Net-Zero Building Design

Comprehensive design requirements guide for new building construction and renovations

Version 1.0 | March 2023

Welcome

Net-zero building design is essential for Thermo Fisher Scientific to achieve net-zero emissions by 2050.

This comprehensive design guide for our suppliers is intended to inform the design and construction process, establish base expectations, help track performance, and ultimately ensure that new building construction and renovations are developed with a net-zero emissions approach.

The world's leading scientists have sent a clear message that urgent action is needed to avoid the worst impact of climate change. This means limiting global temperature increase to 1.5˚C above pre-industrial levels – the most ambitious aim of the Paris Agreement.

Thermo Fisher has established a target whereby 90% of our suppliers (by spend) will set science-based targets by 2027. With this target we are holding our suppliers to the same level of ambition we are setting for ourselves.

For more information, please email Supplier.Responsibility@thermofisher.com.

Table of Contents

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Introduction

Introduction
Company Commitments

As the world leader in serving science, Thermo Fisher is committed to sustainability and aligned with the scientific community's findings on human contributions to climate change.

Thermo Fisher operates in 52 countries around the world, many of which are attempting to reduce their greenhouse gas emissions with current or emerging regulations.

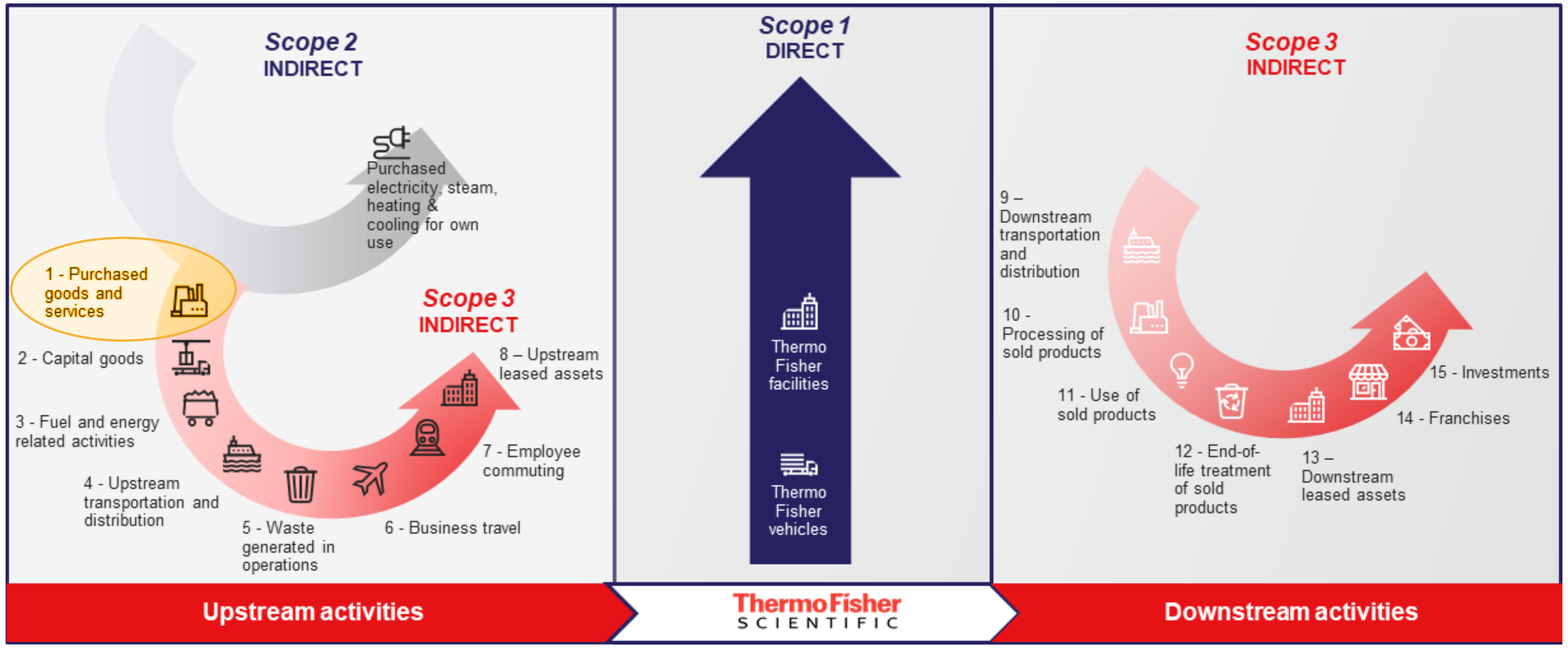
Thermo Fisher is a signatory to the United Nations (UN) Global Compact, a voluntary leadership platform for responsible business practices, and has disclosed the company's global greenhouse gas emissions through annual reporting to the Carbon Disclosure Project (CDP) since 2010.

The annual Corporate Social Responsibility (CSR) Report reflects Thermo Fisher's commitment to society, to stakeholders, and to environmental, social and governance issues. Thermo Fisher is deeply committed to taking action that addresses the UN Sustainable Development Goals (SDGs) with strategic alignment on SDG 13 – Climate Action – taking urgent action to combat climate change and its impacts.

Lowering our Scope 3 emissions, particularly from Purchased Goods and Services, requires our suppliers to reduce their Scope 1 and 2 emissions. This guide demonstrates how suppliers can reduce their Scope 1 and 2 emissions in their operations, driving collective impact across the value chain.

Our path to net-zero

- Reduce Scope 1 + Scope 2 greenhouse gas emissions globally by 50% of 2018 levels by 2030
- 90% of our suppliers (by spend) will set science-based targets by 2027
- Achieve net-zero emissions by 2050



Source: Greenhouse Gas Protocol, WRI, Science Based Target initiative

"Our responsibility to society extends to protecting the planet. We recently committed to achieving net-zero emissions by 2050, in addition to our earlier commitment to reduce our greenhouse gas emissions by 50% by 2030. We're making progress by reducing energy use in our facilities, developing greener products and helping our customers achieve their own environmental stewardship goals."

- Marc N. Casper, Chairman, President and CEO

https://corporate.thermofisher.com/us/en/index/corporate-social-responsibility/environment/performance-and-disclosures.html
https://www.epa.gov/climateleadership/scope-1-and-scope-2-inventory-guidance
https://thermofisher.sharepoint.com/sites/Sustainability/SitePages/2030-Vision.aspx

Introduction
Purpose of Guide

This document provides design guidance for suppliers who are expanding or upgrading their physical footprints; including the build-out of offices, laboratories, distribution centers, and manufacturing facilities around the world.

As Thermo Fisher expects suppliers to set science-based greenhouse gas emissions reduction targets in line with our SBTi goal, we understand that some suppliers may be less familiar with how to reduce their emissions from operations. As such, we have modified our internal Net Zero Building Design Guide and now offer this as a free resource to our suppliers. We recommend that this guide be shared with architects, contractors, facilities managers, manufacturing equipment buyers, etc., to minimize energy use and replace fossil fuels and high emitting refrigerants that contribute to greenhouse gas emissions.

Thermo Fisher supports building to green building standards, such as LEED. Use of this guide can support the pursuit of a LEED Green Building certification, and while Thermo Fisher supports building to the standards of the LEED rating system, the decision to pursue a LEED certification is made by each business or project team.

Scope of Guide
Operational greenhouse emissions reduction for Scope 1 + Scope 2

Applicability
New construction, renovations and asset management at all Thermo Fisher locations around the world

Responsibility
Project Manager and project team at Thermo Fisher oversee the design team

Requirements
All local codes, laws and regulations must be followed where more stringent.

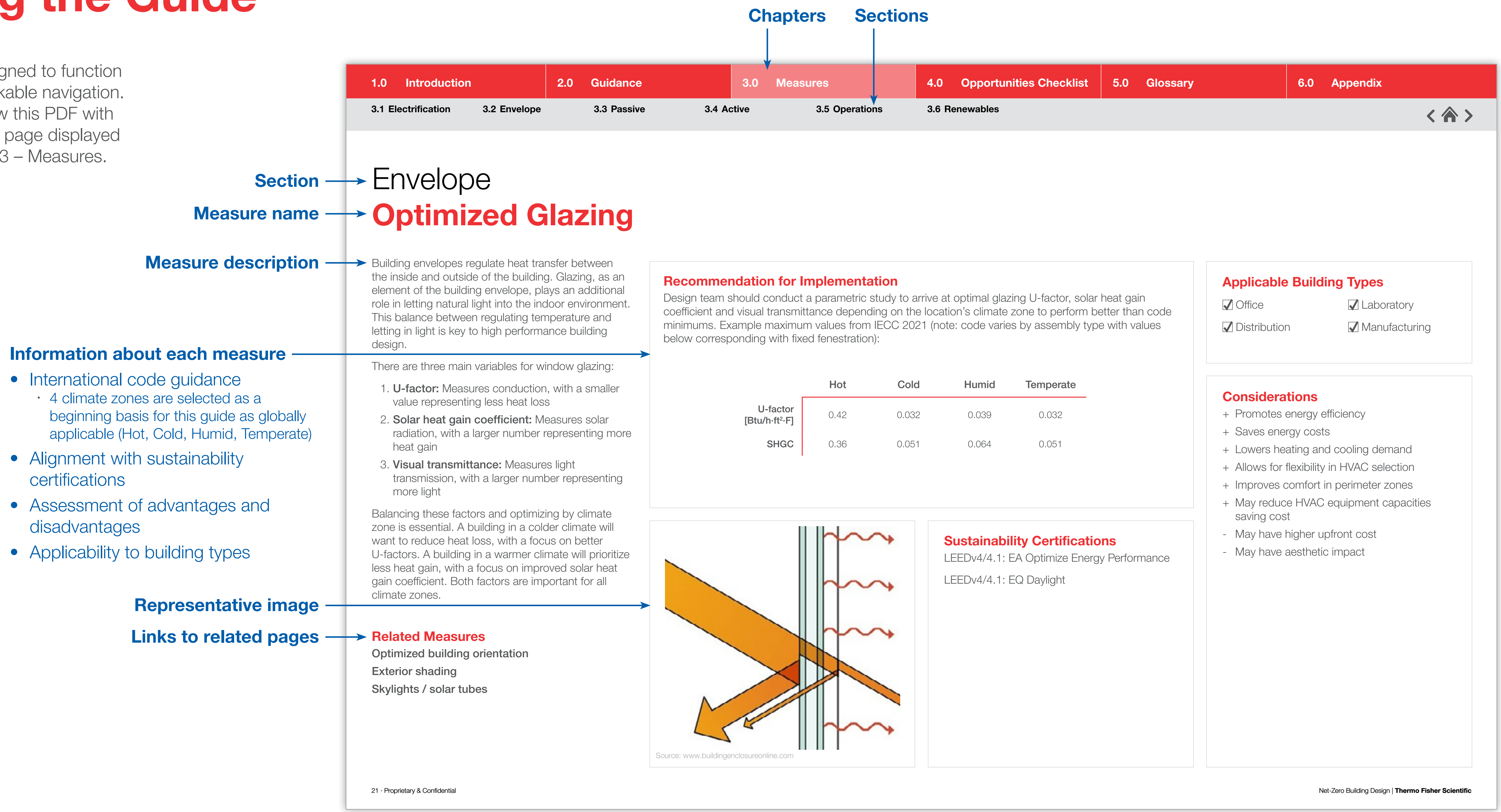
Objective
Inform design and construction process, establish base expectations, track performance and ensure buildings are designed and constructed in line with commitments

