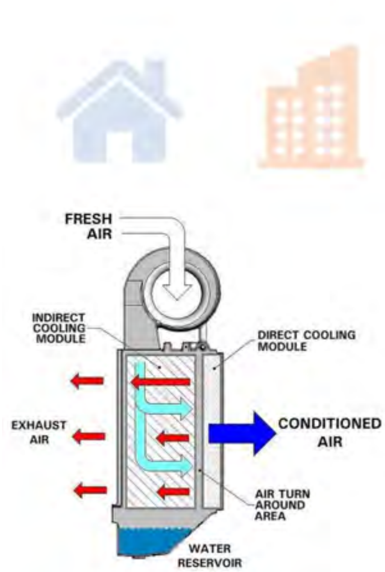
Radiant Heating and Cooling

Radiant heating and cooling limits fan energy to ventilation only and relies on the mean radiant temperature rather than just air temperature to meet conditioning needs. Radiant systems are particularly well-suited to spaces that require or experience higher levels of air changes, or those that rely on natural ventilation. But radiant systems are less appropriate for spaces with unpredictable schedules or load characteristics where responsiveness is required and/or desired. Radiant options include slabs, and wall panels, and chilled beams.

Ceiling and floor slabs work well in spaces with stable occupancy density and standard ventilation rates and not responsive to rapid temperature changes. When cooling, ceiling slabs are often more effective than floor slabs. Chilled beams work well in spaces that require high ventilation rates, high ceilings, and can be combined with radiant slabs to meet large sensible cooling loads.

Ceiling and radiant wall panels offer a faster thermal response than slabs, making them more effective in spaces with frequently changing thermal demands or for cooling-dominated applications and work well in a retrofit application.

Humidity can be a significant concern for radiant cooling applications. In applications that require humidity control, installation of a properly designed Dedicated Outside Air System (DOAS) system is critical to adequately control humidity.



Evaporative Cooling

Evaporative coolers work by adding water vapor to hot, dry air which, through the process of evaporation, removes sensible heat from the air and effectively lowers its temperature. Indirect evaporative cooling (IEC) systems are typically used in modern construction, rather than the direct-effect “swamp coolers” of yesteryear. In an IEC system, the supply air is passively cooled before it enters the space by passing over a medium that has been directly evaporatively cooled on an adjacent but isolated side.

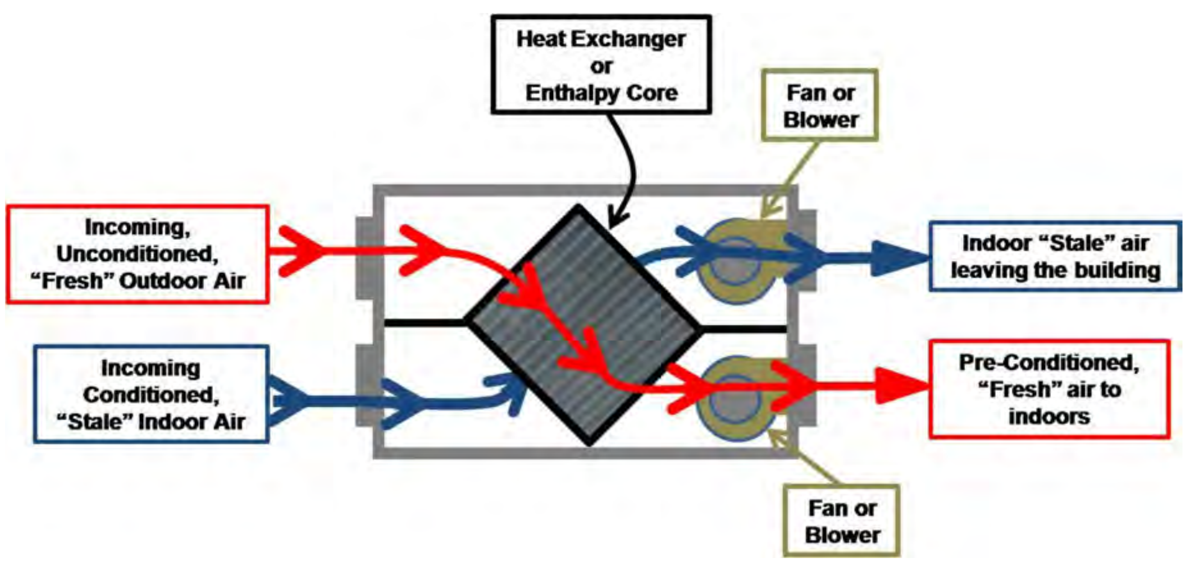
The IEC’s advantage over traditional evaporative cooling is that no moisture is added to the supply air stream, providing improved indoor air quality. IEC systems are suitable for buildings with cooling towers because they can precool ventilation air, reducing the use of mechanical cooling. Consider the estimated water use when comparing different evaporative approaches and equipment. Many systems meet higher water efficiency

Evaporative Cooling (continued)
standards such as the California Energy Commission (CEC) water-use-level recommendations for evaporative units of 0.15 gallons per minute per ton (gpm/ton). When located on the roof, consider the structural implications of the unit's water weight.

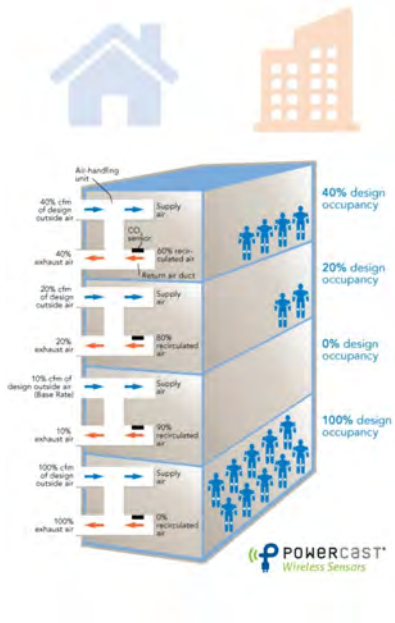
Ventilation

Heat and Energy Recovery Systems
Energy Recovery Ventilation (ERV) and Heat Recovery Ventilation (HRV) systems transfer energy between the supply and exhaust airstreams. When there is a cooling load, heat in the supply airstream is transferred to the cooler exhaust airstream, lowering the temperature of the supply air, requiring less energy to reduce the air to the design temperature. When there is a heating load, heat in the exhaust airstream is transferred to the cooler supply airstream, raising the temperature of the supply air, again requiring less energy to raise the air to the design temperature. This system works well for larger buildings in climate zones with relatively high space conditioning requirements. Compact contained HRV systems may be appropriate for smaller spaces.

An ERV system can transfer both sensible and latent heat through transferring moisture between the exhaust and supply air streams with an enthalpy wheel. This makes ERVs far more effective in transferring heat under cooling loads than HRVs. In hot, dry climates, it is more cost effective to utilize HRV than ERVs. In these climates, the efficiency gains of ERVs are reduced, even though the price is higher. The design of ERVs systems must account for several additional design and air quality concerns. Avoid cross-contamination of the make-up and exhaust airstreams. This is one reason that the pressure drop on the supply and exhaust side needs to be limited. The design should also account for frost protection in cold climates. ERVs save energy, but those savings are offset somewhat by the energy needed to run the ERV system itself and the pressure drop created by the ERV unit. As a result, it is essential for ERVs to have a bypass that allows the ERV to be powered down and the airstreams to be routed around the ERV unit.



HVAC Systems



Demand Control Ventilation

Demand control ventilation reduces ventilation flow rates, based on occupancy, reducing the need for heating and cooling outside air while maintaining high indoor air quality. CO2 controls identify areas where occupancy is variable or irregular, such as meeting rooms, studios, theaters, educational facilities, etc. CO2 control should allow for both a reduction of outside air flow when occupancy is low and an increase in outside air flow beyond minimum set points when occupancy is high.

DCV will not provide substantial energy savings when occupancy schedules are consistent and predictable, such as an open office, and are better suited for large meeting spaces, cafeterias, and other assembly areas. Other spaces where DCV may not be suitable include: systems where the total supply air flow is less than 1000 cfm, systems with exhaust air energy recovery and an exhaust air flow rate of less than 1000 cfm, and in space types with specific contaminants (such as retail applications with VOC from retail stock), where occupant density may not be an appropriate basis for control of ventilation rate.

Graphic Source: AirFixture

Raised Floor Air Distribution

Raised floor air distribution delivers air low in the space, at low velocity and relatively high temperature compared to traditional plenum mounted distribution systems. Delivering air through a series of adjustable floor-mounted registers permits room air to be stratified with lower temperatures in the bottom portion of the room where people are located and high temperatures towards the ceiling. This system type is attracting increasing interest because it has the potential to save energy and to provide a high degree of individual comfort control. These systems have historically used constant-volume air delivery. Manufacturers are now beginning to offer VAV systems that are more easily designed, installed, and operated with raised floor plenum systems.

Resources and Information:

U.S. Department of Energy, Building America Solution Center:
https://basc.pnnl.gov/
ENERGY STAR, Benefits of Duct Sealing:
https://www.energystar.gov/campaign/heating_cooling/duct_sealing/benefits
New Buildings Institute, National Grid Presents — Best Practices for Small HVAC:
https://newbuildings.org/webinar/best-practices-for-small-hvac/
MEEA, Residential HVAC Quality Installation and Quality Maintenance Toolkit:
https://www.mwalliance.org/residential-hvac-quality-installation-and-quality-maintenance-toolkit
ENERGY STAR, A Guide to Energy-Efficient Heating and Cooling:
https://www.energystar.gov/ia/partners/publications/pubdocs/HeatingCoolingGuide%20FINAL_9-4-09.pdf
US Department of Energy, Energy- and Cost-Savings Calculators for Energy-Efficient Products:
https://www.energy.gov/eere/femp/energy-and-cost-savings-calculators-energy-efficient-products
National Institute of Building Sciences, Whole Building Design Guide, High Performance HVAC:
https://www.wbdg.org/resources/high-performance-hvac
National Institute of Building Sciences, Whole Building Design Guide, Building Commissioning:
https://www.wbdg.org/building-commissioning
California Commissioning Collaborative, Existing Building Commissioning Toolkit:
https://www.cacx.org/resources/rcxtools/

WATER RETURN
SER WATER SUPPLY
CHWP-4

Section 11

Renewable Energy

As noted in the introduction, a Net Zero Energy building (NZE), must meet its entire annual energy used with an equal, or greater, amount of renewable energy created on the site, or through off-site renewable energy sources. Off-site renewable energy sources include offsite generation, a Power Purchase Agreement (PPA), or through the purchase of Renewable Energy Credits.

The following is an overview of the types and opportunities for renewable energy for Net Zero Energy buildings.

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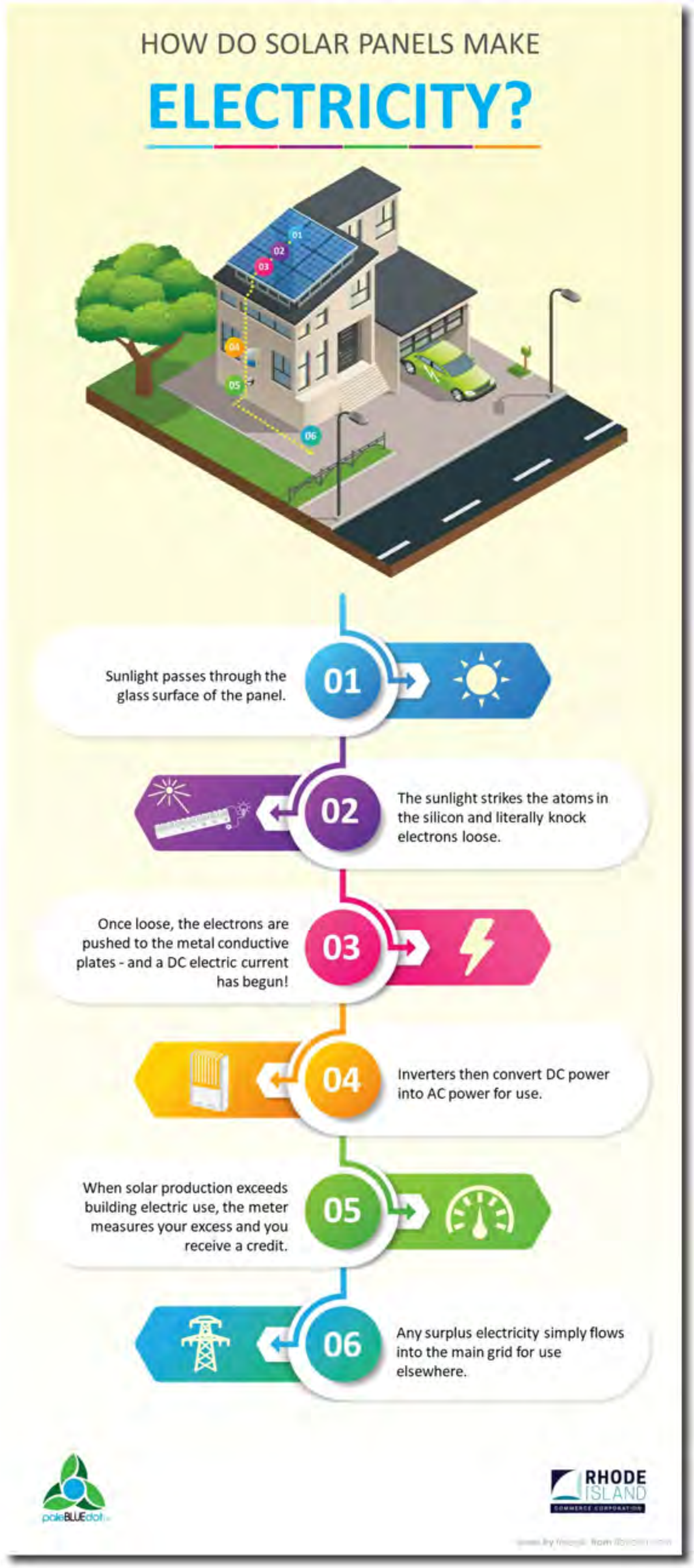
Renewable Energy

RENEWABLE ENERGY STRATEGIES

RE1 Grid-Tied Solar PV

A grid tie solar electric system – also referred to as grid-tied or utility inter-tie photovoltaics (PV) – uses solar panels, a power inverter and other components to turn sunlight into electricity for the building's use. The systems produce DC current that is converted to AC by an inverter so it can be used for normal building uses. Using net metering, when the PV array makes more energy than is needed, it is exported to the grid and when the building needs more energy than is available from the PV array, it draws from the grid. Through net metering connections with the utility, the amount of energy supplied to the grid is accounted for and credited on the site's electricity bills. Large multi-story commercial buildings may have too small a roof area for the number of solar panels required to meet the building's energy needs. In such cases, PV panels can be located over parking lots, parking structures, open site areas, or integrated into other building surfaces (see Building Integrated Photovoltaics).