2.0

Guidance

Guidance
Navigating the Guide

This interactive guide is designed to function similar to a website with clickable navigation. For the best experience, view this PDF with Adobe Acrobat. The sample page displayed on the right is from Chapter 3 – Measures.



1.0 Introduction | 2.0 Guidance | 3.0 Measures | 4.0 Opportunities Checklist | 5.0 Glossary | 6.0 Appendix
3.1 Electrification | 3.2 Envelope | 3.3 Passive | 3.4 Active | 3.5 Operations | 3.6 Renewables

Envelope
Optimized Glazing

Building envelopes regulate heat transfer between the inside and outside of the building. Glazing, as an element of the building envelope, plays an additional role in letting natural light into the indoor environment. This balance between regulating temperature and letting in light is key to high performance building design.

There are three main variables for window glazing:

1. **U-factor:** Measures conduction, with a smaller value representing less heat loss
2. **Solar heat gain coefficient:** Measures solar radiation, with a larger number representing more heat gain
3. **Visual transmittance:** Measures light transmission, with a larger number representing more light

Balancing these factors and optimizing by climate zone is essential. A building in a colder climate will want to reduce heat loss, with a focus on better U-factors. A building in a warmer climate will prioritize less heat gain, with a focus on improved solar heat gain coefficient. Both factors are important for all climate zones.

Related Measures
Optimized building orientation
Exterior shading
Skylights / solar tubes

Recommendation for Implementation
Design team should conduct a parametric study to arrive at optimal glazing U-factor, solar heat gain coefficient and visual transmittance depending on the location's climate zone to perform better than code minimums. Example maximum values from IECC 2021 (note: code varies by assembly type with values below corresponding with fixed fenestration):

	Hot	Cold	Humid	Temperate
U-factor [Btu/h-ft²-F]	0.42	0.032	0.039	0.032
SHGC	0.36	0.051	0.064	0.051

Source: www.buildingenclosureonline.com

Sustainability Certifications
LEEDv4/4.1: EA Optimize Energy Performance
LEEDv4/4.1: EQ Daylight

Applicable Building Types
☑ Office ☑ Laboratory
☑ Distribution ☑ Manufacturing

Considerations
+ Promotes energy efficiency
+ Saves energy costs
+ Lowers heating and cooling demand
+ Allows for flexibility in HVAC selection
+ Improves comfort in perimeter zones
+ May reduce HVAC equipment capacities saving cost
- May have higher upfront cost
- May have aesthetic impact

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Guidance

Navigating the Guide

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Includes:

- ✓ Tier "Mandatory", "Recommended", "Stretch"
- ✓ LEED credit alignment "Yes"
- ✓ Space type alignment "Office", "Distribution", "Laboratory", "Manufacturing"
- ✓ Impact criteria "Good, Better, Best" for low complexity, low capital cost, and high energy reduction

Most measures may contribute to the LEEDv4/4.1 EA credit Optimize Energy Performance through energy cost savings compared to the ASHRAE 90.1 baseline. The LEED column indicates which measures overlap with additional LEED credits. For example, Envelope: Cool Roof may contribute to LEEDv4/4.1 SS credit Heat Island Reduction.

	Opportunities Checklist	Tier	Impact	Metric		
		Mandatory / Recommended / Stretch	High Energy Reduction	Measures Evaluated	Measures Included in Design	Comments
Performance	Did Project add Fossil Fuels	M			No	
	30% Design Performance Model	M			Yes	
	60% Design Performance Model	M			Yes	
	90% Design Performance Model	M			Yes	
	Energy consumption savings @90% design > baseline.	M			20%	
Electrification	Space Heating	M		Yes	Yes	
	Domestic Hot Water Heating	M		Yes	Yes	
	Process Loads	M		Yes	Yes	
	Cooking Appliances	M		Yes	Yes	
	Laundry Appliances	M		Yes	Yes	
Envelope	Cool Roof [Climate Dependent]	R	◑	Yes	Yes	
	Optimized Insulation	M	●	Yes	Yes	
	Optimized Glazing	M	●	Yes	Yes	
	Thermal Breaks	R	◑	Yes	Yes	
	Weatherization / Air Tightness	R	◑	Yes	Yes	
	Green Roof	S	○	Yes	Yes	
	Thermal Mass	S	◑	Yes	Yes	
	Electrochromic Glass	S	◑	Yes	Yes	
Passive	Exterior Shading	R	◑	Yes	Yes	
	Optimized Building Orientation	R	●	Yes	Yes	
	Skylights / Solar Tubes	R	○	Yes	Yes	
	Light Shelves	S	○	Yes	Yes	
	Outside Air Solar Preheating	S	◑	Yes	Yes	
	Thermal Labyrinth	S	○	Yes	Yes	

○	◑	●	M	R	S
Good	Better	Best	Mandatory	Recommended	Stretch

Guidance
Measure Categories

Electrification
This section covers approaches to building electrification that eliminate greenhouse gas emissions from traditionally gas-powered equipment including space heating, water heating, process loads, cooking and laundry. Compliance with the electrification section is recommended.

Envelope
This section includes components related to the building's exterior skin such as cool roof, green roof, optimized insulation and glazing, thermal breaks and air tightness, thermal mass and electrochromic glass. This section includes recommended and stretch measures.

Passive
The passive section includes features that do not consume energy but contribute significantly to operational energy savings, such as optimized building orientation, exterior shading, skylights and light shelves, as well as more innovative approaches to pre-condition outside air through ground temperatures and solar heating. This section includes recommended and stretch measures.

Active
This section covers topics of lighting, equipment, plumbing, HVAC, process, electrical infrastructure and data centers. This section includes recommended measures.

Operations
While this guide is focused on new construction and renovations, there are a variety of actions within the design and construction process that can improve the operational performance of the building, such as commissioning and interventions to support sustainable energy management, like enhanced metering. This section includes recommended measures.

Renewables
The important last piece of the puzzle is tapping renewable energy sources to power high performance, efficient, all-electric buildings. This section also includes strategies to support grid management, such as energy storage and microgrid controls, as well as electric vehicles. Recommended and stretch measures are included.

3.0

Measures

Electrification
Space Heating

This measure helps remove Scope 1 greenhouse gas emissions associated with burning fossil fuel onsite to keep spaces heated by mandating electrification.

Depending on operating conditions, heat pumps can provide both heating and cooling and can operate at efficiencies in the 200-400% range and higher. Heat pumps can be effectively coordinated with heat recovery chillers to maximize energy savings and take advantage of waste heat. Options are listed below and vary by installation cost and suitability:

- Air source heat pumps (ASHP)
- Air-to-water source heat pumps (AWHP)
- Ground source heat pumps (GSHP)
- Water source heat pumps

Recommendation for Implementation

Design team should perform a study on electrical space heating systems with the understanding that heat pumps are recommended for all new construction. For renovations, an important part of the decision-making process will include integration with existing systems. For example, for existing hydronic heating systems, the operating temperatures may be higher than the temperatures generated by current heat pump technologies. Such a situation may require supplementary 'temperature boosting' equipment or changes to the sizes of the distribution system and end-use heat emitters. Efficiencies listed below are temperature dependent as efficiency tends to degrade in colder climates.