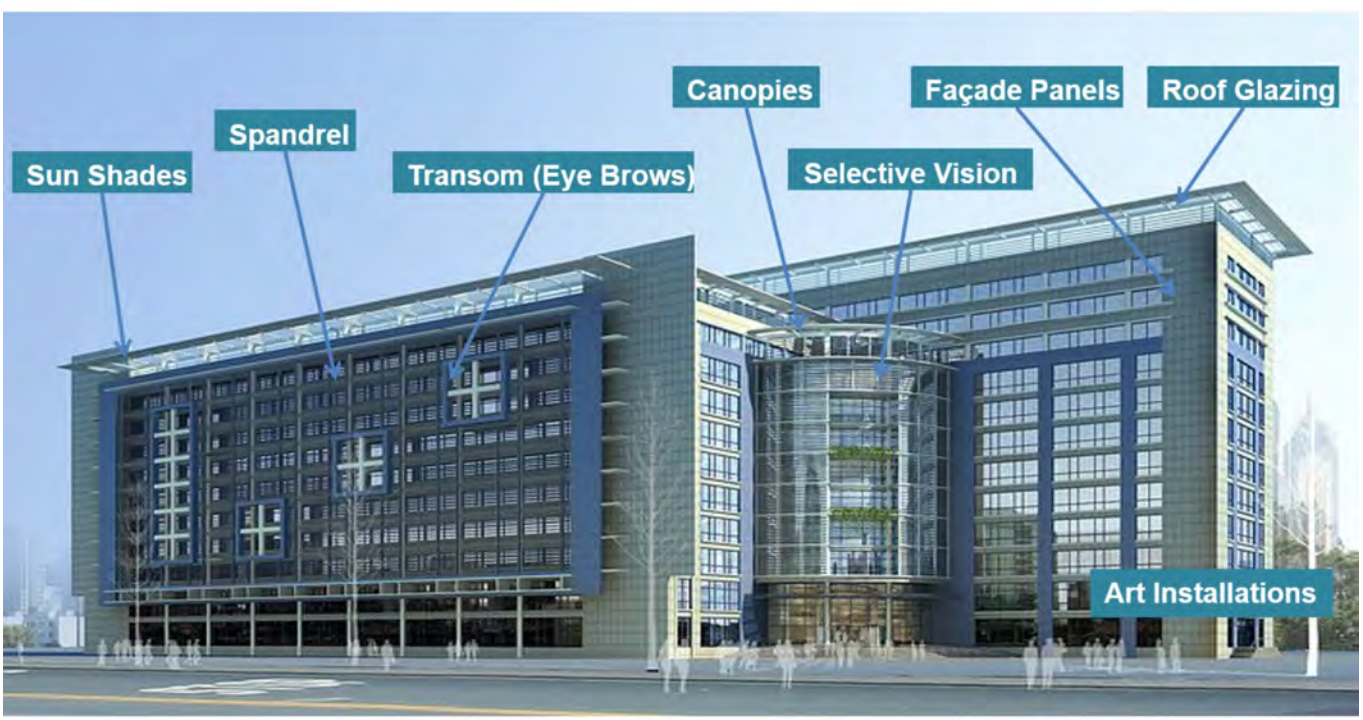


Renewable Energy

RE2 Building Integrated Photovoltaics

Building Integrated Photovoltaics (BIPV) is the integration of photovoltaics (PV) into the building envelope. The PV modules serve the dual function of building skin—replacing conventional building envelope materials—and power generator. By avoiding the cost of conventional materials, the incremental cost of photovoltaics is reduced and its life-cycle cost is improved. That is, BIPV systems often have lower overall costs than PV systems requiring separate, dedicated, mounting systems. Though they can be added to a structure as a retrofit, the greatest value for BIPV systems is realized by including them in the initial building design. Examples of BIPV applications include:

> Building Facade – PV can be integrated into the sides of buildings, replacing traditional glass windows with semi-transparent thin-film or crystalline solar panels. These surfaces have less access to direct sunlight than rooftop systems, but typically offer a larger available area. In retrofit applications, PV panels can also be used to camouflage unattractive or degraded building exteriors.
>
> Rooftops – In these applications, PV material replaces roofing material or, in some cases, the roof itself. Some companies offer an integrated, single-piece solar rooftop made with laminated glass; others offer solar "shingles" which can be mounted in place of regular roof shingles.
>
> Glazing – Ultra-thin solar cells may be used to create semi-transparent surfaces, which allow daylight to penetrate while simultaneously generating electricity. These are often used to create PV skylights or greenhouses.



RE3 Energy Storage
On-site energy storage can help reduce operating costs, provide power resilience during power outages, and enhance the utilization of on-site energy generation:

Reduced Operating Costs: many buildings pay their electric utility not only for the number of kilowatt hours (KWh) they use, but also for their demand charge - fees applied to the electric bills based upon the highest amount of power drawn during any (typically 15-minute) interval during the billing period. On-site energy storage, if designed properly, has the potential of providing the power needed during those highest power draw periods effectively eliminating or reducing the demand charges incurred by the site.

Energy Resilience: on-site energy storage can be designed to meet the emergency power needs of a building during a power outage over a given period of time – typically 2, 4, or 8 hours.

Enhanced On-Site Renewables: When the on-site energy storage is combined with on-site renewable energy generators, like solar PV, the system can be designed to provide emergency power for multiple days. These systems, known as Nanogrids when serving a single building, can be interconnected to other buildings to form a Microgrid for shared energy resilience between buildings or within a district.

RE4 Solar Ready
A Solar Ready building is engineered and designed for solar installation, even if the solar installation does not happen at the time of construction. Solar Ready design is important if photovoltaic (PV) or solar hot water (SHW) technologies are to be installed on a building at any time during the building's lifespan. Solar Ready also allows owners to take advantage of a changing energy market more easily and less expensively in the future. See the City of La Crosse's Solar Ready Guidelines for more information.

RE5 Grid Provided Renewables
Not all buildings can achieve Net Zero Energy solely with on-site renewable energy. Many buildings in dense urban areas – mid-rise or high-rise buildings – and energy intensive building types will require some or all of the renewable energy to be procured off-site in order to achieve Net Zero Energy. Options for obtaining off-site renewable energy include:

Renewable Energy Credits:

Renewable Energy Credits (RECs) are tradable, non-tangible energy commodities that represent proof that a quantity of electricity was generated from an eligible renewable energy resource. RECs represent all of the "green" or clean energy attributes of electricity produced from renewable resources like solar PV. A REC includes everything that differentiates the effects of generating electricity with renewable resources instead of using other types of resources. It is important to remember that a REC also embodies the claim to the "green attributes" of renewable electricity generation, and only the ultimate consumer of the REC has rights to the claim; once a producer or owner of a REC has sold it, rather than consuming it themselves, they have sold the claim and cannot truthfully state that they are using renewable electricity, or that the electricity that was produced with the REC is renewable.

Renewable Energy

RE5 Grid Provided Renewables (Continued)
Renewable Energy Credits (Continued):
The owner and user of a Renewable Energy Certificate (REC) is the only party that can claim the environmental benefits of that REC and claim to be using renewable energy because of that REC. Naturally, issues of REC ownership, validity of certain claims and avoiding double counting are central to a robust voluntary renewable energy market.

Buildings can have their electric use met through renewable energy sources through the purchase of REC's. To do so, a building owner simply purchases enough REC units to cover their building's electric use. Many utilities offer REC purchase arrangements where the utility billing will automatically cover the entire building's electric use with RECs.

Community Solar:
With this arrangement, a renewable energy developer constructs a wind or solar farm and offers capacity to individual building owners or energy users. The local utility is usually a partner with the renewable energy developer and most programs monitor production from the solar panels leased or purchased by the building owner. Typically, renewable energy production is directly credited to the building owner's utility bill as if the solar panels were located on the roof or elsewhere on the property. When subscribing to a Community Renewable project, a building owner must check to see if the purchase includes the rights to the Renewable Energy Credits (REC). Most Community Renewable subscriptions do not include the rights to the energy credits, in which case, a building owner will need to purchase REC's separately in order to achieve Net Zero Energy.

Renewable Energy

RE5 Grid Provided Renewables (Continued)

Renewable Energy Investment Fund:

A Renewable Energy Investment Fund (REIF) is a monetary account set up to accept payment from building owners or developers who are unable to install enough on-site renewable energy. Management of the fund can vary but would likely be done a local or provincial governmental entity, although utilities may also have a role, depending on local circumstances. The managing entity would use the money to acquire or lease land and install renewable energy systems to offset the energy used by the building. The managing entity may choose to outsource development responsibility to renewable energy developers or even purchase virtual PPAs. When engaging a REIF, a building owner must check to see if the purchase includes the rights to the Renewable Energy Credits (REC). If the agreement does not include the energy credits, a building owner will need to purchase REC's separately in order to achieve Net Zero Energy.

Solar Power Purchase Agreement:

A solar power purchase agreement (PPA) is a financial agreement where a developer arranges for the design, permitting, financing, and installation of a solar array on a customer's property. The developer sells the power generated to the host customer – typically at a fixed rate that is lower than the local utility's retail rate. Payments within a PPA agreement are based on the actual energy produced by the solar array every month. This lower electricity price serves to offset the customer's purchase of electricity from the grid. The developer receives the income from the sales of the electricity as well as any tax credits and other incentives generated from the system. Customer's entering into a PPA who wish to claim the "green attributes" of the solar energy will need to negotiate with the solar developer to retain the solar Renewable Energy Credits.

PPA's typically range from 10 to 25 years during which time the developer remains responsible for the operation and maintenance of the system. Some PPA agreements will also offer an early "buy out" clause which enables the customer to purchase the solar array for a predetermined price or fair market value.

Within the PPA, the customer typically pays nothing for the installation or maintenance of the solar system, which will be owned by the solar company. In a PPA, you pay for the electricity produced by the system directly.

Resources and Information:

City of La Crosse, Solar Ready Guide
https://palebluedot.llc/lacrosse-solar-ready-guide
PV Watts Solar PV Calculator:
https://pvwatts.nrel.gov/
Energy Sage Solar Savings Calculator:
https://www.energysage.com/solar/calculator/
AltE Solar Calculator:
https://www.altestore.com/store/calculators/on_grid_calculator/
paleBLUEdot Solar and Energy Calculator:
https://palebluedot.llc/solar-and-energy-calculator
paleBLUEdot, How Solar Works:
http://palebluedot.llc/how-solar-pv-works/
paleBLUEdot, Benefits of Solar PV:
http://palebluedot.llc/benefits-of-solar
paleBLUEdot, Solar Ownership Options:
http://palebluedot.llc/solar-ownership-options
paleBLUEdot, Renewable Energy Credits:
http://palebluedot.llc/what-are-renewable-energy-credits
EnergySage, State of Minnesota Solar PV Incentives:
https://www.energysage.com/local-data/solar-rebates-incentives/mn/
SEIA, Minnesota Solar Overview:
https://www.seia.org/state-solar-policy/minnesota-solar
Midwest Renewable Energy Association, Solar Group Purchase:
https://www.midwestrenew.org/solargroupbuy/

Section 12

Electric Vehicle Readiness

This section outlines strategies and approaches to designing new buildings or building expansions "Electric Vehicle Ready". EV Ready means that the building and site are designed to support the anticipated increased electric vehicle utilization.

According to the Edison Foundation, Electric Vehicle stock in the United States is projected to reach 18.7 million in 2030, up from slightly more than 1 million at the end of 2018. This means EV's will make up at least 7% of the vehicles on the road by that time. For the city of La Crosse, based on the 2022 Climate Action Plan, there is a goal to increase battery electric vehicles (BEV's) to over 11,800 owned and operated by La Crosse residents by 2030. Based on the Edison Foundation study, these EV's will require a minimum of 492 public level II charging ports, 801 workplace level II charging ports, and 60 public CD Fast Charging ports.

The average mileage driven per household in La Crosse is 22,624 miles annually (2019). Just as with gasoline cars, some electric vehicles are more efficient than others, and the average EV needs 28 to 32 kWh of electricity to power the vehicle for 100 miles. This means that each electric vehicle will require 2,800 KWh annually, assuming average annual driver mileage and average EV KWh per 100 miles driven.

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Electric Vehicle Readiness

LEVELS OF EV READINESS

Planning for a Net Zero Building must anticipate what will be needed to support Electric vehicles as well as anticipate the future energy demands they will place on the building. Based on the specifics of the building's function and owner expectations, the building should then be constructed to be Electric Vehicle Supply Equipment (EVSV) Capable, Electric Vehicle Supply Equipment (EVSE) Ready, or EV Ready (see City of La Crosse's Electric Vehicle Ready Guide):

EVSE Capable: EVSE Capable means a building that is capable of meeting the needs of the Electric Vehicle Supply Equipment anticipated. An EVSE Capable building has installed electrical panel capacity to serve future EVSE equipment, with a dedicated branch circuit and continuous raceways from the panel to future EV parking/charging locations in the building or site.

EVSE Ready: EVSE Ready means a building that is ready for the charging station equipment – all that is needed is the final purchase and installation of the charging stations themselves. An EVSE Outlet Ready building meets all of the requirements of an EV Capable building, however, all conduits terminate in a junction box or outlet capable of serving the intended charging station (typically 110 or 240 volt outlet). In addition, an EVSE Ready building has all breakers and wiring installed to support the installation of planned charging stations.

EV Ready: An EV Ready building has all electrical equipment and EVSE equipment installed and operational for a minimum number of charging stations of the required/desired levels (Level 1, 2, or DCFC.

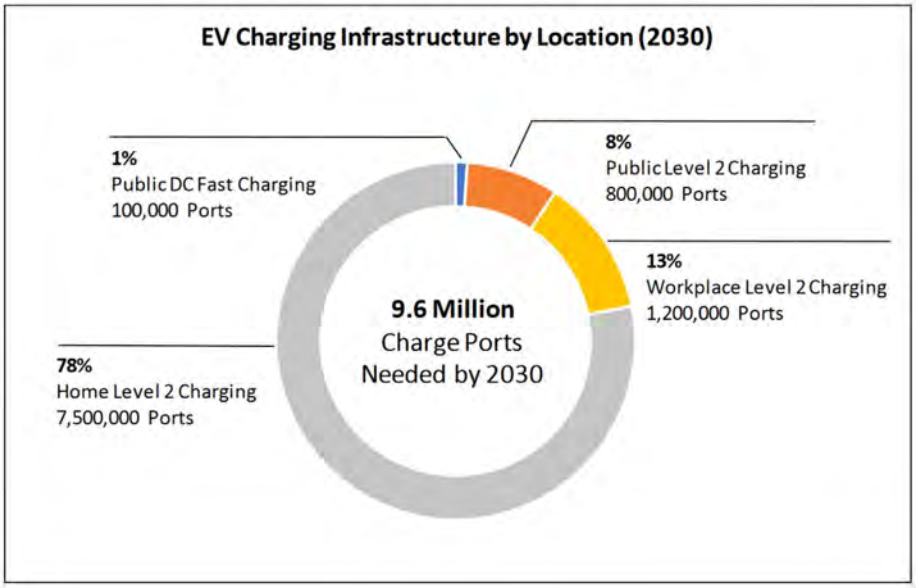
By anticipating the needs to support future EV's and pre-wiring the infrastructure, building owners can save money. A 2016 study for the City of San Francisco found that a building constructed to the level of EVSE Ready could save up to 75% of the costs that would be incurred to retrofit a building to the level of EVSE Ready.

Relative Cost EV Charging Infrastructure per space for New Construction vs Retrofits

(Source: Plug-In Electric Vehicle Infrastructure Cost-Effectiveness Report for San Francisco, Energy Solutions)

Electric Vehicle Readiness

Anticipated EV Charging Infrastructure Needed in US by 2030



ELECTRONIC VEHICLE READINESS STRATEGIES

(see City of La Crosse's Electric Vehicle Ready Guide):

EV1 Determine Readiness Goal

Establish the building's readiness design standard: EVSV Capable, EVSE Ready, or EV Ready.

EV2 Determine EV Load

As outlined above, based on market projections through 2030, a conservative estimate would be to assume 7% of all vehicles on-site will be EV's by 2030. Building owners, designers, and contractors should determine what level of EV share of total on-site vehicles they will design their building to meet. With that number established, the building's electrical system should be designed to meet the total future load. As illustrated above, building designers and owners should anticipate an average of 4,556 KWh in annual demand per EV anticipated at the building site.

EV3 Electrical Room Capacity

Buildings should include the appropriate panel infrastructure to meet the anticipated loads established in the above strategies. See Levels of Readiness.

EV4 Install Raceway

Buildings should include the appropriate cable raceway and conduits connect the building's electrical panel with the anticipated EV parking locations within the building and site. The sizing and pathways for conduit should meet all building codes and current EV best practices. Note, some chargers will require data connections in addition to power connections. Owners, designers, and contractors should be sure to verify whether the EVSE needs Ethernet (Cat5 or Cat6), wireless network access, or cell network access and plan accordingly.

Electric Vehicle Readiness

EV5 Wire for EVSE

To meet ESVE Ready or EV Ready level goals established by the building Owner (see EV1) , the building should have wiring installed connecting the EV designated panel(s) with all EV parking locations (see EV4). The sizing of all wire should meet all building codes and current EV best practices. Owners, designers, and contractors should be sure to verify whether the EVSE needs Ethernet (Cat5 or Cat6), wireless network access, or cell network access and plan accordingly.

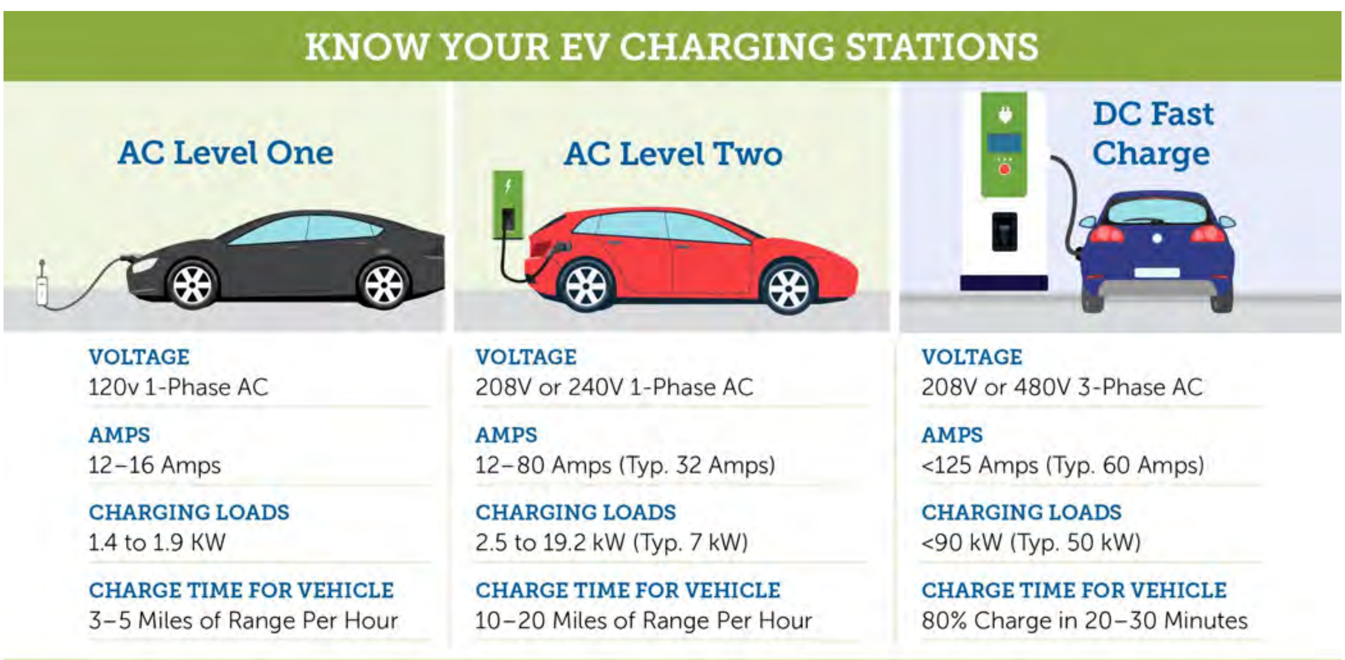
EV6 Charging Station Installations

For owners with the goal of meeting the EV Ready standard (see EV1), appropriate EV charging stations (Level 1, 2, DCFC, or a combination) to meet the building's design goals should be procured, installed, and tested.

EV7 Go Public

For buildings which select the full EV Ready level, with installed and operational EV Charging stations, building owners can consider making charging stations available for public use as pay charging stations. To do so, be sure the EVSE equipment designed for and installed are appropriate for use as public stations. Once installations are complete, notify public databases to assure they are seen by the EV driving public. Databases include:

- US Department of Energy Alternative Fuels Data Center
- Open Charge Map
- Plugshare EV Tool



Graphic Source: Utah Clean Energy

Electric Vehicle Readiness

Resources and Information:

City of La Crosse Electric Vehicle Ready Guide:
https://palebluedot.llc/lacrosse-ev-guide
US Department of Energy Alternative Fuels Data Center:
https://afdc.energy.gov/fuels/electricity_locations.html#/find/nearest?fuel=ELEC
Open Charge Map:
https://openchargemap.org/site
Plugshare EV Tool:
https://www.plugincars.com/how-to-use-plugshare-guide.html
California Plug In Electric Vehicle Collaborative: A Toolkit for Readiness:
https://www.veloz.org/wp-content/uploads/2018/11/PEV_Tool_kit_120827.pdf
EV Charging Infrastructure Toolkit for Fleets:
https://www.kerncog.org/wp-content/uploads/2019/07/Fleets_EVI_Toolkit.pdf
Plug-In NC, Electric Vehicle-Ready Homes Guide for Builders:
https://pluginnc.com/wp-content/uploads/2016/06/Updated-EV-Ready-Homes-Builder-Guide.pdf
Consumers Energy, EV Ready Checklist:
https://www.consumersenergy.com/residential/programs-and-services/electric-vehicles/ev-ready-checklist
US Department of Energy, Charging At Home:
https://www.energy.gov/eere/electricvehicles/charging-home
ChargePoint, Tools for Architects and Designers:
https://www.chargepoint.com/solutions/pre-construction/#resources
Southern California Edison, Electric Vehicles for Business
https://www.sce.com/business/electric-cars?from=/ev4business
US Department of Energy, Alternative Fuels Data Center, Federal and State Laws and Incentives:
https://afdc.energy.gov/laws/search

Section 13

Construction Phase

The potency of a Net Zero Energy building, ultimately, is not in its design. Its potency lays in the actual performance of the building once it is constructed and operated. In the end, Net Zero Energy buildings are not as much about design concepts as they are about achieving a building that generates as much energy on-site as it consumes. The proof, as they say, is in the pudding.

It is true that achieving Net Zero Energy buildings cannot happen without a quality design process. It is also equally true that the best Net Zero Energy building design will fall short of achieving its goals if the implementation of those designs is not equally careful and attentive. Consequently, the construction phase of any Net Zero Energy building is crucial to its success.

The following are processes and considerations for successful Net Zero Energy building construction phase efforts.

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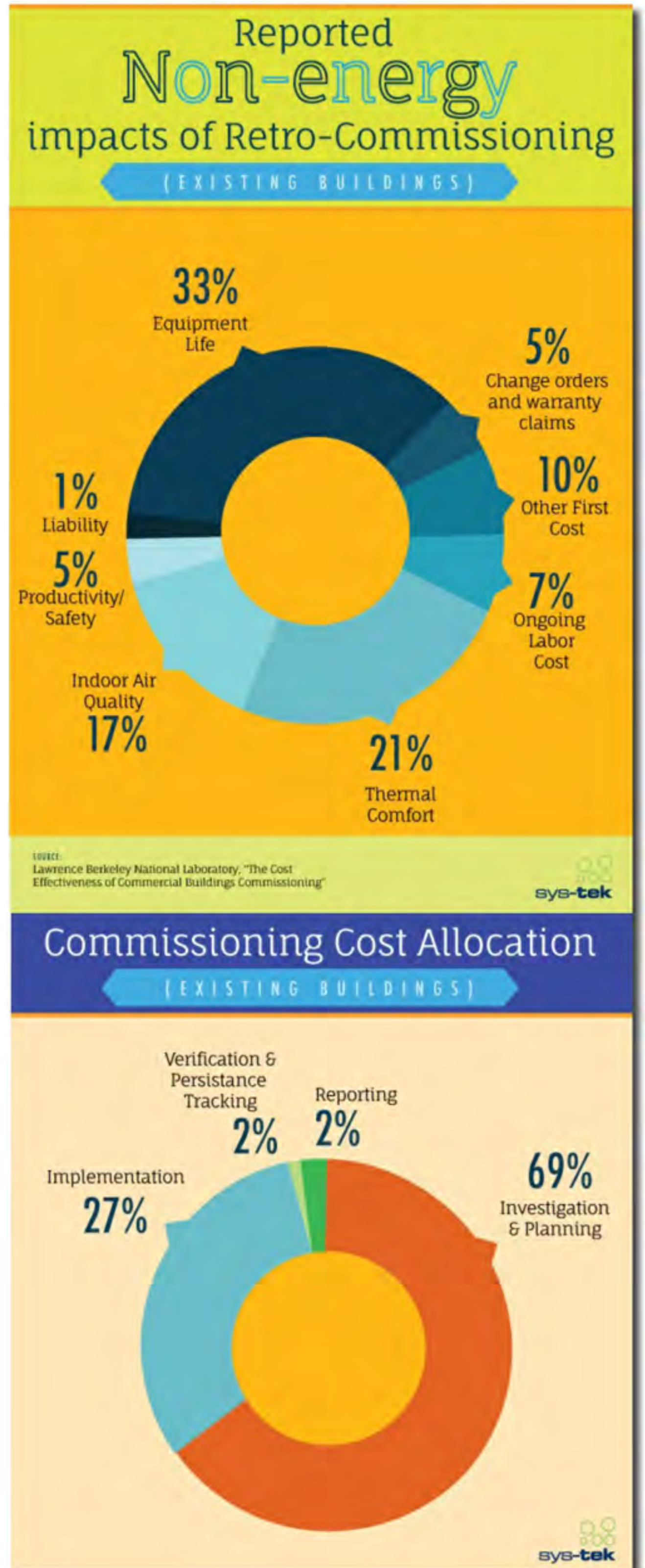
Construction Phase

LEVELS OF EV READINESS

C1 Plan For Commissioning

A critical part of a Net-Zero Energy strategy is to perform *Building Energy Systems Commissioning* before occupancy. Commissioning is a systematic process by which all energy-using equipment within the building is inspected to confirm proper operation so that optimal performance is achieved. This process begins during design and continues through the end of construction. Commissioning ensures that the new building operates initially as the owner intended and that facility management staff are prepared to operate and maintain its systems and equipment. Ideally, an ongoing commissioning (retro-commissioning) program should be initiated to ensure that energy systems continue to operate as designed. The Design phase efforts to support commissioning through the construction phase include:

- Define the Owner's Project Requirements – The first and most important step is to define the owner's operational goals for the building. This becomes a written document called the Owner's Project Requirements (OPR). The OPR covers all aspects of the building from energy performance, to acoustics to life safety. The OPR later forms the Basis of Design (BoD) from which all design, construction and operating decisions stem.
- Develop a Commissioning Plan – The Commissioning Plan establishes team member responsibilities and a framework for how energy systems commissioning will be implemented on a given project.



Construction Phase

C2 Commissioning The Building

Based on the established and approved commissioning plan (see C1), the building and all appropriate building systems should undergo commissioning reviews and testing. In a high-performance building, commissioning of the following components is a critical part of the quality assurance process:

- Building enclosure, including walls, roof, fenestration, and slab
- Building systems, including heating, ventilating, and air conditioning (HVAC); lighting and lighting controls; plug load management; and renewable energy systems
- Indoor environmental quality (IEQ), including air quality, lighting quality, and acoustical performance.

C3 Include "Absolute EUI Goal" In Commissioning Scope

The ultimate measure of whether or not a Net Zero Energy Building is performing as per design is the building's ability to balance its Energy Use Intensity (EUI) with its energy generation capacity. In support of this, it is common for commissioning agent work scope, and contractor agreements to contain an "Absolute EUI" goal. With this included, energy performance becomes the key metric for success. If the building is not performing as designed, the contractor and commissioning agent are "held responsible". This means it is up to the contractor and commissioning agent to optimize and tune the building for performance. Other key considerations in Net Zero Energy Building commissioning include:

- More systems and more equipment are included in commissioning plans and process than what may be included in commissioning for a standard building.
- Extensive control system integration requires specific testing of the integration system itself.
- Owner will need more training and that requirement should be included in the commissioning scope (see C4 Occupant Training)

C4 Occupant Training

Develop tenant guidelines to educate occupants and describe the unique features of the building. Provide information on efficiency measures that may be different from a traditional workstation. The guidelines can also include information about future renovation considerations to maintain ZNE and other green building goals. Incorporate these guidelines into the lease or employee welcome package and occupant feedback to ensure they understand the available energy data. Facility operations and maintenance staff should meet with the design team and commissioning agent to learn about the building systems, controls, and automation systems before taking over maintenance responsibilities. It may be helpful for the design team to develop an operations manual that includes equipment cut-sheets, warranties, product maintenance guidelines, commissioning results, among other information. ZNE performance can be incorporated into building operator job descriptions and performance reviews. Refer to the Controls and Metering section for more information on dashboards and displays.

Construction Phase

C5 Share Energy Use

An energy dashboard is a great opportunity to visually present building energy consumption and production by month, day, hour, or a minute and remind occupants and visitors of the role they play in reducing energy use. Displays can be interactive, educational, or motivating, depending on your audience and the data available. Some energy tracking programs allow occupants to track energy use from a website or their smartphones and will send educational messages and reminders about energy reduction at peak hours. In competitive environments, saving energy can become a game between individuals or departments. Gamification challenges individuals with energy reduction and provides the occupant with progress in energy efficiency. Points and medals are awarded to individuals and teams to motivate users.