	Typical Approximate Efficiency Range
Electric boilers	95-98%
ASHP	200-400%

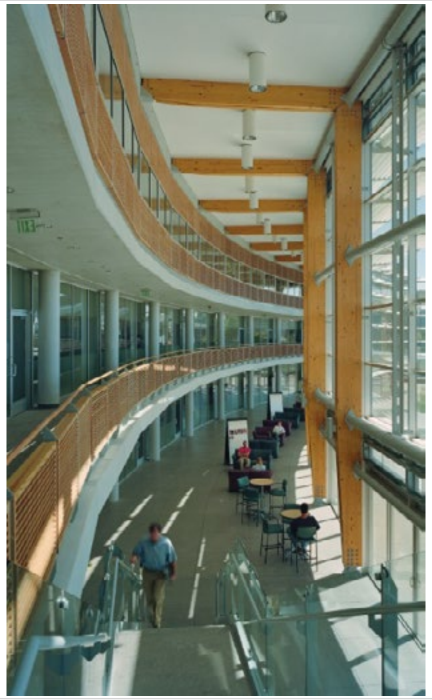
	Typical Approximate Efficiency Range
GSHP	300-450%
Heat recovery chillers	300-500+%

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Avoiding electric resistance heating can save operational costs when compared to heat pumps
+ Integration with existing HVAC systems has cost and levels of disruption to plan around
+ Consideration of space requirements of heating equipment and supporting electrical infrastructure is needed
+ Optimizing unoccupied times for temperature setbacks and other HVAC energy saving techniques align with this measure
- Increase in electrical demand may require significant electrical infrastructure upgrades
- May require additional generator capacity and associated switchgear to match the reliability of the existing fossil fuel systems, depending on criticality of operations.
- Rooftop equipment may require structural upgrades and / or roof replacements.



Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Related Measures

Air source heat pump
Ground source heat pump
Water source heat pump
Heat recovery chiller

Electrification
Domestic Hot Water Heating

This measure helps remove Scope 1 greenhouse gas emissions associated with burning fossil fuel onsite to keep domestic hot water (DHW) heated by mandating electrification.

Domestic hot water represents a relatively consistent year-round heating demand in most buildings. Typically, the water needs to be heated to around 140ºF to mitigate legionnaire's disease and can be blended down to a lower temperature for distribution if needed. The simplest form of DHW electrification is to heat stored water with electric immersion elements through resistance heating with an efficiency of ~95% depending on standing losses, etc.

If a retrofit from gas to electrical DHW heating were to add on significant electrical demand, the existing electrical infrastructure may need to be upsized to accommodate it.

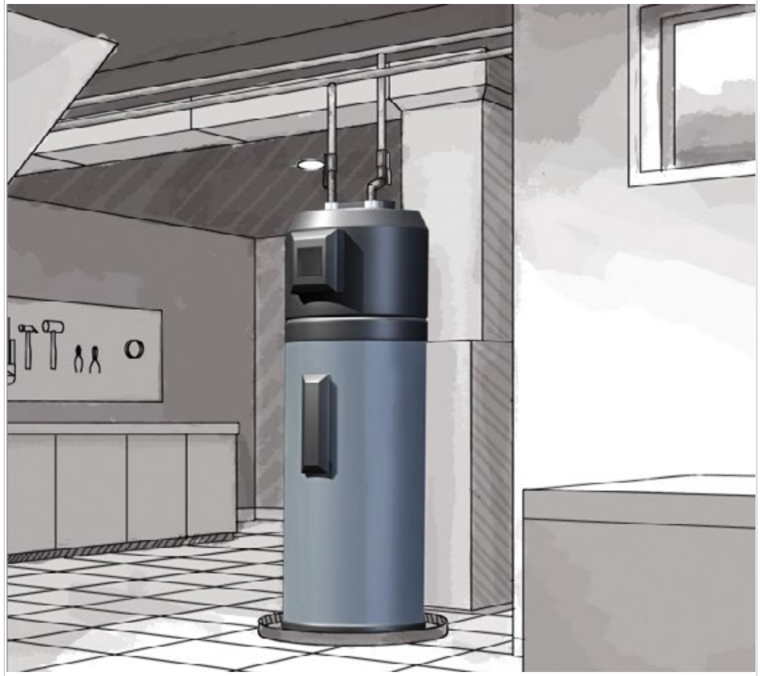
To reduce electrical DHW production costs, other high-efficiency electrical heating technologies can be deployed to either fully or partially heat the DHW. These include: (1) using heat recovery chillers that can transfer heat from cooling the building to heat for DHW, and (2) using air-to-water source heat pumps that extract heat from the outside air and use that to preheat the DHW. See the Space Heating Electrification section for the typical efficiencies of such technologies.

Even if these systems can only achieve 100-120ºF DHW, the remaining heating can be achieved through a 'boost' of supplementary electric resistance heating. Technologies such as CO_2 heat pumps can achieve full DHW heating with no need for supplementary heating but are still relatively emerging technologies in the market.

Recommendation for Implementation

When looking to electrify a DHW system, consider the following factors: system first costs, operating costs, operating energy, space requirements and levels of disruption / phasing. All potential options should be evaluated to understand if the building's electrical infrastructure needs to be upgraded to support the additional load and, if deemed required, the costs rolled into its lifecycle cost assessment.

Typically, heat pump domestic hot water and heat recovery chiller should be the first choices. Making these systems work will require additional connecting infrastructure and controls integration. In some cases, such as when there might be simultaneous need for both chilled and hot water, on-demand electric could be useful. Another consideration is electric distributed / point-of-use tankless hot water heaters vs. a centralized tank with distribution. The distributed strategy reduces heat loss throughout the system.



Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Related Measures

Heat recovery chiller

Solar thermal water heating

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Recommended to eliminate onsite fossil fuels
+ Consider whether the existing electrical infrastructure is adequately sized to support DHW electrification
+ Consider opportunities to integrate high-efficiency technologies with the DHW system such as heat recovery chillers or air-to-water source heat pumps
+ If water usage schedules allow it and storage tank size can be accommodated, consider scheduling water heating to take place outside of peak electrical demand hours to avoid adding to the peak electrical costs where applicable.

Electrification
Process Loads

This measure helps remove Scope 1 greenhouse gas emissions associated with burning fossil fuel onsite for process loads by mandating electrification.

The energy consumption of process loads has a large influence on the achievement of set performance targets.

A process load is defined as "*energy consumed in the support [of] a manufacturing, industrial, or commercial process other than serving commercial refrigeration equipment, conditioning spaces and maintaining comfort and amenities for the occupants of a building.*" (ASHRAE 90.1). This applies not only to classic process technology but also, for example, to the IT equipment in offices. Together with the other loads mentioned above, these comprise the basic load of the buildings.

The first step in the net-zero strategy is electrification. Then, energy efficiency is needed to minimize electrical demand. Due to the long operating times of these systems, reducing the energy efficiency of these loads has a significant impact.

Related Measures

Process efficiencies

Recommendation for Implementation

Design team must take great care in selecting equipment for process loads so that electrification and energy efficiency improvements are possible. The team must create an overview with the loads of all relevant installations. Equipment with the highest loads must be prioritized and investigated for savings potential.

Essential characteristics that must be considered during the investigation include the practical maximum power of all process equipment in consultation with Thermo Fisher, the possible avoidance of equipment by a smart process design, existing surplus energies for the supply (e.g., with heating or cooling), the flexibility, future security, longevity, as well as their maintenance, operation and replacement.

All larger consumers need to be integrated into the customer's energy management system, according to their standards. Interaction with employees is desirable, using dashboards and visualizations.

Source: Arup Asset Bank

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Recommended to eliminate onsite fossil fuels
+ Select more efficient equipment
+ Ability to reclaim energy from process discharge (air, water, etc.) to pre-heat/-cool process medium
+ Adjustment of temperature levels in plants with heating or cooling processes
+ Integration in the interconnection with other plants (digital as well as for surplus energy)
+ Implement process equipment metering and monitoring to optimize and sustain process control over time vs. energy usage
- May have higher upfront cost
- Must align with Thermo Fisher standards
- May impact safety (containment) and regulatory requirements

Electrification
Cooking

This measure helps remove Scope 1 greenhouse gas emissions associated with burning fossil fuel onsite for cooking by mandating electrification.

New gas-fired kitchen equipment is prohibited.

Commercial-scale kitchens serving cafeterias and restaurants often include several gas-burning appliances. These include ovens, griddles, fryers, skillets, steam kettles and food warmers. The gas-burning equipment should have rated nameplate gas-burning capacities that can aid in the sizing of electrical replacements.

Electric equipment eliminates the risk of flammable gas or noxious fumes escaping into the kitchen and dining area.

Related Measures

ENERGY STAR or equivalent appliances

Recommendation for Implementation

The required performance of any proposed replacement cooking equipment should be vetted not only for capacity, but for other performance characteristics such as evenness of heating to ensure no reduction in quality occurs from the switch out.

When the gas-burning appliances have been identified for replacement with electric models, the required electrical loads for the replacement equipment should be calculated. These loads must be checked against the capacities of the existing electrical infrastructure. This will identify whether electrical infrastructure upgrades will need to be made to allow the equipment to become all electric.

When the replacements are completed, the existing gas supply should be disconnected, capped off and made safe.

Jennifer Sheib, Source: NREL

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- [x] Office
- [ ] Laboratory
- [ ] Distribution
- [ ] Manufacturing

Considerations

+ Recommended to eliminate onsite fossil fuels
+ The operating costs of running all-electric equipment compared to natural gas should be planned and accounted for in the decision-making process.
+ Electric appliances have lower first costs, as well as lower installation costs.
+ Any electrical infrastructure upgrades required to support the installations must be accounted for in the cost planning for the measure.

Electrification
Laundry Appliances

This measure helps remove Scope 1 greenhouse gas (GHG) emissions associated with burning fossil fuel onsite for laundry by mandating electrification.

Laundry appliances represent a relatively consistent year-round heating demand in buildings with laundry service. When heated by natural gas, it represents a portion of Scope 1 GHG emissions.

There is current technology for gas or electric dryers. Therefore, electrifying laundry appliances just requires using electric dryers. This also means sizing electrical infrastructure to accommodate for this electrical load in a new build. Dryers should be set up with moisture detection to shut off when the set point is achieved.

If a retrofit from gas to electrical dryer were to add on significant electrical demand, the existing electrical infrastructure may need to be upsized to accommodate it.

Recommendation for Implementation

When looking to electrify dryers, consider the following factors: system first costs, operating costs, operating energy and levels of disruption / phasing.

Evaluate all potential options to understand whether the building's electrical infrastructure needs to be upgraded to support the additional load and, if deemed required, the costs rolled into its lifecycle cost assessment.

Consider sourcing equipment in compliance with a product certification program such as ENERGY STAR or equivalent.

Evaluate newer generation technologies such as heat pump-based clothes dryers to help improve operational efficiency.

Applicable Building Types

- ☐ Office
- ☑ Laboratory
- ☐ Distribution
- ☑ Manufacturing

Considerations

- \+ Recommended to eliminate onsite fossil fuels
- \+ May cost less upfront
- \- May have higher energy cost
- \- May have longer dry times

https://www.lg.com/us/images/dryers/md07000693/gallery/desktop-02.jpg

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Related Measures

Industrial laundry efficiencies

Envelope
Cool Roof

The roof of a building can play a large role in reflecting solar radiation that would otherwise heat the inside of the building. Reflective roofs reduce cooling loads by restricting solar heat gain through the roof. Cool roofs reflect more sunlight away from the roof; less sunlight enters the building, thereby reducing cooling loads.

The reflectivity of materials is measured by the Solar Reflective Index (SRI). The higher the SRI, the more solar radiation the material reflects. The SRI is measured on a scale of 0-100.

The SRI is heavily impacted by the color of the material. Materials with lighter colors will have higher SRI values, while darker-colored materials will have a lower SRI. The SRI of a roof can be increased by using a white-colored roofing material on the topmost layer.

Related Measures

Onsite solar photovoltaics

Green roof

Recommendation for Implementation

Design team should specify cool roofs where viable to exceed IECC 2021 dependent on climate zone. IECC includes a minimum Solar Reflectance Index of 64 or a three-year-aged solar reflectance of 0.55 and three-year-aged thermal emittance of 0.75 for warmer climate zones. Exceptions to roof portions include photovoltaic systems, green roofs, skylights and others.

The viability of cool roofs will vary based on climate zone. Heating dominated climate zones may receive useful solar heat through the roof, which reduces heating energy usage. This should be evaluated based on project location.

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

LEEDv4/4.1: SS Heat Island Reduction

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

- \+ Promotes energy efficiency
- \+ Saves energy costs in certain climate zones
- \+ Lowers heating and cooling demand
- \+ Reduces urban heat island effect
- \+ Coordinates with solar photovoltaics
- \- Requires maintenance to keep clean

Envelope
Optimized Insulation

Increasing wall and roof insulation reduces the heat conductivity through the building envelope. This strategy works best when the thickness and type of insulation within walls, roofs and floors are optimized based on the climate zone and type of assembly being designed.

There are two key units used to describe the insulating properties of opaque envelope assemblies:

1. **U-factor:** Measures conduction, with a smaller value representing better performance (W/m².K or BTU/h.ft².F))
2. **R-Value:** The inverse of U-factor; indicates how well a material or assembly resists the conduction of heat, with higher values representing better performance (m².K/W or ft²F-h/Btu))

Recommendation for Implementation

Design team should complete parametric studies to arrive at the optimal insulation U-factor, considering climate zone, to exceed code minimums. Example maximum values from IECC 2021 (note: code varies by assembly type with roof values below corresponding with insulation entirely above deck and exterior wall values corresponding with wood-framed walls):

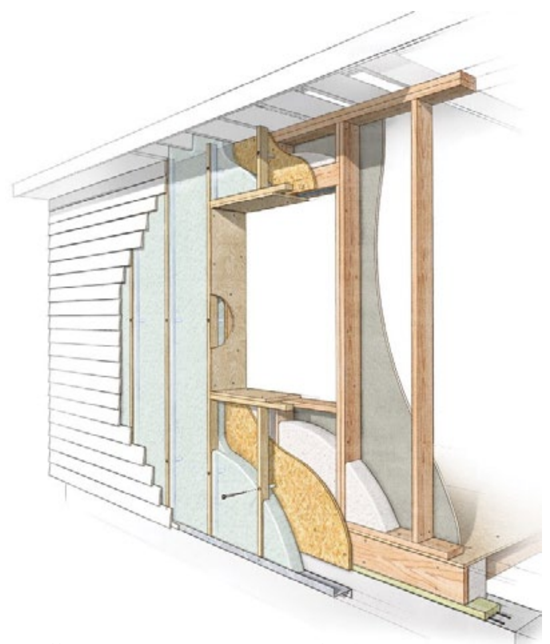
	Hot	Cold	Humid	Temperate
Roof U-factor [Btu/h·ft²·F]	0.039	0.032	0.039	0.032
Exterior Wall U-factor [Btu/h·ft²·F]	0.064	0.051	0.064	0.051

Applicable Building Types

☑ Office
☑ Laboratory
☑ Distribution
☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Can lower heating and cooling demand
+ Insulation optimization should be evaluated on a per-climate basis to avoid diminishing returns.
+ It is significantly cheaper to add insulation during construction than during a retrofit.



Source: https://www.finehomebuilding.com/

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Related Measures

Optimized glazing
Thermal breaks
Thermal mass

Envelope
Optimized Glazing

Building envelopes regulate heat transfer between the inside and outside of the building. Glazing, as an element of the building envelope, plays an additional role in letting natural light into the indoor environment. This balance between regulating temperature and letting in light is key to high performance building design.

There are three main variables for window glazing:

1. **U-factor:** Measures conduction, with a smaller value representing less heat loss
2. **Solar heat gain coefficient (SHGC):** Measures solar radiation, with a larger number representing more heat gain
3. **Visual transmittance:** Measures light transmission, with a larger number representing more light

Balancing these factors and optimizing by climate zone is essential. A building in a colder climate will want to reduce heat loss, with a focus on better U-factors. A building in a warmer climate will prioritize less heat gain, with a focus on improved solar heat gain coefficient. Both factors are important for all climate zones.

Related Measures

Optimized building orientation

Exterior shading

Skylights / solar tubes

Recommendation for Implementation

Design team should conduct a parametric study to arrive at optimal glazing U-factor, solar heat gain coefficient and visual transmittance depending on the location's climate zone to perform better than code minimums. Example maximum values from IECC 2021 (note: code varies by assembly type with values below corresponding with fixed fenestration):

	Hot	Cold	Humid	Temperate
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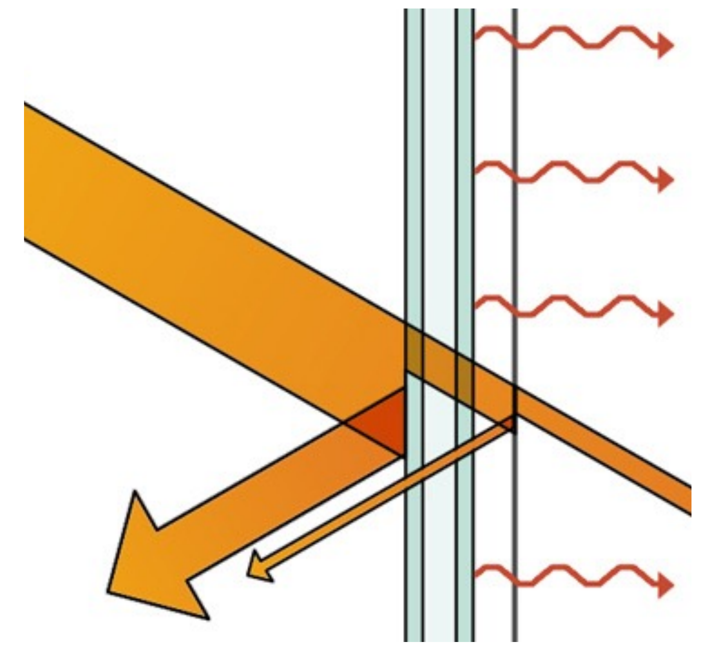
SHGC	0.25	0.38	0.25	0.38



Source: www.buildingenclosureonline.com

Sustainability Certifications

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LEEDv4/4.1: EQ Daylight

Applicable Building Types

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Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Lowers heating and cooling demand
+ Allows for flexibility in HVAC selection
+ Improves comfort in perimeter zones
+ May reduce HVAC equipment capacities saving cost
- May have higher upfront cost
- May have aesthetic impact

Envelope
Thermal Breaks

A guiding principle in designing high performing envelopes is to control heat flow. Thermal breaks are a break in the conductive material between the exterior and interior of the building. Mitigating thermal bridges, which act as unregulated points of heat flow, provides two benefits:

1. Improving building energy performance
2. Mitigating condensation risk. Condensation at the interior or within the wall build-up can lead to degradation of sensitive materials and mold growth, impacting occupant health.

Penetration in the thermal line for structural connections (e.g., canopies or balconies) also can provide a path for unmitigated heat flow.

Related Measures

Optimized glazing

Optimized insulation

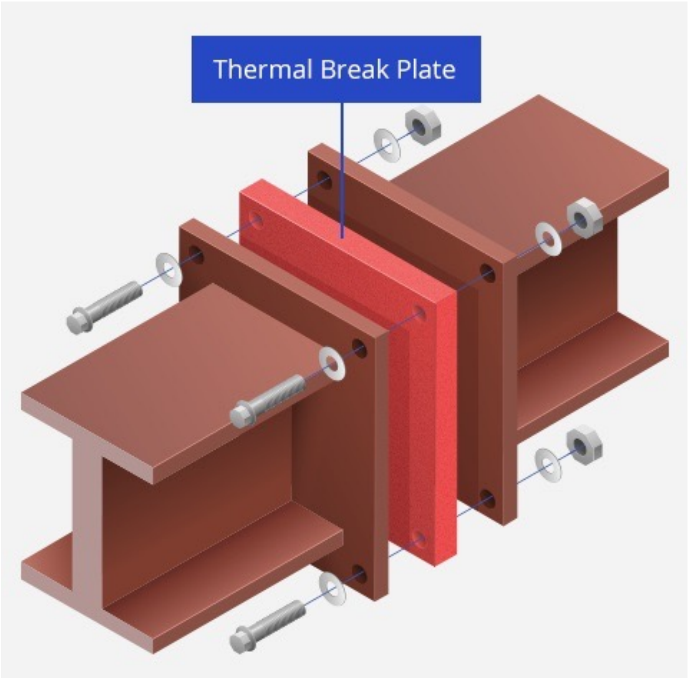
Weatherization / air tightness

Recommendation for Implementation

Design team should integrate thermal breaks within envelope construction. Consider the following design options:

Thermally-broken glazing frames: The frames of punched windows or curtain walls are typically metal and inherently act as a thermal bridge, reducing thermal performance (U-value) of the glazing system. As a result, thermal breaks can be incorporated into the framing design. These are typically ¼- to 1-inch thick, poured elements that are less conductive but structurally rigid (e.g., polyester reinforced nylon).