C6 Benchmark Energy Performance

One full year of energy consumption and production data is necessary to verify NZE performance. Research has shown that some NZE buildings may not operate at design levels during the first twelve months of occupancy. Instead, it may take longer to meet the target. Ongoing tracking and review of energy performance with a Building Management System, energy dashboard, or ENERGY STAR Portfolio Manager is helpful to understand energy performance and renewable energy production if incorporated. Most electricity and natural gas utilities can automate data transfers. Arrange for departments to enter water use manually. Facility staff can compare actual energy consumption to predicted performance to identify if systems are operating as designed. Uncovering irregularities through frequent data review can help to correct the issue promptly.

C7 Net Zero Energy Performance (after 1+ year) and Certification

After one year of energy use, review the building energy use and generation data to identify if zero net energy was achieved. Submit the energy data to the NBI Getting to Zero Database or the International Living Future Institute (ILFI) for third-party verification and recognition. If your building came short of achieving a net EUI of 0, evaluate the opportunities for improvement. Work with the commissioning agent, calibrate the energy model, and engage the occupants, etc., to ensure the performance meets NZE goals.

Construction Phase

Resources and Information:

US GSA, Building Commissioning Guide:
https://www.gsa.gov/real-estate/design-construction/commissioning/commissioning-program
California Commissioning Collaborative, Commissioning Toolkit:
https://www.cacx.org/resources/rcxtools/
National Institute of Building Sciences, Whole Building Design Guide, Commissioning:
https://www.wbdg.org/building-commissioning
US DOE and Pacific Northwest National Laboratory, Guide to Building Commissioning:
https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-21003.pdf
US DOE Operations and Maintenance Best Practices Guide:
https://www.energy.gov/sites/prod/files/2013/10/f3/omguide_complete.pdf
US GSA Sustainable Facilities Tool, Waste Reduction:
https://sftool.gov/explore/green-building/section/57/solid-waste/system-overview
National Institute of Building Science, Whole Building Design Guide, Construction Waste Management:
https://www.wbdg.org/resources/construction-waste-management
US GSA Sustainable Facilities Tool, Occupant Training:
https://sftool.gov/explore/green-building/section/37/lighting/human-impact#behavior/occupant-behavior-energy-efficiency
US GSA Sustainable Facilities Tool, Sustainable Janitorial Services:
https://sftool.gov/greenprocurement/green-services/7/janitorial-services
US DOE, Better Buildings, Comprehensive Occupant Engagement Program:
https://betterbuildingssolutioncenter.energy.gov/implementation-models/comprehensive-occupant-engagement-program
Bentall Kennedy, Sustainable Tenant Improvement Manual:
https://downloads.energystar.gov/cf/temp/1028978_24-28.pdf
US EPA ENERGY STAR, 8 Great Strategies to Engage Tenants on Energy Efficiency:
https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/8-Great-Strategies-to-Engage-Tenants.pdf
BOMA, Guide for Landlords and Tenants:
https://rmi.org/wp-content/uploads/2017/04/2012-05_GuideForLandlordsTenants.pdf
PaleBLUEdot, Using ENERGY STAR Portfolio Manager:
http://palebluedot.llc/using-portfolio-manager

Section 14

Financing and Incentives

There are a number of incentives and financing options which can be applicable to Net Zero Energy buildings. Incentives for both energy efficiency and on-site renewable energy (particularly Solar) exist.

The purposes of these incentives relates not only to the interest in advancing energy efficiency and renewable energy, but it is also a reflection of the community value these strategies provide. As an example, solar energy delivers positive environmental impacts, and contributes to our nation's energy independence. According to the Department of Energy, solar provides more jobs in electricity generation nationally (373,800) than coal, natural gas, oil, nuclear, and other fuels combined (288,000).

To encourage the continued expansion of solar, governments, and utilities offer solar tax breaks and financial incentives to make solar more accessible for today's businesses and homeowners. As a result, you can reduce the net cost of your solar panel system by anywhere from 30 to 50 percent.

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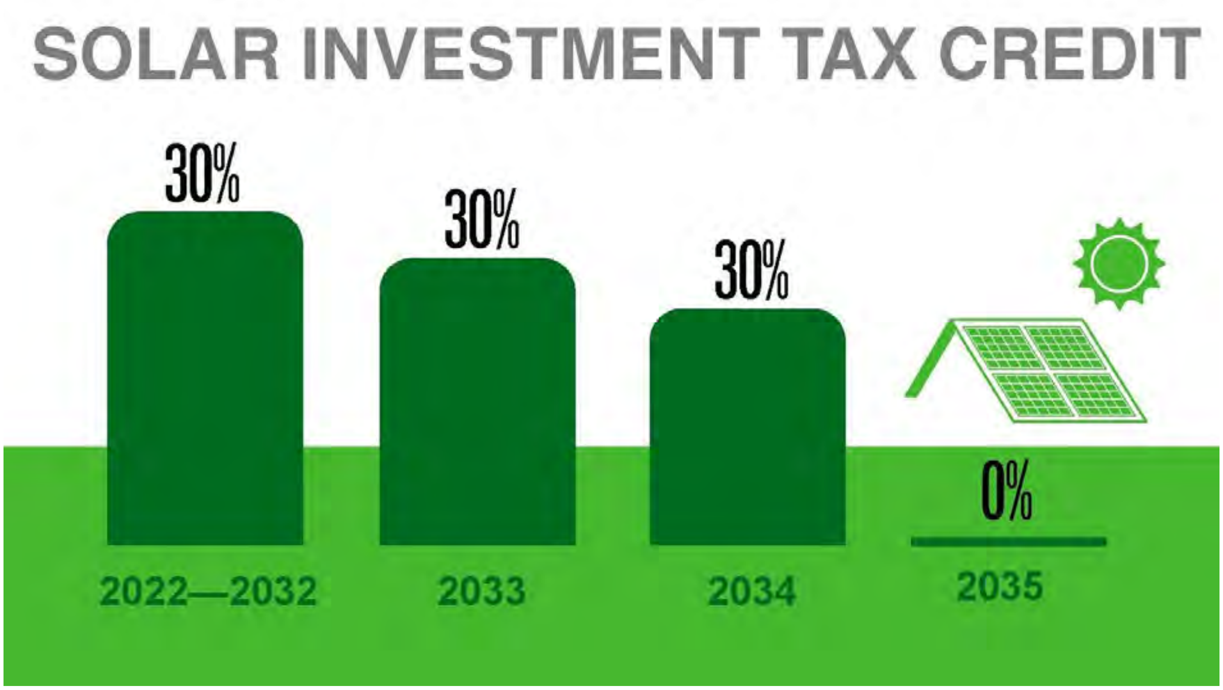
Financing and Incentives

FINANCING AND INCENTIVES

The Federal Investment Tax Credit

The Incentive Tax Credit (ITC) is a Federal tax credit for a portion of the solar pv installation costs. The ITC credit is equal to 30% of the project costs for years 2023 - 2032 and will be stepping down to 26% in 2033, 22% in 2024 and 0% for years 3035 and beyond.



Modified Accelerated Cost Recovery System (MACRS)

The U.S. tax code allows for a tax deduction for the recovery of the cost of tangible property over the useful life of the property. The Modified Accelerated Cost Recovery System (MACRS) is the current depreciation method for most property. The market certainty provided by MACRS allows businesses in a variety of economic sectors to continue making long-term investments and has been found to be a significant driver of private investment for the solar industry and other energy industries. Businesses can write off the value of their solar energy system through using MACRS, reducing their tax burden and accelerating returns on solar investments. Accelerated depreciation can reduce net system cost by an additional 30 percent.

Note: The Consolidated Appropriations Act, signed in December 2015, extended the "placed in service" deadline for bonus depreciation. Equipment placed in service before January 1, 2018 can qualify for 50% bonus depreciation. Equipment placed in service during 2018 can qualify for 40% bonus depreciation. And equipment placed in service during 2019 can qualify for 30% bonus depreciation.

Property Tax Exemption

A newly-installed solar power system is 100% exempt from associated property taxes in the State of Wisconsin. When a solar power system is installed, your property value rises significantly, however, the solar array is property tax exempt.

Financing and Incentives

Wisconsin Sales Tax Exemption
The purchase of your solar power system in Wisconsin is 100% exempt from sales tax, an upfront savings of 5%. The exemption is very broad and could apply to solar Photovoltaic (PV) systems, solar water-heating systems and solar space-heating systems. All components of these systems are exempt, including panels, wiring, pipes, pumps and racks.

PACE Financing
Property Assessed Clean Energy or PACE allows businesses and eligible nonprofit organizations to obtain solar systems without upfront costs through a voluntary special assessment placed onto the property tax statement. The benefits of PACE financing include:

- **Preserve Cash**: Upgrade your property while preserving traditional bank credit and cash for other projects.
- **Low Annual Payments:** Long term PACE financing results in low annual payments allowing energy savings to offset PACE payments.
- **Get Tax Incentives and Rebates:** With PACE financing the property owner owns the system so they keep all rebates and tax incentives for the improvement.
- **Transfer Lien with Property:** PACE lien is attached to the property and can transfer to next owner on sale of the property.
- **Off Balance Sheet:** PACE financing is potentially off balance sheet. Consult your accountant for guidance

How Does PACE Work?

Graphic Source: US Department of Energy

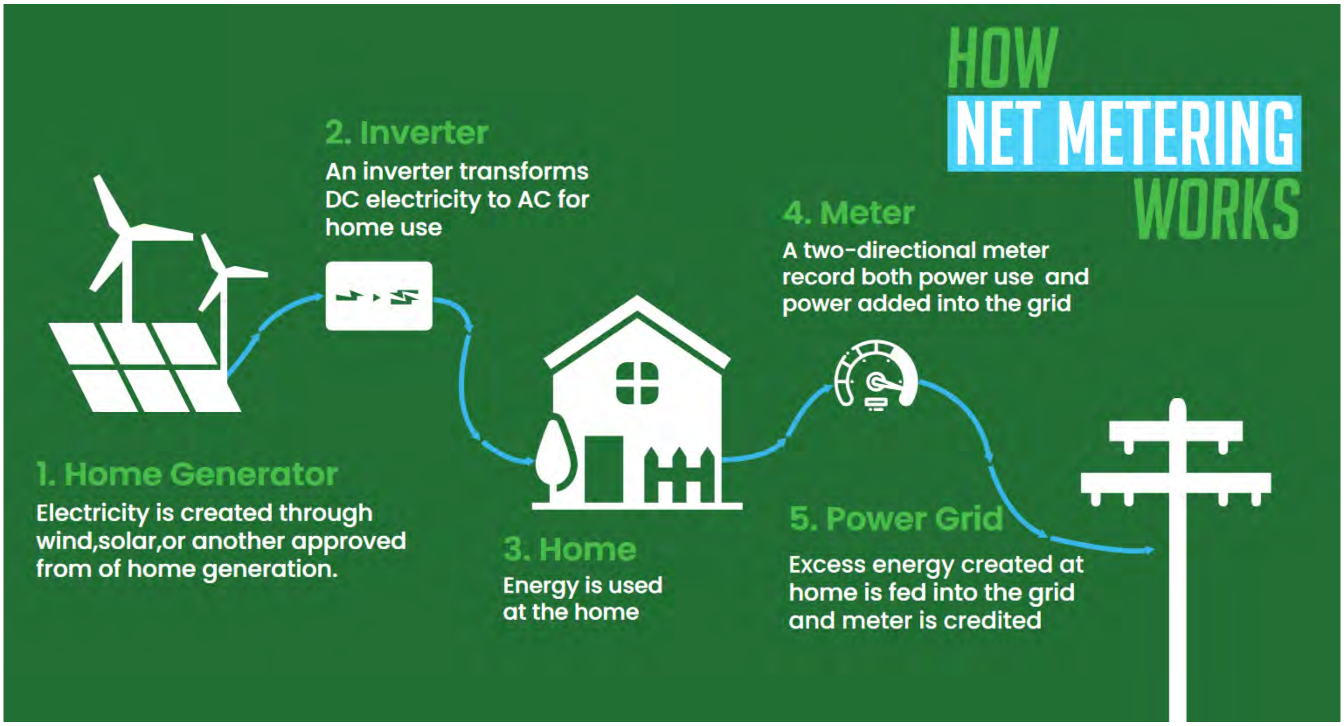
Midwest PACE Financing by Property Type:

Graphic Source: Midwest Energy Efficiency Alliance

Financing and Incentives

Net Metering

Net metering tracks the amount of energy generated on site as well as the amount of energy consumed from the grid. Net metering allows customers to get credit back from excess generation on a bill when the amount of energy a solar panel system generates is greater than the amount of energy consumed from the electric utility. Customers receive payment for the excess energy generated. Such interconnection is considered non-incentivized, meaning that the site/ solar array owner will retain the renewable energy credit that the PV system produces.



Solar access rights

Wisconsin has several laws that protect rights to install and operate a solar or wind energy system. These laws cover zoning restrictions by local governments, private land use restrictions, and system owner rights to unobstructed access to resources. The state's original laws were enacted in 1982 and have been amended several times. See

Solar easements in Wisconsin

Wisconsin law allows for the negotiation of solar easements. Statute 700.40(3)(a)4 lays out the rules and required components of a solar easement. The easement rule allows a property owner to negotiate with neighbors to ensure access to sunlight is secured for the life of the system.

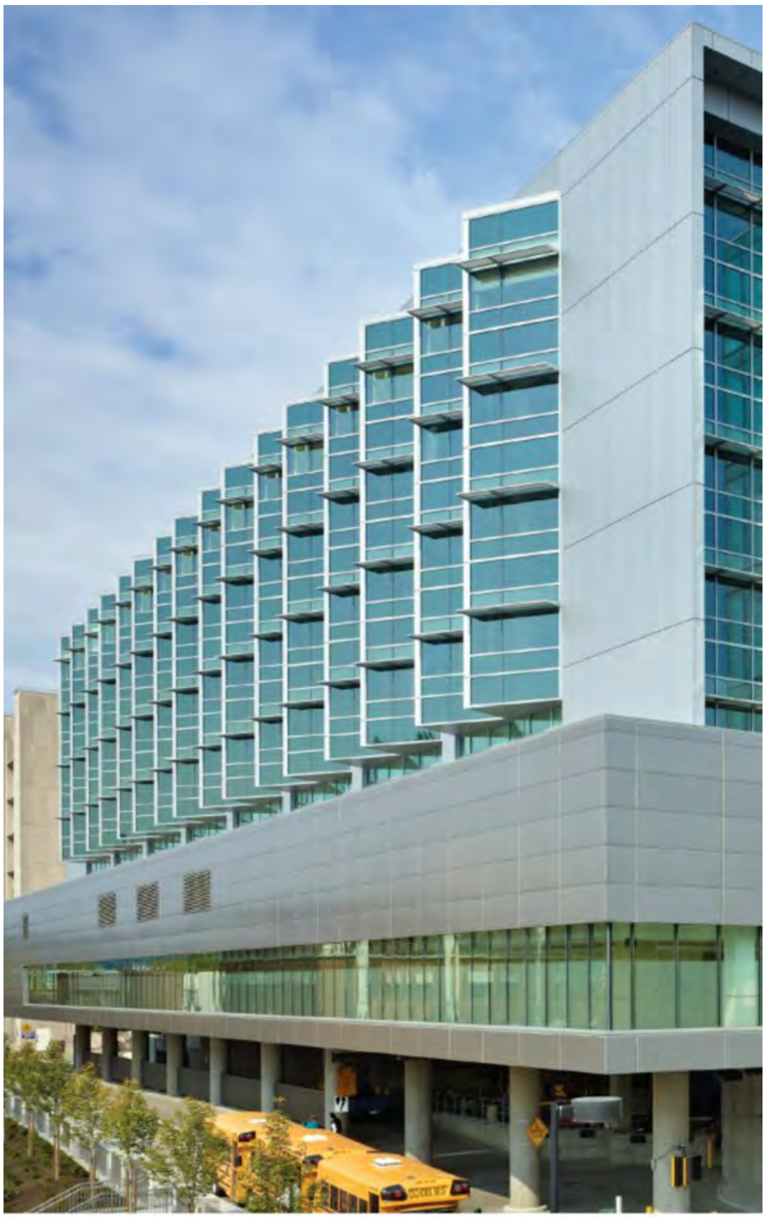
Financing and Incentives

Resources and Information:

City of La Crosse, Solar Ready Guide
https://palebluedot.llc/lacrosse-solar-ready-guide
EnergySage, Federal Solar Tax Credit:
https://www.energysage.com/solar/cost-benefit/solar-investment-tax-credit/
SEIA, Federal Solar Tax Credit:
https://www.seia.org/initiatives/solar-investment-tax-credit-itc
SEIA, Modified Accelerated Cost Recovery System:
https://www.seia.org/initiatives/depreciation-solar-energy-property-macrs
North Carolina Clean Energy Center Modified Accelerated Cost Recovery System:
https://programs.dsireusa.org/system/program/detail/676
North Carolina Clean Energy Center, Database of State Incentives for Renewables & Efficiency (DSIRE):
https://www.dsireusa.org/
EnergySage, State of Minnesota Solar PV Incentives:
https://www.energysage.com/local-data/solar-rebates-incentives/mn/
Database of State Incentives for Renewables & Efficiency, Wisconsin Solar and Wind Rights
https://programs.dsireusa.org/system/program/detail/313
Pace Wisconsin
https://www.pacewi.org/

Section 15

Net Zero Leasing



University of Washington Medical Center - Montlake Tower
NBBJ
Seattle, Washington, United States
Credit: Benjamin Benschneider

Net Zero Leases establish guidelines and requirements that modify traditional commercial or residential leases to drive Net Zero Energy achievement for the leased space as well as for the overall building.

Net Zero Leases offer a benefit to building owners who wish to advance Net Zero Energy on the properties they own - as well as a tool to attract tenants interested in occupying Net Zero Energy space. Inversely, Net Zero Leases offer opportunities to individuals or businesses who value environmental responsiveness or have corporate mandates to achieve energy efficiency or carbon footprint reductions to achieve those goals without needing to own the space they occupy.

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Net Zero Leasing

THE BUSINESS CASE FOR NET ZERO ENERGY LEASES

Tenant Attraction

Nationally, there is an increasing trend towards high flexibility of office space utilization, and healthy work environments. These trends are being driven by a number of factors including an increase in tenants with corporate sustainability goals and changes in the workforce - an increasing need for innovative and collaborative staff, combined with an increasing challenge of finding and retaining qualified candidates. Additionally, 90 percent of millennial employees report that they wish to work for a company with a strong green reputation.

Employers are placing an increasing priority on healthy, productive, and engaging spaces that can attract and retain top talent and the leadership that businesses need to thrive today. The strategies outlined in this Net Zero Energy guide lead to spaces that are healthy, productive, and engaging. Net Zero Energy buildings result in quality daylight, improved thermal comfort, fresh air, increased occupant health, and innovative technologies. Studies indicate that the advantages of Net Zero Energy buildings attract tenants up to 20 percent faster than standard buildings.

Lower Vacancy Rates and Improved Tenant Retention

High performance buildings attract and retain tenants as reflected in their vacancy rates. Studies have shown ENERGY STAR buildings have a 3% lower vacancy rate than standard buildings. For LEED-certified buildings the vacancy rate drops even further to 8% lower.

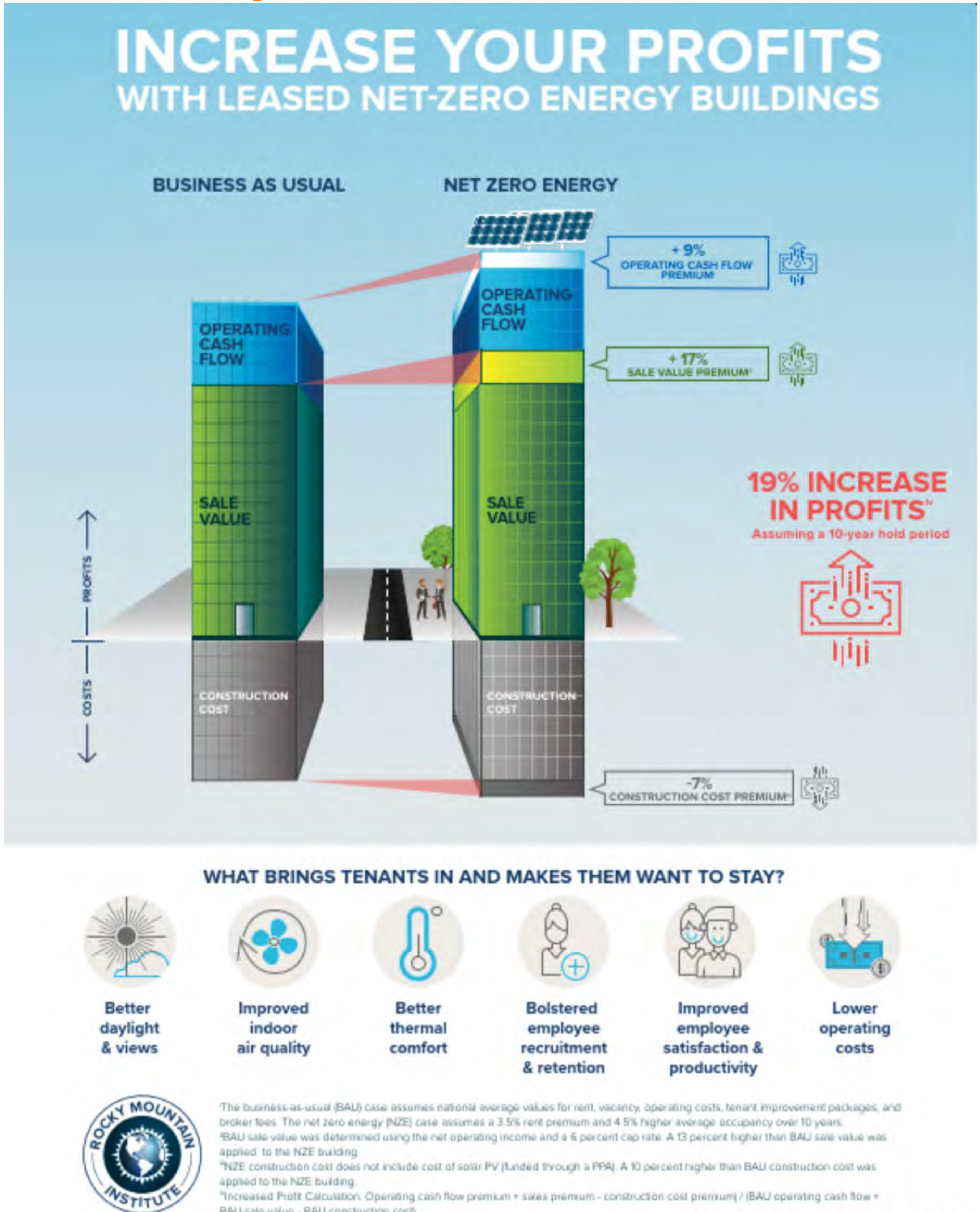
Higher Rent Value

Net Zero Energy buildings are unique and stand out in the market. Net Zero Energy buildings are typically of higher-quality construction with better-performing systems. Occupant comfort often increases with Net Zero Buildings due to increased thermal comfort, improved lighting, natural daylight and exterior views. This improved occupant comfort and sense of value supports rental premiums. Market research of 21,000 U.S. rental buildings has illustrated rent premiums of 3.5 percent for ENERGY STAR certified properties.

Higher Resale Market Value

Net Zero Energy building owners benefit from these increases in value, even if the building owner plans on reselling the building within a short period of time. Efficient buildings tend to have lower capitalization rates due to their lower overall energy costs, higher occupancy rates, and reduced tenant turnover. As a result of these factors, higher anticipated rent, and lower operating expenses, energy efficient buildings can sell for a premium of about 13% over standard buildings.

Net Zero Leasing



Graphic Source: Rocky Mountain Institute
"Best Practices for Leasing NZE Buildings"

Net Zero Leasing

COMPONENTS OF A NET ZERO ENERGY LEASE

The following are core components of a Net Zero Energy Lease:

An established energy budget. This budget establishes the amount of energy allocated to each tenant. The budget is based on the total energy consumption the building can experience while still remaining within the on-site renewable energy generation capacity. Implementation of the energy budget will require the landlord to track energy consumption by tenant. Energy budgets may also include incentive structures to align tenant behavior with the net zero goals (or penalty structures, like the responsibility of the tenant to purchase renewable energy credits for all overages on a monthly basis)

Submetering and disclosure: As noted above, implementing an energy budget requires measurement of energy consumption trends on the tenant level. To achieve this, the building must be submetered between individual tenants and common area uses. Disclosure and transparency of the energy consumption data is a critical aspect of assuring both parties of the accuracy of the data. Disclosure can also be leveraged as a behavior change agent by increasing awareness of all occupants of the net zero energy goals and the performance of their space against the energy budget.

Recommissioning: Leases should include a requirement for recommissioning as an operating expense. This ensures that the building continues to operate as efficiently as possible and can be used to identify strategies for improvement of operation.

Cost recovery: Leases should have language that allows the costs and benefits for solar photovoltaic (PV) and efficiency upgrades to flow back to the proper party or parties.

NEW CONSTRUCTION AND EXISTING BUILDINGS

Net Zero Energy building leases are possible and profitable for both new construction and existing buildings. Existing buildings typically have existing tenants and leases. Consequently, the landlord and tenants must work together in order to transition the building into a Net Zero Energy building. The following are the general steps in this transition:

- Step 1: Gather past energy data on the building and share it with tenants
- Step 2: Set aggressive yet achievable energy goals with tenants
- Step 3: Recommission the building so it is operating as efficiently as possible
- Step 4: Implement energy efficiency and solar PV upgrades using financing mechanisms that can be passed through to the tenant such as a solar power purchase agreement (PPA) or commercial property assessed clean energy (PACE) financing.

Resources and Information:

Institute for Market Transformation, Using The Lease to Drive Innovation and Clean Energy:
https://www.imt.org/resources/green-lease-leaders-using-the-lease-to-drive-innovation-and-clean-energy/

BOMA, Designing a Successful Net Zero Energy Lease:
https://www.boma.org/BOMA/Research-Resources/News/Sustainability___Energy_Management/Designing_A_Successful_Net_Zero_Energy_Lease.aspx

Lease Example: Rocky Mountain Institute, RMI Net Zero Lease Agreement at Boulder Commons (Redacted), 2017:
https://rmi.org/wp-content/uploads/2017/07/MCI-Boulder-Commons-Lease-RMI-FINAL-00241161xA14B2-1_Redactedv3.pdf

Lease Example: City of New York, PlaNYC Energy Aligned Clause:
file:///C:/Users/tredm/OneDrive/Documents/WORK/AAA-PaleBlueDot/Consulting/01%20Cities/City%20of%20Eau%20Claire%20WI/REAP/Net%20Zero%20Design%20Guide/Examples%20and%20resources/eac_overview.pdf

BOMA, Guide for Landlords and Tenants:
https://rmi.org/wp-content/uploads/2017/04/2012-05_GuideForLandlordsTenants.pdf

ULI Tenant Energy Optimization Program:
https://tenantenergy.uli.org/

Institute for Market Transformation, Green Lease Library:
http://www.greenleaselibrary.com/

Section A1

Glossary of Terms

Advanced Framing
A construction method (also known as "Optimum Value Engineering" or "OVE") that uses less material in the framing of a home and can reduce labor and material costs, improve structural integrity, and improve energy efficiency.

Air Source Heat Pump
A home comfort system using refrigeration technology to either heat or cool a building. An outdoor unit exchanges heat with the outdoor air while an indoor unit delivers conditioned air to the occupied space. Air source heat pumps can deliver between two and four units of heat for every unit of electricity used, making them far more energy efficient that other mechanical comfort systems.

Blower Door Test
A test that measures the air tightness of a building and helps reveal air leaks. To run the test, the house is depressurized using a fan mounted in one of the doors. Test results are expressed as air changes per hour at 50 Pascals (ACH50). Pascals are units of air pressure. Typical values for new construction range from 5 to 7 ACH50, while energy-efficient homes can be in the 1 to 2 ACH50 range. The tightest houses can reach less than 0.25 ACH50.

Building Envelope
The building envelope is like a six-sided box that separates the interior and exterior environment of a building. The six sides consist of a floor or basement, a ceiling or roof, and 4 walls including windows and doors. The goal is to keep that box as airtight and insulated as feasible.

Carbon Footprint
A calculation of the amount of greenhouse gases produced as a result of commercial, industrial, and individual activities. An individual's carbon footprint is a calculation of the amount of greenhouse gases they produce from daily living, home energy use and transportation.

Ceiling Fans
Fans attached to ceilings that circulate air within living spaces. In rooms with high ceilings, where warm air collects near the ceiling, a fan can mix the air to improve comfort and reduce winter heating costs. In summer, they can cut cooling costs when they are used in lieu of air conditioners.

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Glossary of Terms

Cellulose Insulation
Plant fiber insulation that is used in wall and roof cavities to separate the inside and outside of the building thermally and acoustically. Typically, cellulose insulation is made by recycling old newspapers and telephone directories. Borates and ammonium sulfate are included to retard fire and pests.

Certified Zero Energy Home
These are zero net energy homes that have been certified to be net zero by third party certifiers, such as Earth Advantage, Living Building Challenge, or independent energy analysts. Certification is based on energy modeling, on-site inspections and sometimes energy use monitoring.

Compact Fluorescent Lamp (CFL)
Small fluorescent light bulbs that can be used in place of incandescent light bulbs. CFLs consume about 75 percent less electricity and last 8-10 times longer than incandescent bulbs. All fluorescent lamps contain a small amount of mercury. See LED lamps below for the most efficient, durable and safest type of lighting.

Daylighting
Designing a building with building orientation and window placement to take advantage of natural sunlight illumination.

Double Pane Windows
Double pane glass windows often contain argon, krypton, or other gases between two panes of glass to reduce heat flow and improve insulation.

Double-Stud Walls
A method to increase the insulating value of exterior walls by making them thicker so they can hold more insulation material. Walls are generally between 10 and 16 inches thick. Not only do they save energy, but they also block sound making for a quieter home.