Thermally-broken rainscreen attachment: Rainscreen panels are supported by a back-up wall, often with a line of rigid insulation within the cavity. This often looks like vertical or horizontal metal z-girts disrupting the thermal insulation, thereby creating continuous paths of thermal bridging. To mitigate this, choose products that either incorporate a thermal break or are made of a less conductive material (like FRP).



Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

LEEDv4/4.1: EQ Daylight

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Lowers heating and cooling demand
+ Allows for flexibility in HVAC selection
+ Improves comfort in perimeter zones
+ May reduce HVAC equipment capacities saving cost
- May have higher capital cost for design and construction
- Thermal breaks should be considered wherever there are disruptions in the thermal line (connection, transitions between systems, etc.)

Envelope
Weatherization / Air Tightness

Weatherization is a process that involves identifying and sealing any leaks in the building envelope. This helps maintain thermal comfort and prevent both infiltration of outside air and the escape of conditioned air. Air leakage is the uncontrolled flow of air through the building envelope; it is typically driven by imbalances caused by wind, stack effect or mechanical equipment.

Weatherization works in tandem with insulation, as it can improve thermal and occupant comfort by reducing drafts and noise. It can also improve indoor air quality by limiting contaminants from entering occupied or functional space.

Recommendation for Implementation

To identify leaks and determine the air leakage rate in the building envelope, conduct testing during the construction phase. One common test is the “blower test,” which involves using a single calibrated fan against a depressurized (50 Pa) indoor space, with all other fenestrations closed and HVAC systems turned off. The fan air flow, measured in CFM at 50 Pa (CFM50), is used to calculate the air exchange rate: ACH50 = CFM50*60*(volume). Door blower testing can be completed on a sampling of room types or on room types with complex façade conditions, to help mitigate potential schedule impacts and cost.

There are various standards that detail testing criteria for air leakage, including:

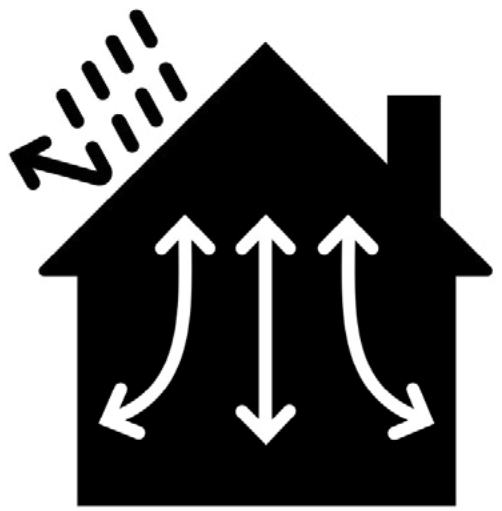
- ASTM E3158 – Standard Test Method for Measuring the Air Leakage Rate of a Large or Multizone Building
- ISO 9972:2015 – Thermal Performance of Buildings – Determination of Air Permeability of Buildings – Fan Pressurization Method

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Lowers heating and cooling demand
+ May reduce HVAC equipment capacities saving cost
+ Can reduce flow of moisture throughout building enclosure
+ Reduces potential for movement of moisture in building
+ Most recent energy codes now require building tightness testing.
+ Reduces the ingress of dust and exterior contaminants, potentially reducing frequency of cleaning



Source: https://www.iccsafe.org/wp-content/uploads/proclamations/TN02-Building-Tightness_pdf.pdf

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Related Measures

Optimized glazing
Optimized insulation
Thermal breaks

Envelope
Green Roof

Like cool roofs, green roofs can also improve envelope performance. The moisture within the soil provides a barrier to heat transfer. When the green roof is heated, the moisture within the soil can absorb the heat, minimizing heat transfer into the building itself. As a result, cooling loads are reduced. Green roofs are more effective at reducing solar heat gain than traditional roofs, lowering both cooling loads and cooling costs.

Green roofs are probably best applied where they are accessible to building occupants, allowing the space to be used as a building amenity and providing building occupants the benefits associated with biophilic design.

By using locally applicable plant palettes, green roofs also help promote biodiversity for flora and fauna.

It is also feasible to combine roof mounted solar energy with green roofs, maximizing the roof's value. Applying both technologies provides co-benefits for each. Solar energy performs more efficiently due to lower roof temperatures provided by the green roof. Solar helps shade parts of the green roof, allowing a wider range of habitats.

Related Measures

Onsite solar photovoltaics

Cool roof

Recommendation for Implementation

A green roof is comprised of vegetation and a waterproofing membrane. It can be constructed by placing layers of soil and seeds on the roof, or by placing adjacent trays or modules.

Given the amount of soil, plants and waterproofing, green roofs can have higher upfront costs compared to traditional roofs. Green roofs are typically heavier and require structural analysis to find the optimal design.

A vegetated roof that covers at least 50% of the roof area and uses native or adapted plant species is sufficient to earn LEED credits. Green roofs also facilitate stormwater management, improve local air and water quality while increasing quality of life, human health and occupant comfort.

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

LEEDv4/4.1: SS Heat Island Reduction

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Lowers heating and cooling demand
+ Reduces urban heat island effect
- Increases landscaping maintenance
- Good practice and regulatory considerations regarding air intakes and green roofs (i.e., insects and filter)
- Requires frequent cleaning

Envelope

Thermal Mass

Building materials absorb, store and release thermal energy in an attenuated way. Thermal mass walls are heavyweight materials that absorb heat during the daytime and release that heat into the space as the outdoor temperature starts to cool down. Then, as the temperature rises again during the day, the thick thermal mass causes a delay in the transfer of solar gain to the interior space.

Utilized correctly, this can decrease the heating and cooling loads of a building, as thermal mass makes use of natural diurnal shifts for "free" heating and cooling with the thermal lag.

Thermal mass is most effective when paired with nighttime purging. This technique involves using the low temperature night air to flush out and replace the leftover warm interior air. This also purges the heavyweight materials of heat overnight. This way, the materials can radiate cool air during the morning and absorb heat gains from the space.

Related Measures

Optimized insulation

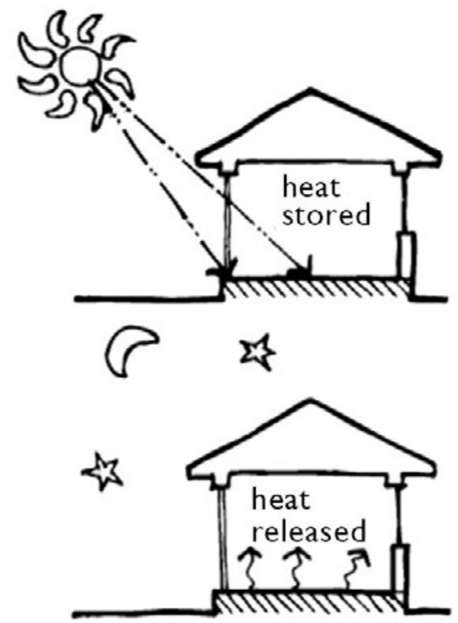
Thermal breaks

Recommendation for Implementation

Thermal mass surfaces should be employed in spaces that receive significant solar access (southern facing in the northern hemisphere, or northern facing in the southern hemisphere). Thermal mass works most effectively in climates with a large diurnal (night and day) temperature differential, typically of at least 15°F. Below that, thermal mass may not be as effective, and could even cause an energy increase.

Most thermal mass constructions are made of thick concrete, which significantly increases the embodied carbon of the building. Alternatives do exist, however, including using creative construction into ground mass and other lower embodied carbon materials. Thermal mass may also be added in the form of a rock store, which can pre-cool incoming ventilation air.

Thermal mass is also available through products such as phase change materials. These can be added within walls or ceiling cavities and have a similar effect to using heavy mass fabric to attenuate heat losses and gains.



Source: https://www.greenspec.co.uk/building-design

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Lowers heating and cooling demand
+ Thermal mass coupled with nighttime purging may reduce boiler / chiller equipment sizes.
+ Cooler climates with lower window to wall ratios will see higher energy savings.
- Hot humid, warm humid and temperate climates are less suitable for thermal mass design.
- The heavyweight components should remain unfinished, as rougher surfaces are more suitable to interact with the air. This may impact building aesthetics.

Envelope
Electrochromic Glass

Electrochromic glass (or "smart" glass) is a type of glazing that can tint itself when the solar radiance it receives reaches a specified threshold.

Tinting can also be controlled by the occupant to maximize comfort by reducing glare and solar heat gain.