Dual Flush Toilets
Toilets with two flush options, one for liquid and another for solid waste. The button for liquid waste uses less water per flush.

Energy Audit
A building inspection to determine how energy is used in a home or building and how energy use can be reduced. A qualified inspector first measures the dimensions of various building components, such as walls, ceilings, floors and windows, and the type and amount of insulation is recorded. The inspector conducts a visual assessment and uses methods and measurements, such as blower door tests, that comply with industry standards. A written report should include recommendations and a detailed cost and savings analysis.

Energy Efficient Appliances
Products that use less energy than conventional models. The ENERGY STAR® label is a credible third-party certification of a product's energy efficiency. Consumers can also refer to the FTC's Energy Guide label, a yellow label affixed to most appliances today.

Glossary of Terms

Energy Efficient Light Fixtures
Fixtures holding high-efficiency bulbs, such as compact fluorescent lights (CFLs) or light emitting diodes (LEDs), and designed to emit a high proportion of the energy generated by the lamp as light rather than as heat.

Energy Efficient Mortgage (EEM)
Loan products that take a home's energy efficiency into account when determining the qualifying ratios for a buyer. The rationale is that an efficient home will result in lower monthly energy bills, making more funds available for the mortgage payment. Also, occupants of energy efficient properties have proven to have a lower risk of default. EEMs primarily apply to new construction. In some markets, an energy improvement mortgage (EIM) can be used to make energy improvements in existing homes.

Energy Guide Label
An appliance label that provides an estimate of how much energy the appliance uses, compares energy use of similar products, and lists approximate annual operating costs. It is required by the U.S. Department of Energy on many appliances. Clothes washers, dishwashers, refrigerators, freezers, water heaters, window air conditioners, central air conditioners, furnaces, boilers, heat pumps, and pool heaters can get the label. Televisions, ranges, ovens, clothes dryers, humidifiers, and dehumidifiers do not receive such labels.

Energy Modeling
The use of a computer program to project how much energy a home will use. Modeling shows energy use by building component, such walls, and by end use, such as space heating. This allows designers and builders to focus efficiency efforts in the most cost effective areas. Energy modeling estimates for zero energy homes should come very close to zero.

Energy Monitoring
Each major electric circuit of the home is monitored to determine the energy use of appliances, heating and cooling system, lights and electronics. Based on this information, homeowners can determine how best to conserve energy and identify malfunctioning equipment.

Energy Performance Score (EPS)
A score developed by the Energy Trust of Oregon that shows the total energy use of a home. The score allows home buyers to compare the energy use of different homes, just as MPG allows car buyers to compare the gas mileage of different vehicles. The EPS scoresheet shows total energy use in million BTUs (MMBTUs), total energy cost, and carbon footprint.

Energy Rating
An energy rating provides a ranking for building energy use along a standardized scale, providing an objective expression of the home's energy use. Examples include Energy Performance Score (EPS) or Home Energy Rating System (HERS) rating. Energy ratings can be used to qualify for an energy efficient mortgage, compliance with building codes or conformity with green ratings.

Glossary of Terms

Energy Recovery Ventilator (ERV)
A type of ventilation system in which the heated (or cooled) air being vented out of the home is used to heat (or cool) the supply air being pulled in from outdoors. The approach decreases the amount of energy needed to heat or cool the supply air and provides fresh filtered air. They are needed in very air-tight homes, such as zero energy homes, to provide fresh air. Unlike heat recovery ventilators, ERVs recover water vapor as well as sensible heat. This is useful in warm humid climates where air conditioning is common and in very dry, desert climates where the outside air has very low humidity.

ENERGY STAR®

A certification granted by the US Department of Energy for household appliances and buildings that perform at specified levels of energy efficiency. Also see Energy Efficient Appliances.

Ground Source Heat Pump

Ground source heat pumps (GSHPs) use the constant temperature of the earth to provide cooling and heating for a home. A loop of piping is buried in the ground and fluid circulates through the loop to a heat pump compressor. The temperature of the earth is relatively stable compared to the seasonal temperature swings of the atmosphere and benefits the heat pump as a highly effective source for heating or a sink for cooling. As a result, the efficiency of a ground source heat pump is around 400 percent.

Grey Water System
A system to reuse wastewater from bathtubs, shower drains and sinks. Greywater systems require separate wastewater collection pipes, storage tanks, filters and other equipment. Reusing greywater reduces the use of potable water for purposes that don't require treated drinking water, such as irrigation, toilets, and exterior washing.

Grid Tied
Connected to the electric utility system or grid. Zero energy homes are grid tied, meaning the excess energy they produce goes to utility and the homeowner is given credit that can be used when their energy production is lower than their energy use, such as at night, during cloudy days or in winter.

Heat Pump Water Heater

A very energy efficient water heater that uses refrigeration technology to extract heat from the surrounding air to heat water for household use.

Heat Recovery Ventilation (HRV)

A type of ventilation system in which the heated (or cooled) air being vented out of the home is used to heat (or cool) the supply air being pulled in from outdoors. The approach decreases the amount of energy needed to heat or cool the supply air and provides fresh filtered air. They are needed in very air-tight homes, such as zero energy homes, to provide fresh air. Unlike an energy recovery ventilator, HRVs transfer only sensible heat and not moisture.

Glossary of Terms

Home Energy Rating System (HERS)
An energy scoring system established by the Residential Energy Services Network (RESNET) which uses a “HERS Reference Home” as a standard for comparing energy efficiency in other homes. Homes built to the specifications of the HERS Reference Home score a HERS Index of 100, while a net zero energy home scores a HERS Index of 0. Each 1-point decrease in the HERS Index corresponds to a 1% reduction in energy consumption compared to the HERS Reference Home. Thus, a home with a HERS Index of 85 is 15% more energy efficient than the HERS Reference Home, and a home with a HERS Index of 80 is 20% more energy efficient.

High Efficiency Furnace

Furnaces that have an Annual Fuel Utilization Efficiency (AFUE) of 85% (oil) and 90% (gas) or higher. In general the higher the AFUE, the more efficient the furnace. The Energy Guide label on the equipment can be consulted to determine whether a furnace is efficient. More information on the Energy Guide label is available at http://www.ftc.gov/opa/2007/08/energy.shtm.

High Efficiency Water Heaters

Water heating models with an ENERGY STAR rating are considered highly efficient. Heat pump water heaters are the most energy efficient water heaters available.

Hot Water Circulation Loop

A water-conservation device that rapidly moves water from a water heater to fixtures. This is desirable when one or more fixtures is a long distance from the water heater. Instead of turning on the hot water tap and running clean water down the drain until hot water arrives, a circulation loop rushes hot water to the fixture. Typically the circulation loop operates continuously or during certain periods of the day controlled by a timer. These typical systems waste energy with unnecessary pump operation and heat loss from the hot water as it circulates around the loop.

An on-demand system uses less energy than continuous or timed pump operation. Hot water recirculation systems can be activated by a push button, or motion sensor. When activated the pump pushes water that has been sitting in the hot water line back to the water heater through the cold water line, while quickly bringing in hot water to the fixture.

Insulated Concrete Forms (ICF)
Rigid plastic foam forms that hold concrete in place during curing and remain in place afterwards to serve as thermal insulation for concrete walls. The foam sections are lightweight and result in energy-efficient, durable construction. The approach decreases the number of breaks in the thermal barrier of the building envelope. It also can save on construction costs because it is fast, especially compared with “stick built” homes.

Indoor Air Quality (IAQ)
A measurement of the overall cleanliness of the air within a building or home. Indoor air may contain a number of contaminants, including carbon monoxide, formaldehyde, mold, lead, volatile organic compounds, and many others. Even water vapor can be considered undesirable when it reaches high levels that support mold and decay. The EPA has a builder program called Indoor airPLUS.

Glossary of Terms

Induction Stove Top
A highly energy efficient electric stove top that heats more quickly and with more precise settings than a gas stove. It uses an electromagnetic field to heat the metal pan directly, so the stove top stays relatively cool, making it easy to clean up spills and less likely to burn skin.

Inverter
Used with solar PV systems, inverters are necessary to change the direct current (DC) produced by the solar panels into alternating current (AC) that can be used in the home and sent to the grid. Grid-tied inverters also include safety measures to protect the grid during power outages. Stand-alone inverters work with off-grid homes.

Insulation – Blown-In
Fiberglass, cellulose, or wool insulation that is blown into building cavities. It is often easier to install than batts of fiberglass insulation. Blown-in insulation fills cavities completely with less chance for gaps and other flaws.

Insulation – Spray Foam
Insulation that is sprayed into place and then expands to fill cavities. It both insulates and seals air leaks. It can be used to replace standard insulation batts or in combination with other types of insulation to optimize costs and benefits. The two types of spray foam are open cell (low-density) and closed cell (high-density). Closed cell foams typically have a higher R-value and are more vapor impermeable compared to open-cell foam.

LEED (Leadership in Energy and Environmental Design)
The green building certification program created by the United States Green Building Council (USGBC). The comprehensive rating system (based on prerequisites and points) takes a whole building approach factoring in community resources & public transit, site characteristics, water efficiency, energy efficiency, materials & resources, indoor environmental quality, awareness & education, and innovation.

LED (Light-Emitting Diode) Lamp
A semiconductor device that emits light when a current passes through it. LEDs are highly efficient and last longer than any other commercially available light source. Unlike CFLs, they contain no mercury.

Living Building Challenge
The International Living Future Institute has created the most rigorous performance standards for homes and buildings, called Living Building Challenge. Their standards call for the construction of buildings that operate as cleanly, beautifully, and efficiently as nature's architecture. To be certified under the Challenge, buildings must meet a series of stringent performance requirements, such as zero net energy and zero off-site water use. Monitoring is required over a minimum of 12 months of continuous occupancy.

Low Flow Toilet
A toilet that combines efficiency and high performance. The toilet must average no more than 1.28 gallons per flush. Design advances enable these toilets to save water with no trade-off in flushing effectiveness. Such toilets often have the EPA's WaterSense label.

Glossary of Terms

Low Flow Fixture
A faucet with aerator installed to reduce the flow of water but not reduce water pressure. A low-flow showerhead uses 2.0 gallons per minute (GPM) or less. A faucet uses 1.5 GPM or less. However, some products have lower flow rates.

Mini-Split Heat Pump
A type of air source heat pump with an outdoor unit to exchange heat and indoor unit to deliver conditioned air to the living space. Refrigerant moves through tubes between the units. In smaller systems, one outdoor unit drives a single indoor unit. In other cases, one outdoor unit can drive two to four indoor units. They are very quiet and provide very even heating. Mini-splits are distinguished from central split-system heat pumps in several ways. First, capacity is smaller, ranging from 8,000 BTUs per hour to 24,000 BTUs per hour. Second, each indoor unit serves a small area, so multiple indoor units may be needed for larger homes. Third, duct work is generally not used, although sometimes short ducts may be installed inside the conditioned space of the building. Fourth, current models use an inverter-drive compressor that provides variable speed operation to match output to the need of the conditioned space. Fifth, the most energy efficient mini-splits can be up to 400% efficient, exceeding the most efficient central heat pumps. Sixth, mini-splits operate efficiently at very low outdoor temperatures. Sometimes they are called ductless heat pumps.

Net Metering
A method for giving credit for excess electricity produced by a consumer's home, often by means of solar panels. In most zero energy homes, the excess energy produced in the summer goes to the utility grid and credit is given, via net metering, for the energy supplied. Then in the winter, the home can use the credit to power the home without an energy bill. Net metering arrangements vary widely between locations and must be thoroughly researched before undertaking a zero energy home project.

Passive House Standard
A voluntary international building standard developed by the Passive House Institute (PHI). The Passive House Standard is composed of several strict performance requirements for new building construction, including a roughly 90% reduction in heating and cooling energy usage in new construction, and up to a 75% reduction in primary energy usage from existing building stock. These strict standards must be met using passive design measures before any renewable energy, such as photovoltaic panels, are added.

Passive Solar
A type of design which takes maximum advantage of the sun's energy to help warm the living space in winter and helps to redirect or block the sun's energy to reduce cooling needs in the summer. Passive systems rely on the building structure to achieve greater efficiency and comfort, as compared to active systems that use mechanical devices and energy inputs to increase efficiency. Solar water heaters or photovoltaic systems are examples of active systems.

Glossary of Terms

Photovoltaic (PV)
This system captures light from the sun and converts it into electricity through solar panels usually installed on roofs, ground-mounted systems, or "carport" structures over parking.

Programmable Thermostat
Programmable thermostats save energy by permitting occupants to set temperatures according to whether the house is occupied and allowing homeowners to set the temperature at different levels at different times of day. For example, in winter, it could be set to be colder while occupants sleep and warmer as occupants awaken. These thermostats typically have a digital interface that allows more precise temperature control and a wider range of options or features for saving energy.

Radiant Barrier
A barrier, installed on the underside of roof sheathing in warm or hot climates to reflect some of the sun's radiant heat energy so it does not enter the attic. Radiant barriers can also help prevent winter heat loss from the home. Radiant barriers are most useful in cooling-dominated climates where summer heat gain is a greater concern that winter heat loss.

Radiant Heated Floors
A way to heat spaces using radiant energy that is emitted from a heat source. There are three types of radiant floor heat: radiant air floors (air is the heat-carrying medium); electric radiant floors; and hot water (hydronic) radiant floors. Hydronic radiant floors are the most energy efficient.

Radiant Floors – Hydronic
A popular and cost-effective choice that pumps heated water from a boiler through tubing underneath the floor. In some systems, the temperature in each room is controlled by regulating the flow of hot water through each tubing loop. This is done by a system of zoning valves or pumps and thermostats. The most efficient source of hot water for hydronic radiant floors is a ground source heat pump in most applications.

Retrofitting
Adding new energy efficient features, such as added insulation or solar collectors, either in a new home after completion or in an existing home.

R-Value
R-value indicates an insulation material's resistance to heat flow. The higher the R-value, the greater the insulating effectiveness. This is the inverse of U-value, which is used for rating windows.

Sealed Combustion Fireplace / Wood Stove
A sealed combustion fireplace or woodstove gets its combustion air from outside of the home and exhausts 100 percent of the combustion by-products to the outside. This eliminates the likelihood of "backdrafting," a situation in which combustion gases are pulled back into the home and cause health problems. It also eliminates the use of heated indoor air for combustion and sending it up the chimney.

Glossary of Terms

Sealed Ducting
A way to save energy, improve indoor air quality and avoid moisture damage by sealing all the seams in newly installed ductwork or by sealing improperly installed existing ducts. Duct mastic is a paste-like sealant that is applied with a brush or a gloved hand for sealing ducts.

SEER Rating
Seasonal Energy Efficiency Ratio (SEER) is a rating system used to measure the efficiency of central air conditioners and air source heat pumps. The higher the rating, the more energy efficient it is. For reference, air conditioners that are 14 or higher SEER meet ENERGY STAR criteria.

Structured Insulated Panels (SIP)
Panels made from a thick layer of foam (polystyrene or polyurethane) sandwiched between two layers of oriented strand board (OSB), plywood or fiber-cement. SIPS are often used in panelized construction and timber-frame buildings. The result is an engineered panel that provides structural framing, insulation, and exterior sheathing in a single, solid component.

Solar Hot Water
Solar thermal collectors on the roof supplement (but do not exclusively supply) the hot water to the home. Water pre-heated by solar energy is piped into the hot water heater so that less energy is required to bring the water up to the temperature setting of the conventional water heater. Solar water heaters can reduce water heating energy by around 80 percent for a family. Except in homes with many inhabitants who use a great deal of hot water, it is more cost effective to install a heat pump water heater or power a standard electric water heater with solar PV.

Solar Orientation
In northern latitudes, a home that is oriented toward the south will capture the sun's heat during the winter, but will be shielded from overheating during the summer. Southern exposure also increases the amount of natural daylight that can be gathered by windows. Solar orientation is a key element of passive solar design.

Spray Foam Insulation
See "Insulation—Spray Foam".

Sunscreens
External awnings, overhangs, and plantings or internal window treatments or shades, which effectively block the sun's heat in summer, while allowing it to enter in winter.

Glossary of Terms

Sustainable Resources
Resources that are renewable or recyclable and are used in ways that do not deplete the supply, so future generations can use the same materials.

Sustainable Flooring
Flooring made from bamboo, cork, reclaimed wood, or other rapidly renewable wood sources.

Tankless Water Heater
A system that delivers hot water at a preset temperature when needed, but without requiring the storage of water. Tankless water heaters have an electric, gas, or propane heating device that is activated by the flow of water. The approach reduces or eliminates energy standby losses. Tankless water heaters can be used for supplementary heat, such as a booster to a solar hot water system, or to meet all hot water needs.

Thermal Barrier
When the building envelope is insulated and air-sealed it acts as a thermal barrier – keeping cold air out and warm air inside in winter.

Triple Pane Windows
Triple pane glass windows often contain argon, krypton, or other gases between 3 panes to reduce heat flow and improve insulation. The middle pane may be glass or a plastic film.

U-Value
Also called U-factor, this is the rate of heat flow expressed as a decimal number. Higher numbers mean greater heat loss. U-value is used to express the energy performance of windows. Zero energy homes often have windows with U-values between 0.15 to 0.24. U-value is the reciprocal of R-value.

VOCs (volatile organic compounds)
Organic gases with harmful effects on air quality and health. VOCs are frequently associated with paint, pesticides, carpets, and adhesives. They are often the carrier chemicals that evaporate as the product cures. VOCs can be released into the air for months or even years after a product is installed. The VOC content of paints, coatings, finishes, adhesives and sealants is listed on the product label in grams per liter. In some products, VOCs can reach zero, while others still contain VOCs at a reduced level. To be considered low-VOC, interior or exterior house paint would need to be 50 grams per liter or less.

Water Footprint
An estimation of the amount of water used in a building.

Xeriscaping
A landscaping method used in drier areas that incorporates native plants that can tolerate infrequent watering.

Glossary of Terms

Zero Energy Building
A building that uses as much energy as it produces. The building is made as air-tight and well-insulated as possible and uses highly energy efficient heating and cooling systems, hot water system and appliances. After all the energy saving measures have been taken, sufficient on-site renewable energy generation (typically solar pv panels) are added to balance the amount of energy produced with the amount of energy used over the course of a year.

Zero Energy Ready Building
A zero energy ready building is one that is built to the same energy saving standards as a zero energy building and has the roof space and all the fixtures installed ready for solar installation. However, the solar panels and inverter are not installed at the time of construction. It is ready for solar collectors that can easily be installed at a later day.

Section A2

Climate Adaptive Tree Species

(A document by the National Institute of Applied Climate Science of the USDA Forest Service)

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CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES

DRIFTLESS AREA (ECOLOGICAL SECTION 222L)

Midwestern forests will be affected by climate change during this century. Several reports describe the climate change risks to the region's forests and natural communities (WICCI 2017, Handler 2012). Foresters and researchers can use experience and information from past events to develop expectations about how future change might affect forests, but there are limits to what we can learn from the past. For example, future climate change may be beyond what has been experienced in recent centuries. Tools like computer models can help provide answers by testing scenarios that haven't been experienced before.

Remember that models are just tools, and they're not perfect. Models don't account for some factors that could be modified by climate change, like droughts, wildfire activity, and invasive species. If a species is rare or confined to a small area, Tree Atlas results may also be less reliable. These factors, and others, could cause a particular species to perform better or worse than a model projects. Human choices will also continue to influence forest distribution, especially for tree species that are projected to increase. Planting programs may assist the movement of future-adapted species, but this will depend on management decisions.

TREE SPECIES INFORMATION:

The "Tree Atlas" tool uses climate scenarios and current distribution information to project future habitat suitability for individual tree species (Landscape Change Research Group 2014). This page shows the most common tree species in this local area, organized into general categories of future expectations. Full results for all species for two climate scenarios can be compared side-by-side on page 2 to get a sense for the range of possible outcomes.

Despite these limits, models provide useful information about future expectations. It's perhaps best to think of these projections as indicators of possibility and potential change. The model results presented here can be combined with information from published reports and local management expertise to draw conclusions about potential risk and change in the Driftless Area.

SPECIES	ADDITIONAL CONSIDERATIONS
LIKELY TO DECREASE	
Bigtooth aspen	Early-sucessional colonizer, but susceptible to drought
Eastern white pine	Good disperser, but susceptible to drought and insects
Northern pin oak	Tolerates drought and fire
Northern red oak	Susceptible to some insect pests and oak wilt
Paper birch	Early-sucessional colonizer, but susceptible to insects and drought
Quaking aspen	Early-sucessional colonizer, but susceptible to heat and drought
Red maple	Competitive colonizer tolerant of disturbance and diverse sites
Red pine	Susceptible to insect pests and diseases, and limited dispersal.
MAY DECREASE	
American basswood	Tolerates shade but susceptible to fire
Sugar maple	Grows across a variety of sites and tolerates shade
White oak	Fire-adapted and grows on a variety of sites
MIXED MODEL RESULTS	
Black cherry	Susceptible to insects and fire, tolerates some drought
Ironwood	Grows across a variety of sites and tolerates shade

SPECIES	ADDITIONAL CONSIDERATIONS
NO CHANGE	
Black oak	Tolerates drought, but susceptible to pests and diseases
Bur oak	Tolerates drought and fire
Slippery elm	Affected by Dutch elm disease, but tolerates shade
MAY INCREASE	
American elm	Affected by Dutch elm disease, grows across a variety of sites
Bitternut hickory	Tolerates some drought, but not shade
Black walnut	Doesn't tolerate drought or shade
Black willow	Susceptible to drought and fire
Boxelder	Tolerates drought, also disperses and establishes well
Eastern redcedar	Tolerates drought, but susceptible to fire and insect pests
Green ash	Emerald ash borer causes mortality
Hackberry	Tolerates drought, but susceptible to fire
Shagbark hickory	Susceptible to insects and fire
Silver maple	Good disperser and tolerates wet soils, but vulnerable to drought
White ash	Emerald ash borer causes mortality

NIACS Northern Institute of Applied Climate Science

www.forestadaptation.org

Get this handout online at: www.forestadaptation.org/Northwoods_treehandouts

FUTURE PROJECTIONS

Data for the end of the century are summarized for the Climate Change Tree Atlas (www.fs.fed.us/nrs/atlas) under two climate change scenarios. Tree Atlas models future suitable habitat.

▲ **INCREASE**
Projected increase of >20% by 2100

● **NO CHANGE**
Little change (<20%) projected by 2100

▼ **DECREASE**
Projected decrease of >20% by 2100

★ **NEW HABITAT**
Tree Atlas projects new habitat for species not currently present

ADAPTABILITY

Factors not included in the model, such as the ability to respond favorably to disturbance, may make a species more or less able to adapt to future stressors.

\+ high
Species may perform better than modeled

· medium

– low
Species may perform worse than modeled

SPECIES	LOW CLIMATE CHANGE (PCM B1)	HIGH CLIMATE CHANGE (HAD A1FI)	ADAPT
American basswood	●	▼	·
American beech	▲	●	·
American elm	▲	●	·
American hornbeam	▼	●	·
Balsam poplar	★	★	·
Bigtooth aspen	▼	▼	·
Bitternut hickory	▲	●	+
Black ash	▼	▼	–
Black cherry	▲	▼	–
Black hickory		★	·
Black locust	▲	▲	·
Black maple	▼	▼	·
Black oak	●	●	·
Black walnut	▲	▲	·
Black willow	▲	▲	–
Blackjack oak		★	+
Boxelder	▲	▲	+
Bur oak	●	●	+
Butternut	▼	▼	–
Cedar elm		★	·
Chestnut oak	★	★	+
Chinkapin oak	★	★	·
Chokecherry	▲	●	·
Common persimmon	★	★	+
Eastern cottonwood	▲	▲	·
Eastern redbud	★	★	·
Eastern redcedar	▲	▲	·
Eastern white pine	▼	▼	·
Flowering dogwood	★	★	·
Green ash	●	▲	·
Hackberry	▲	▲	+
Honeylocust	▲	▲	+
Ironwood	▲	▼	+
Jack pine	▼	▼	·
Kentucky coffeetree		★	·

SPECIES	LOW CLIMATE CHANGE (PCM B1)	HIGH CLIMATE CHANGE (HAD A1FI)	ADAPT
Mockernut hickory	★	★	+
Northern catalpa		★	·
Northern pin oak	▼	▼	+
Northern red oak	▼	▼	+
Ohio buckeye	★	★	·
Osage-orange	▲	▲	+
Paper birch	▼	▼	·
Pawpaw	★	★	·
Peachleaf willow		★	·
Pecan		★	–
Pignut hickory	★	★	·
Pin oak	★	★	–
Post oak	★	★	+
Quaking aspen	▼	▼	·
Red maple	▼	▼	+
Red mulberry	▲	▲	·
Red pine	▼	▼	·
River birch	▲	▲	·
Sassafras	★	★	·
Shagbark hickory	▲	●	·
Shellbark hickory	★	★	·
Shingle oak	★	★	·
Silver maple	▲	▲	+
Slippery elm	●	●	·
Sugar maple	●	▼	+
Sugarberry		★	·
Swamp white oak	▲	▲	·
Sycamore	★	★	·
Tamarack	▼	▼	–
Water oak		★	
Waterlocust		★	
White ash	▲	▲	–
White oak	●	▼	+
Wild plum	▲	▲	·
Winged elm		★	·
Yellow-poplar	★	★	+

RESOURCES: Handler, S.D., et al., 2012. Climate change vulnerabilities within the forestry sector for the Midwestern United States. In: U.S. National Climate Assessment Midwest Technical Input Report. J. Winkler, J. Andresen, J. Hatfield, D. Bidwell, and D. Brown, coordinators. **www.glisa.umich.edu/media/files/NCA/MTIT_Forestry.pdf**

Landscape Change Research Group. 2014. Climate Change Atlas. Northern Research Station, U.S. Forest Service, Delaware, OH. **www.fs.fed.us/nrs/atlas/**

Wisconsin Initiative on Change Impacts [WICCI]. 2017. Climate Vulnerability Assessments for Plant Communities of Wisconsin. Wisconsin Initiative on Climate Change Impacts, Madison, WI. **www.wicci.wisc.edu/plants-and-natural-communities-working-group.php**

Section A3

Selecting Cool Roof and Cool Pavement Materials

(Excerpt from Global Cool Cities Alliance's "A Practical Guide to Cool Roofs and Cool Pavements")

https://coolrooftoolkit.org/wp-content/pdfs/CoolRoofToolkit_Full.pdf

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Choosing a Cool Roof

The cool roof options available to a building owner depend in large part on the building and roof type they are working with. That said, there is a cool option for nearly every type of roof. Cool roofs are relatively easy to implement for commercial buildings. The roofs of most commercial and high-rise residential buildings are low-sloped (i.e., almost flat),[28] and are generally not visible from the street. As a consequence, there is little resistance or cost to changing the color of these roofs during routine retrofits or when waterproofing.

In contrast, residential buildings often have steep-sloped roofs that can be seen from the ground. In many parts of the world, white is not currently a popular color for residential roofs, and as a result there can be aesthetic concerns about using white materials. To address this, roofing manufacturers have developed "cool" materials in popular roof colors (e.g., red and gray) that strongly reflect the invisible heat component of sunlight and much of the sun's energy away from the building.[29]

The desirability of cool roofs depends on latitude, altitude, annual heating load, annual cooling load, peak energy demands, and sun blockage by trees, buildings, and hills for the particular building. Cool roofs on buildings in some far northern communities such as Anchorage, Alaska or in forested mountainous areas such as at Lake Tahoe, Nevada, may not be appropriate. That said, whether or not a cool roof is appropriate in any climate depends on the building, its energy usage pattern, existing needs, and costs.

Caution: Mind your surroundings

Cool roofs must be considered in the context of their surroundings. It is relatively easy to specify a cool roof and predict energy savings, but some thinking ahead can prevent other headaches. Ask this question before installing a cool roof: *Where will the reflected sunlight go?* A bright roof could reflect into the higher windows of taller neighboring buildings. In sunny conditions, this could cause uncomfortable glare and unwanted heat for you or your neighbors. In these cases, building owners can opt for a cool colored roof to provide some improvement in reflectance without significantly affecting neighboring buildings.

Common Building Types and Roofing Materials

Cool roofing options are available for all standard roofing materials. (See table on page 24).

A flat-roofed commercial building in Shenzhen. Photo: dcmaster

Red tile roofs in Dubrovnik. Photo: Marcel Oosterwijk

A steep-sloped single family home with asphalt roof shingles in the U.S. Photo: Eric Allix Rogers

Multi-story buildings with concrete or cement roofs are common in India. Photo: John Roberts

Corrugated metal roofs in Rio de Janeiro. Photo: whl.travel

Urban rooftops in Mexico City. Photo: Storkholm Photography

Cool colors

White is the “coolest” color, but there are cool versions of a wide variety of popular colors. Building owners have more choice than they realize. Highly reflective roofs can come in popular colors such as red, green, and gray. Cool colored materials are available for all types of steep-sloped (pitched) and low-sloped (nearly horizontal) roofs. These materials include asphalt shingles, metal, clay tiles, and concrete tiles. Highly reflective colored roofs typically have an initial solar reflectance 0.30 to 0.55, compared with around 0.10 for conventional dark steep-sloped roofs.

Cool colored metal roofs. Photo: Custom Bilt Metals

Cool roofs come in many colors.
Many roof materials in any color can be treated with a reflective coating, giving them a higher solar reflectance than the standard version of that material.

Standard Concrete Tiles (SR)	0.04	0.18	0.24	0.33	0.17	0.12
With Cool Coating Applied (SR)	0.41	0.44	0.44	0.48	0.46	0.41

Source: Adapted from data from American Rooftile Coatings.