Some advantages of electrochromic glass include:

- Reduces energy use and greenhouse gas emissions
- No need to install and maintain interior curtains or exterior shading devices
- Improves occupant comfort
- High UV radiation protection
- Allows the building to be naturally daylit, while providing solar control when needed in a dynamic way

Related Measures

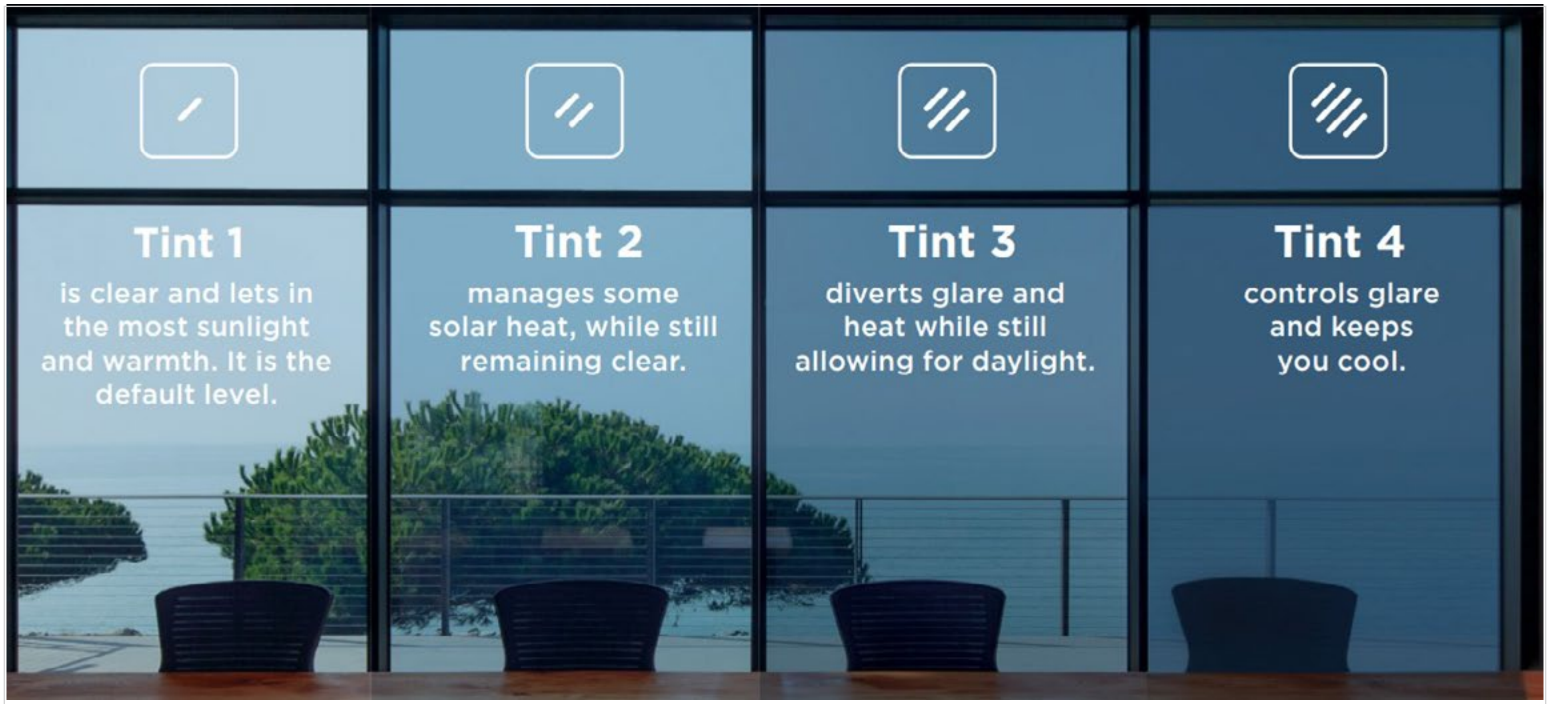
Optimized glazing
Optimized building orientation
Exterior shading

Recommendation for Implementation

In its tinted form, electrochromic glass consumes a very small amount of energy (less than 0.1 watt per square foot). The amount of voltage applied to the glass is proportional to how tinted the glass becomes.

When connected to the building automation system, the glazing can simultaneously utilize natural daylight in the morning and reduce solar heat gain in the afternoon. If the views are important, the glass can be programmed not to be entirely opaque.

In addition to electrochromic glass, there are alternative "passive" smart glass types, such as those using photochromic or thermochromic technology. This glazing automatically tints in response to UV light or solar gain intensity.



Source: https://www.view.com/product

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Lowers heating and cooling demand
+ Focuses on sun-facing orientations
- May have higher upfront cost
- May impact occupant views and have aesthetic impacts due to appearance

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

LEEDv4/4.1: EQ Daylight

Passive
Exterior Shading

Exterior glazing can be a major source of solar heat gains in the building envelope. Shading devices, such as overhangs and side fins, can reduce this envelope solar gain.

The impact of exterior shading is quantified through the window's shading coefficient. The shading coefficient is defined as the ratio of the solar heat gain that passes through the glass relative to the solar heat gain of a baseline glass type.

As an alternative to exterior shading devices, windows can also be recessed within the building façade, giving similar benefits.

For shading devices, the larger the length of the overhangs or side fins relative to the height and width of the window, the larger the reduction in shading coefficient and solar gain. Lower solar gains may result in lower cooling loads. In some climates, it may also result in more heating energy use required from the loss of passive heating.

Related Measures

Optimized glazing

Optimized building orientation

Recommendation for Implementation

Evaluate exterior shading on a project-by-project basis, factoring in climate conditions, size and configuration of the windows and building orientation. In some climates, the balance point needs to be found between the control of solar gain in the summer and the allowance of useful solar gain in winter and shoulder periods to offset heating loads.

https://www.archiexpo.com/prod/merlo/product-55355-859946.html

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

LEEDv4/4.1: EQ Daylight

Applicable Building Types

- [x] Office
- [x] Laboratory
- [x] Distribution
- [x] Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Lowers heating and cooling demand
+ Visibly promotes commitment to sustainability efforts and social responsibility
+ Helps maintain clear glazing and views
- May have higher upfront cost
- May increase maintenance on envelope systems and complexity of façade construction

Passive
Optimized Building Orientation

Optimizing the building orientation, or position of the building relative to the sun's path, can have a positive impact on energy performance.

In the northern hemisphere, glazing on the south side will have the highest solar heat gain. (for the southern hemisphere, glazing on the north side of the building will have the highest solar heat gain). This heat gain can provide free heating to the building during winter months but can also require more cooling during the summer months (without window shading).

Where possible, orienting new buildings on a generally east / west axis so that longer sides are facing south or north will most likely give the best energy performance. The inverse of this orientation would lead to more extensive windows located on east and west orientations, leading to greater difficulty in controlling solar gain.

Some advantages of having an optimized building orientation include:

- Free heating from solar heat gains
- Passive reduction in cooling loads
- Minimize exposure of glazing to sun
- Easier to control solar gain via façade elements such as exterior shading devices

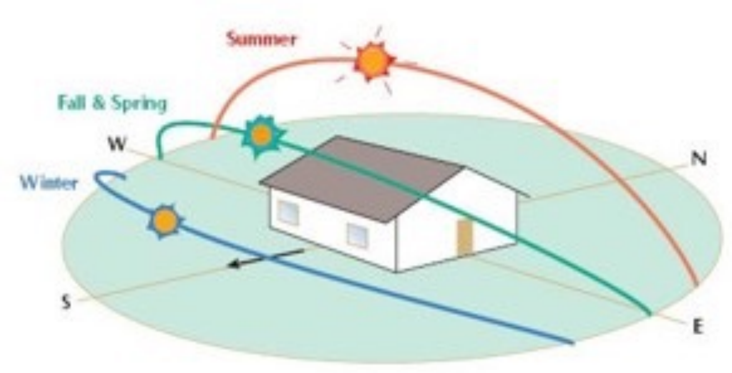
Related Measures

Exterior shading

Optimized glazing

Recommendation for Implementation

Design team should perform a parametric study to arrive at optimal building orientation, where applicable depending on site conditions and opportunities.



Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

LEEDv4/4.1: EQ Daylight

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

- \+ Promotes energy efficiency
- \+ Saves energy costs
- \+ Lowers heating and cooling demand
- \+ May reduce HVAC equipment capacities saving cost
- \+ Glazing on the south side in the northern hemisphere and on the north side in the southern hemisphere triggers high cooling loads.
- \+ Different orientations can impact occupant views.
- \+ Solar gains can increase cooling load.
- \- May not be possible to orient optimally due to other planning aspects such as site arrangement or site access

Passive
Skylights / Solar Tubes

Skylights and solar tubes increase daylight and save on lighting energy use. Both are a type of device that is installed on the roof of a building and typically made of clear glass, acrylic or polycarbonate. There are a range of sizes for each, with skylights starting around 1 square foot and solar tubes starting at 10-inch diameter.

Solar tubes (sometimes referred to as sky tunnels, light tubes or tubular skylights) consist of PVC domes in the roof that are connected to a metal tube inside the building. These tubes can vary in length and be placed to diffuse light wherever it might be needed. Light enters the building via a prismatic lens that helps with light diffusion.

Installing skylights and solar tubes requires additional carpentry and flashing work to prevent leakage. It is typically more expensive to install a skylight than a solar tube, since rafters must be cut and adjusted. Most skylight manufacturers are now adding filters on their products to reduce and block UV light rays.

Solar tubes are more effective at preventing UV light rays from entering the space because they utilize the metal tube to transfer the light. Since solar tubes utilize diffusion to disperse the light, there is less solar heat gain that enters the building space, adding less to the cooling load.

Related Measures

Advanced lighting controls

Recommendation for Implementation

Design team should consider skylights or solar tubes for interior spaces to provide natural light to occupants and reduce lighting energy use during daytime occupancy. Study effectiveness of these devices through energy modeling to balance solar heat gain, since too much heat gain would increase cooling energy use and offset the savings from lighting if not properly designed and balanced.