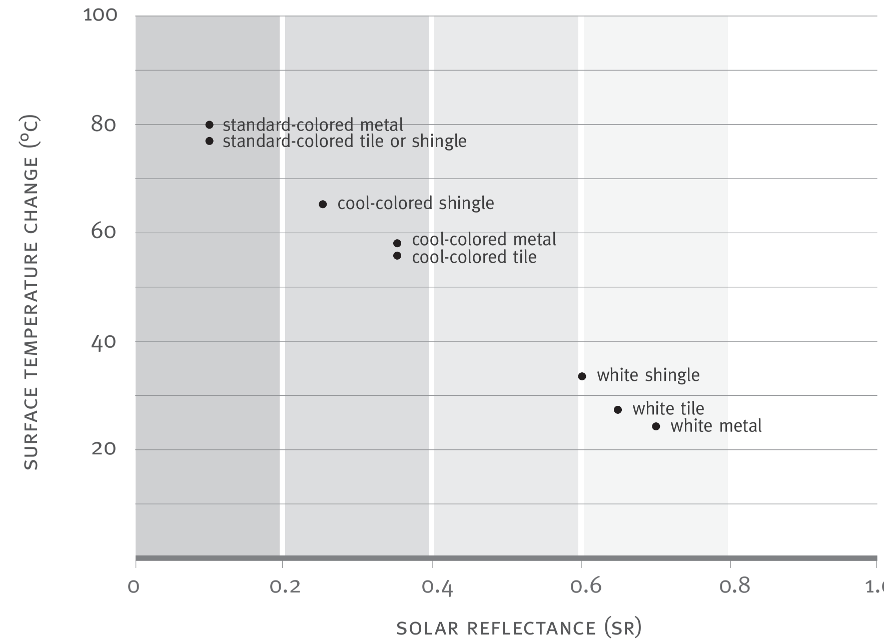
Beware of “paint”

Although many cool roof advocates call for building owners to “paint” their roofs white, using white house paint to coat any kind of roof is inappropriate and ill-advised. Some roof coatings are installed by using rollers like the ones used for indoor house paint, thus it may look like roofs are being “painted.” In fact they are being “coated” with products made specifically for roofs. The major difference between paint and coatings are that paints are typically cosmetic in nature and significantly thinner applications than coatings. Also, coatings are more reliably weather resistant.

Some shingle manufacturers will not honor the warranty of their products if the roof has been painted or coated in any way. Be sure to check with your roof manufacturer before installing a cool roof on top of your existing roof.

In some countries, notably India and Greece, whitewashing homes to keep them cooler in summer months is a long-standing tradition. This is an advisable and appropriate practice for some building materials, depending on availability and cost of more permanent alternatives.

Solar Reflectance of Common Roofing Materials
Surfaces that are more reflective tend to remain cooler than those that are less reflective. Both solar reflectance and (surface) temperature rise should be considered when assessing a cool surface material. The graph shows solar reflectance and temperature rise of common steep-sloped roofing materials (Air temperature is 37 degrees Celsius / 13 degrees Fahrenheit). Source: Adapted from data from LBNL.

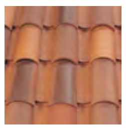
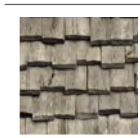


Photos: Creative Commons and LBNL

Uncoated metal | Cool-colored metal (coated) | White metal (coated)

Ceramic tiles | Cool-colored clay tiles | White coating

Common Roofing Materials and Cool Options*

	Roof Type	Life Expectancy (years)	Roof Slope	Non-Cool Roof Options	Non-Cool Roof Solar Reflectance	Cool Roof Options	Cool Roof Solar Reflectance
	**Asphalt Shingle**	15 to 30	steep-sloped	black or dark brown with conventional pigments	0.05–0.15	"white" (actually light gray) or cool color shingle	0.25
	**Built-Up Roof**	10 to 30	low-sloped	with dark gravel	0.10–0.15	with white gravel	0.30–0.50
				with aluminum coating**	0.25–0.60	white smooth coating	0.75–0.85
	**Clay Tile**	50+	steep-sloped	dark color with conventional pigments	0.20	terracotta (unglazed red tile)	0.40
						color with cool pigments	0.40–0.60
						white	0.70
	**Concrete Tile**	30 to 50+	steep-sloped	dark color with conventional pigments	0.05–0.35	color with cool pigments	0.30–0.50
						white	0.70
	**Liquid Applied Coating**	5 to 20	low- or steep-sloped	smooth black	0.05	smooth white	0.70–0.85
	**Metal Roof** Uncoated corrugated metal is typically less durable than coated metal	20 to 50+	low- or steep-sloped	unpainted, corrugated**	0.30–0.50	white painted	0.55–0.70
				dark-painted corrugated	0.05–0.10	color with cool pigments	0.40–0.70
	**Modified Bitumen**	10 to 30	low-sloped	with mineral surface capsheet (SBS, APP)	0.10–0.20	white coating over a mineral surface (SBS, APP)	0.60–0.75
	**Single-Ply Membrane**	10 to 20	low-sloped	black (polyvinyl chloride (PVC) or ethylene propylene diene monomer rubber [EPDM])	0.05	white (PVC or EPDM)	0.70–0.80
						color with cool pigments	0.40–0.60
	**Wood Shake**	15 to 30	steep-sloped	painted dark color with conventional pigments	0.35–0.50	bare	0.40–0.55

Source: Adapted from coolcalifornia.org roofing options table. Photos: Creative Commons and LBNL

* Spray polyurethane foam is not included in this chart because it is typically coated by a reflective liquid applied coating to minimize ultraviolet damage to the foam. ** Aluminum and metal have high solar reflectance but their low thermal emittances reduces their ability to stay cool.

What happens as the surface ages?

Over time, white roofs get dirty; they collect soot, dust, salt, and, in some climates, biological growth. As a result, their reflectance decreases. The aged solar reflectance of a white roof is typically 0.55 to 0.65. Replacing a dark roof with an aged white roof still reduces the amount of sunlight absorbed by around 40 to 50 percent. Codes and standards typically use the aged SR value of white roofs.

The reflectivity of pavements also changes as they age. Concrete pavement tends to be initially more reflective and get darker with age and use. Dark asphalt pavement tends to lighten to a gray color over time. Despite this convergence in reflectivity, concrete typically remains more reflective than asphalt pavements.

Rating products

Most countries have enacted some voluntary or mandatory codes and standards for buildings and energy use. Some of these include language covering cool roofs and pavements. In order for codes to be effective, there must be a broadly accepted rating and labeling system for materials.

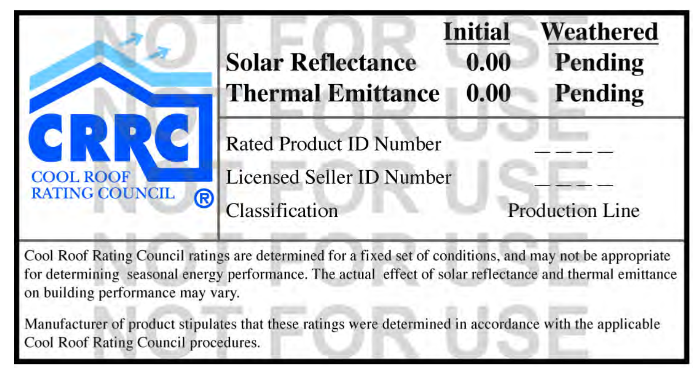
Determining both the initial and aged solar reflectance of a given material or roofing product requires testing. In the U.S., the Cool Roof Rating Council (CRRC) has been established as an independent, non-profit organization that maintains a third-party rating program, which rates and publishes a roof product's solar reflectance and thermal emittance. The CRRC allows standardized test methods as agreed to under the American Society for Testing and Materials (ASTM). Once a product is rated the results are published on CRRC's online Rated Products Directory and given a label with the results (see sample below). Manufacturers are encouraged to list their roofing products in the CRRC Rated Product Directory; in order to do so, they must follow the CRRC Product Rating Program Manual (CRRC-1) testing method. Since all roofing products can be rated by CRRC, consumers and builders should use the CRRC label to identify which roof products meet their purchasing objectives (e.g., qualifying for ENERGY STAR certification, meeting building code requirements, and/or qualifying for utility rebates).

All products that have been tested by the CRRC are listed in their online directory, which can be found at coolroofs.org/products/search.php.

A product's inclusion in the Directory does not mean that the product is "cool" as defined by any particular code body or program.

A European Cool Roofs Council was established recently to begin to establish testing infrastructure for cool roofs in Europe. Their website is coolroofs-eu-crc.eu. Similar initiatives are underway in India, China, Japan, Brazil, Thailand, and Australia.

Applying white coating to a roof in China. Photo: United Coatings



An example of a CRRC label. Source: CRRC.

How cool is cool?

Any shift along the solar reflectance continuum towards more reflective materials will create benefits from an energy savings, local cooling, and global cooling perspective. However, for codes and standards to be effective and useful, they need to establish a threshold value for compliance. Cool roof requirements have been included in a number of mandatory and voluntary standards. See the Building Codes and Standards Table on page 72 for further information.

Choosing Cool Pavements

A range of materials are available for standard paving needs. Pavement criteria can vary greatly depending on the use. Highways, highway shoulders, municipal streets, parking lots, sidewalks, playgrounds, driveways, bridge decks, and plazas all have specific functionality requirements that can be met by a range of cool pavement options. Many kinds of permeable pavements, including pervious concrete, porous asphalt, and reinforced grass pavements, are also considered cool because they can cool a pavement surface through the evaporation of moisture stored in the pavement. Permeable pavements have the added benefit of providing storm-water management. Some common pavement types are described in the table on the facing page.

In Chicago there are 1,900 miles of alleyways, only part of the total 3,500 acres of impermeable surfaces in the city. Photo: City of Chicago

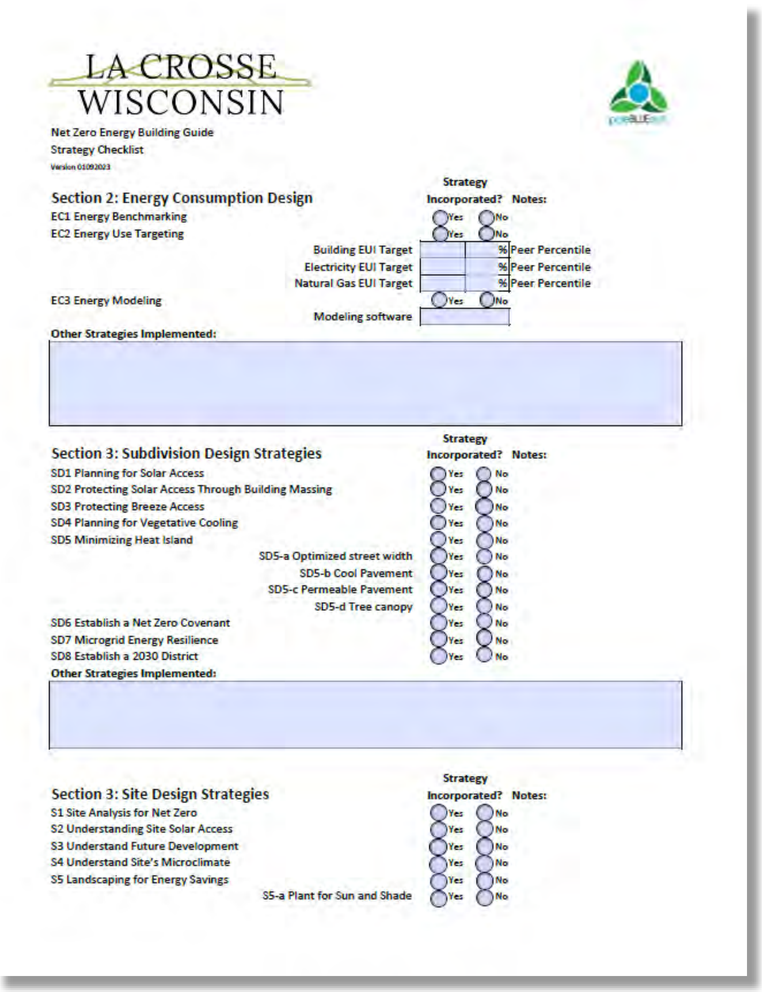
Cool Pavement Materials

Pavement type	Solar Reflectance (SR)	Uses	Pavement surface life
Clear Resin Binders	Depends on aggregate	New construction & maintenance for streets, sidewalks, parking lots, etc.	20 years
Coatings (e.g., cementitious coating, elastomeric coating)	New: 35–55%	Coatings for preventive maintenance for streets, driveways, parking lots, etc.	1 to 5
Light-Colored Aggregates (e.g., chip seal)	Depends on aggregate	Overlay for preventive maintenance for highways, streets, parking lots	2 to 5 years
Light-Colored Cement (e.g., slag, white cement)	New: 70–80%	New construction & maintenance for highways, streets, sidewalks, parking lots, etc.	40 years
Porous Asphalt Cement (AC), Pervious Portland Cement Concrete (PCC), & Reinforced Grass Pavements	Depends on pavement type	New construction, to aid with stormwater management	varies
Portland Cement Concrete (PCC)	New (gray cement): 35–50% Aged (gray cement): 20–35%	New construction & maintenance for highways, streets, sidewalks, parking lots, etc.	40 years

Source: Adapted from LBNL common pavement types table.

Section A4

NZE Guide Checklist



LA CROSSE WISCONSIN

Net Zero Energy Building Guide
Strategy Checklist
Version 01092023

Section 2: Energy Consumption Design — Strategy Incorporated? — Notes:

EC1 Energy Benchmarking	Yes	No	
EC2 Energy Use Targeting	Yes	No	
Building EUI Target		%	Peer Percentile
Electricity EUI Target		%	Peer Percentile
Natural Gas EUI Target		%	Peer Percentile
EC3 Energy Modeling	Yes	No	
Modeling software			

Other Strategies Implemented:

Section 3: Subdivision Design Strategies — Strategy Incorporated? — Notes:

SD1 Planning for Solar Access	Yes	No
SD2 Protecting Solar Access Through Building Massing	Yes	No
SD3 Protecting Breeze Access	Yes	No
SD4 Planning for Vegetative Cooling	Yes	No
SD5 Minimizing Heat Island	Yes	No
SD5-a Optimized street width	Yes	No
SD5-b Cool Pavement	Yes	No
SD5-c Permeable Pavement	Yes	No
SD5-d Tree canopy	Yes	No
SD6 Establish a Net Zero Covenant	Yes	No
SD7 Microgrid Energy Resilience	Yes	No
SD8 Establish a 2030 District	Yes	No

Other Strategies Implemented:

Section 3: Site Design Strategies — Strategy Incorporated? — Notes:

S1 Site Analysis for Net Zero	Yes	No
S2 Understanding Site Solar Access	Yes	No
S3 Understand Future Development	Yes	No
S4 Understand Site's Microclimate	Yes	No
S5 Landscaping for Energy Savings	Yes	No
S5-a Plant for Sun and Shade	Yes	No

This guide includes a strategy checklist. The checklist provides a working format for building owners, designers, or contractors to track the strategies which are incorporated into their projects.

All of the strategies outlined in this guide are included in the NZE Strategy Checklist.

The NZE Strategy Checklist can be found here:
https://palebluedot.llc/lacrosse-net-zero-energy-guide

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