These technologies are ideally paired with photo sensors that allow artificial lights to dim when adequate daylight is entering the space.

IECC 2021 provides guidance on skylight fenestration area with a rule of thumb covering 3% of roof area for spaces with ceiling heights of 15 feet or greater. Exceptions are listed by climate zones, spaces with lighting power densities less than 0.5 W/ft^2 and others.

IECC 2021 also provides guidance for skylights depending on climate zones with maximum U-factor ranging from 0.41 to 0.70 Btu/h·ft^2·F and solar heat gain coefficient (SHGC) ranging from 0.30 to 0.40.

© Benny Chan/Fotoworks

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

LEEDv4/4.1: EQ Daylight

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Minimizes daytime electrical illumination of interior spaces and corridors
+ Beneficial to the health and wellbeing of occupants, links to productivity
+ Building orientation and placement of skylights or solar tubes should be optimized
- Requires specialized installers
- Glass can collect condensation, but this can be mitigated by controlling moisture inside the building
- May increase cooling load

Passive
Light Shelves

Light shelves are horizontal surfaces that are mounted inside or outside of a building. They typically divide windows into two portions: one that remains a viewable window and one that brings natural light atop the shelf. The top portion directs lights onto the shelf, which reflects the light up toward the ceiling, allowing diffuse daylight further into the floorplate.

Light shelves are a passive strategy to help increase daylighting while minimizing solar heat gain. They are often used to bring more natural light into a space, which increases occupants' sense of health and well-being. They can also help reduce solar glare within workspaces.

Recommendation for Implementation

The width of a light shelf should be comparable to the height of the glass above it. This typically allows a 2.5:1 ratio of light that reaches further into a building. For example, for 3 feet of window space above a light shelf, the shelf should be 3 feet wide, and the light reflected will extend 7.5 feet into the floorplate.

It is also recommended to choose a light-colored shelf with a reflective surface, to ensure daylight is reaching the inner parts of the floorplate.

Light shelves are ideally used in conjunction with photo sensors, allowing artificial lighting to be dimmed when there is adequate natural light.

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Improves comfort in perimeter zones
+ Can reduce electricity cost and cooling load related to artificial lighting
+ Increases daylighting
+ Provides health and wellness benefits for occupants
- Requires specialized installers
- Requires additional maintenance due to additional horizontal surfaces potentially gathering dust

© Arup

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

LEEDv4/4.1: EQ Daylight

Related Measures

Advanced lighting controls

Passive
Outside Air Solar Preheating

Solar preheating of outside air involves tempering outside air before introducing it into a space. The system can be installed on sun-facing walls or roofs.

The system consists of perforated metal panel constructions treated to absorb solar heat; it uses solar radiation energy to preheat the conditioned air. As air is drawn through the system, it absorbs heat from the internal surfaces of the metal panels. The heated air is then distributed to the space without needing any additional preheating. This solution is also commonly used with conventional air handling units, reducing the heating energy used by conventional heating coils.

Some advantages of solar preheating include:

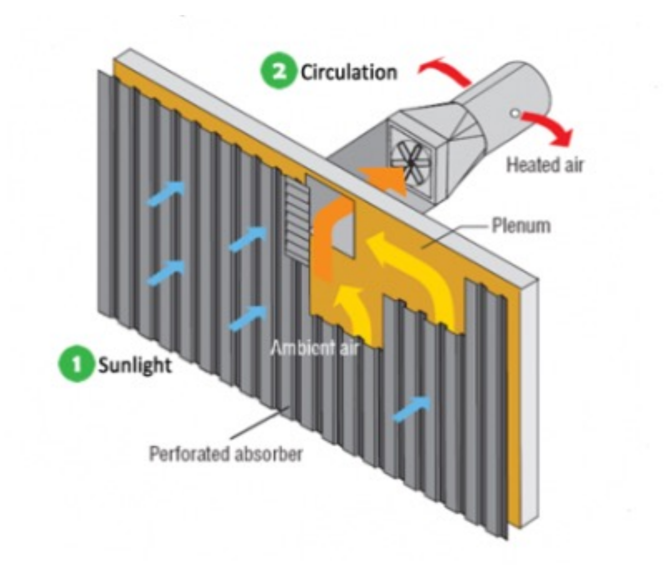
- Low maintenance costs and longer building lifespan
- Can reduce the energy related to heating outside air in heating-dominated climates
- The system can also work as an additional layer of insulation, providing a buffer between the wall it is installed on and the outside air, thereby reducing thermal losses.
- Solar ventilation is less costly than other technologies using solar energy, such as photovoltaics or solar thermal.

Related Measures

Optimized insulation

Recommendation for Implementation

Solar preheating of outside air is a passive design strategy best suited for heating-dominated climates. Other factors to consider when implementing a solar preheating system are the building location, orientation and intended use. Consider a preheating system if there is a steady demand of ventilated air, low internal heat gains and large, sun-facing walls that are far from sources of pollution (such as roads or truck bays). This solution can also be coupled with conventional air handling units as part of a building's air conditioning system, reducing the amount of tempering needed through conventional heating coils.



Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

- \+ Promotes energy efficiency
- \+ Saves energy costs
- \+ May reduce HVAC equipment capacities saving cost
- \+ Visibly promotes commitment to sustainability efforts and social responsibility
- \- May have higher upfront cost
- \- Requires additional fan power to draw air through the solar chimney, though this is often negligible due to the low velocities and pressure drops associated with this technology

Passive
Thermal Labyrinth

A thermal labyrinth is a ventilation system that draws outside air through a concrete structure shaped like a labyrinth, typically located underneath the building, and introduces it into indoor spaces. It uses geothermal heat exchange to pre-cool or pre-heat the outside air. This is achieved through the large contact area between the surfaces of the thermal labyrinth and the air, and the steady ground temperatures throughout the year.

The system is pre-cooling and pre-heating the volume of outside air provided to the usable space. The volume of a thermal labyrinth is dependent on the volume of outside air required to meet the ventilation requirements of the indoor space.

In lieu of a custom-built labyrinth, there are also approaches that use off-the-shelf clay pipes buried in the ground to achieve a similar effect.

Related Measures

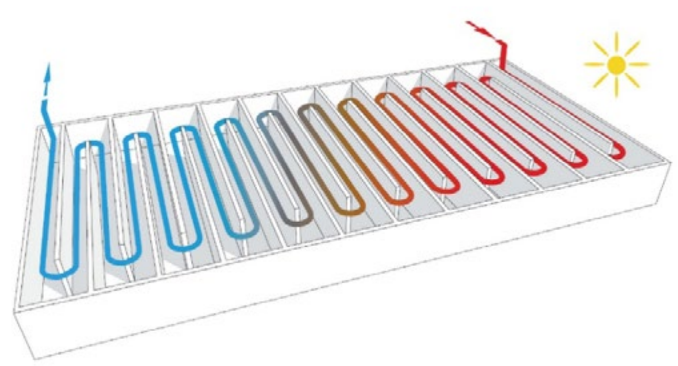
Outside air solar preheating

Recommendation for Implementation

Thermal labyrinths are better suited for buildings with cooling demand, located in climates with large diurnal (day and night) swings. Using the ground continuously as a heat sink can affect the temperature of the soil and affect its ability to further absorb heat from the air. This system should be combined with a bypass damper to maintain the structure's cooling capacity.

A thermal labyrinth can reduce the energy required to pre-temper outside air through the dedicated outside air system. At the subterranean or slab level, a labyrinth can be used to pre-cool and pre-heat outside air provided to the dedicated outdoor air system.

This solution is likely more cost viable on projects that already include significant earth works, such as those associated with below grade parking.



Source: https://www.designingbuildings.co.uk/wiki/File:Thermal_labyrinth.jpg

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

- \+ Promotes energy efficiency
- \+ Saves energy costs
- \+ Lowers heating and cooling demand
- \+ Allows for flexibility in HVAC selection
- \- May have higher upfront cost due to excavation
- \- May require additional fan power, though this is small due to the lower velocities this type of system needs to be effective

Active | Lighting

LED Lighting

Light-emitting diode (LED) bulbs are high-efficacy light sources, meaning they possess high lumens per watt efficiency and do not have any attributes that would make the light less effective or less suitable in application. Widely available in the market, LED lighting is expected to be included in all new builds and retrofitted for all existing locations.

According to The Climate Group, lighting accounts for nearly 5% of global greenhouse gas emissions. LED lighting is recognized as one of the most actionable and ready-to-implement low energy technologies because it achieves savings of 50-70%+ compared to alternatives. It is estimated that a comprehensive global switch to energy-efficient LED technology could save more than 1,400 million tons of greenhouse gas emissions and avoid the construction of 1,250 power stations.

Recommendation for Implementation

Design team should execute all LED lighting designs. When selecting, care should be taken to exceed local specifications and ensure several years of future-proofing.

Consider specifying LED bulbs that are ENERGY STAR qualified (or equivalent), as they are independently certified to deliver high quality lighting, save energy and help protect the environment.

When selecting products in Europe, follow EU energy labels and the Ecodesign standard. The new EU energy labels were rescaled in 2021 and use a scale from A (most efficient) to G (least efficient).

IECC 2021 provides guidance on maximum lighting power densities by indoor space types. For example, open plan offices should not exceed 0.61 W/ft^2 and warehouse distribution spaces should not exceed 0.33 W/ft^2. IECC 2021 also provides guidance on exterior lighting power with given allowances based on zone and type. Design team shall demonstrate improved performance from these baseline allowances.

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Longest lifespan of all bulb options
+ Most energy-efficient and durable option
+ Reduced maintenance effort and cost
+ Illuminates immediately
+ Produces less heat
+ Does not contain mercury
+ Provides directional lighting
+ Available in a range of light color temperatures
- May have higher upfront cost
- Dimming requires LED compatible switch

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Related Measures

DC power distribution

Advanced lighting controls

Active | Lighting

Advanced Lighting Controls

The two overall advantages of lighting controls are: (1) a reduction in power demand, which reduces energy consumption and cost, and (2) an improved experience for occupants, due to enhanced quality and control of lighting.

Lighting controls reduce energy consumption by automatically dimming lights or turning them off when not needed. It's common to forget or fail to notice that lights are on and not being used, so lighting controls manage that overuse. For indoor use, occupancy sensors are used to turn lights on when a person enters a space and turn them back off when no activity is detected. For outdoor use, photosensors and motion detectors are common and can be used to prevent operating outdoor lighting during daylight.

With controls, occupants can select the right amount of light for the space based on the task at hand, personal preference and time of day. Lighting also plays a central role in regulating circadian rhythm (the body's internal clock), and a circadian control system cycles through warm and cool lighting to mimic the illuminance levels and color spectrum of the sun traveling from sunrise to sunset. Such improved working environments can improve productivity and occupant satisfaction.

Related Measures

DC power distribution

LED lighting

Building Management System (BMS)

Recommendation for Implementation

Design team will meet or exceed minimum requirements from International Energy Conservation Code (IECC) and/or International Green Construction Code (IgCC).

	Minimum International Code Requirement
Occupant sensor controls	Installed in the following space types: training rooms, conference/meeting rooms, copy/print rooms, lounges/breakrooms, enclosed and open plan offices, restrooms, storage, locker rooms, corridors and other enclosed spaces that are 300 ft^2 (28 m^2) or less.
Time-switch controls	Installed in spaces not provided with occupant sensor controls
Light-reduction controls	Installed in general lighting spaces not provided with occupant sensor controls
Daylight-responsive controls	Provided in toplit and sidelit daylight zones
Exterior lighting controls	Provided with daylight shutoff, lighting setback, time-switch control function and/or occupant sensor control, including in parking garages

Lighting Control Sensor © Arup

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

LEEDv4/4.1: EQ Interior Lighting

Applicable Building Types

☑ Office
☑ Laboratory
☑ Distribution
☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Improves occupant satisfaction and productivity
+ Extends the average service life of bulbs
- May require ongoing maintenance or calibration

Active | Lighting
DC Power Distribution

Alternating current (AC) has been the most prevalent of the two types of power distribution, but recently direct current (DC) has made a resurgence. Now there is greater market availability of DC sources like solar photovoltaics (PV) and battery storage as well as DC end uses like electric vehicle (EV) charging, solid-state lighting (SSL) and power over Ethernet (PoE) lighting.

PoE lighting is smart lighting that uses Ethernet cables to both provide DC power and enable network communication with lighting fixtures, sensors and devices that improve control over light quality, reduce energy bills and lengthen bulb lifespan. Beyond lighting, PoE is expected to grow as technologies are developed and adopted more broadly.

Increasing energy efficiency and decreasing dependence on fossil fuels are driving the resurgence of DC power. Renewable energy sources such as wind and solar produce DC power. In many cases the DC power generated is converted to AC for distribution on the grid and then often converted back to DC to power lighting and electronic devices, and the conversion two times over wastes as much as 15% of the renewable energy generated due to energy loss during conversion.

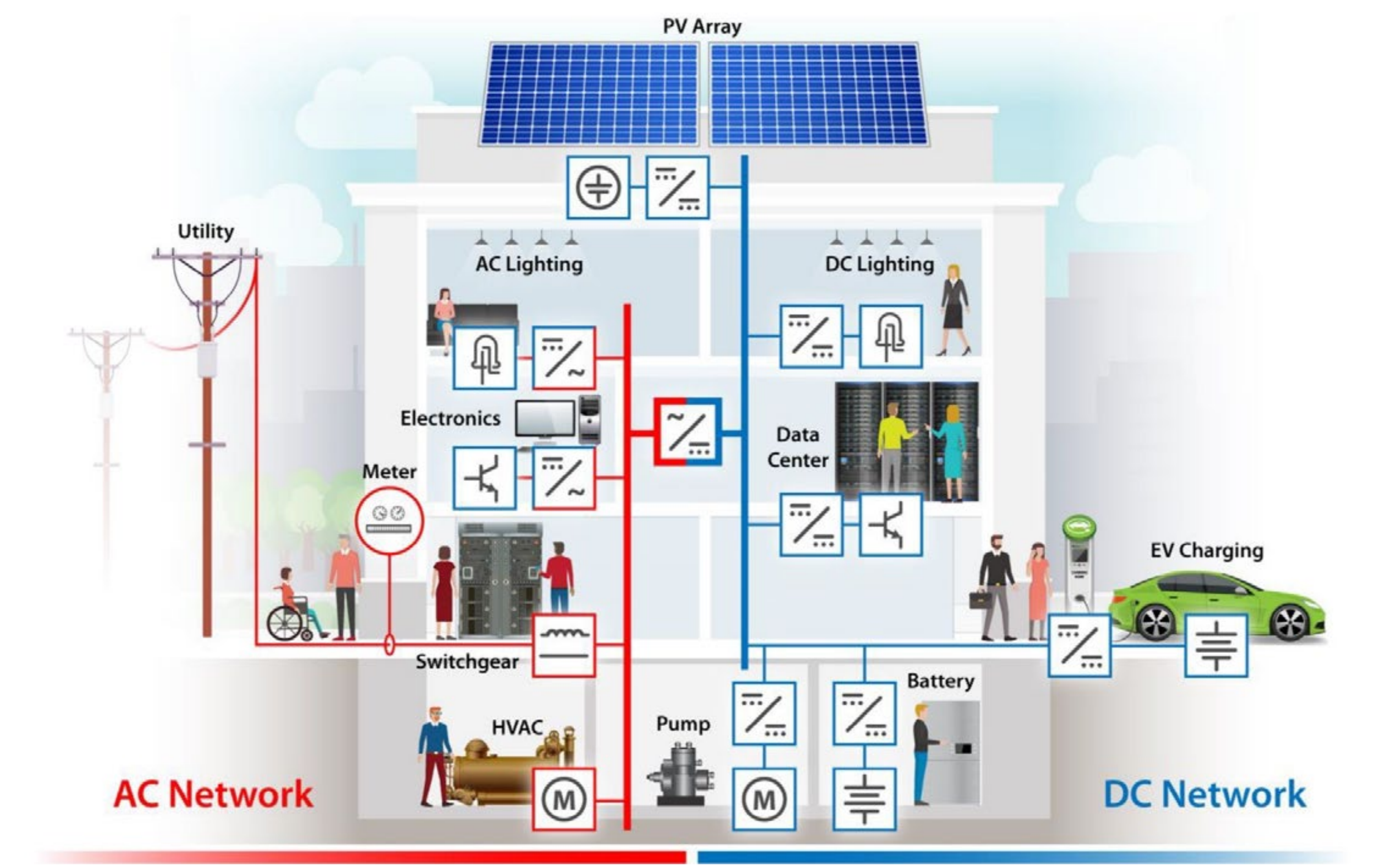
Related Measures

Advanced lighting controls
Onsite solar photovoltaics
Battery energy storage
Electric vehicle charging

Recommendation for Implementation

Design team to evaluate the adoption of DC power distribution for the following applications:

- Direct-DC LED lighting systems
- PoE smart lighting systems
- Onsite solar generation



Applicable Building Types

☑ Office ☑ Laboratory
☑ Distribution ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Simplifies installation
+ Improves reliability
+ Provides flexibility and integration opportunities
+ Enables connection to lighting controls
- May have higher upfront cost

Sustainability Certifications

LEEDv4: EA Optimize Energy Performance

Active | Equipment

ENERGY STAR or Equivalent Appliances

ENERGY STAR qualified appliances save energy, reducing energy costs and greenhouse gas emissions that contribute to climate change.

High performance standards created by the US Environmental Protection Agency (EPA) ensure appliances are thoroughly tested and only qualified appliances can be labeled ENERGY STAR certified. As an executive agency of the US, the EPA has established international partners to advance the efficiency of appliances globally. While ENERGY STAR testing protocols and levels of efficiency are referenced internationally and encouraged in all markets, the ENERGY STAR label is limited to the United States and partner countries, currently Canada, Japan, Switzerland and Taiwan.

In Europe, follow EU energy labels and Ecodesign standards when selecting products. The new EU energy labels were rescaled in 2021 and use a scale from A (most efficient) to G (least efficient). In China, follow China Energy Labels when selecting products.

Recommendation for Implementation

Design team to specify ENERGY STAR certified or equivalent rated appliances where available, or otherwise specify appliances with compliant efficiency levels and performance requirements. Sample requirements from the International Green Construction Code (IgCC) for commercial buildings:

	IP units	SI units	
Clothes washers	4.0 gal/ft³	0.53 L/L	max. water factor (WF) of drum capacity normal cycle
Standard-sized dishwashers	3.8 gal	14.3 L	max. water factor (WF) per full operating cycle
Compact dishwashers	3.5 gal	13.2 L	max. water factor (WF) per full operating cycle
Commercial dishwashers, Air-cooled ice machines, Room air cleaners, Water coolers, etc.	Comply with ENERGY STAR eligibility criteria or EU Commission Ecodesign requirements		

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

\+ Promotes energy efficiency
\+ Saves energy costs
\- May have higher upfront cost
\- Not yet available for all locations globally. Currently, only Australia, Canada, Japan, New Zealand, Switzerland, Taiwan and of course the United States recognize ENERGY STAR certifications, as those countries have agreements with the US EPA. There may be local alternative rating systems that can be adopted.

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Related Measures

Plug load management

Low-flow fixtures

Active | Equipment
Industrial Freezer Efficiency

Industrial freezers are critical for the operation of laboratories and use a significant amount of energy. In order to manage this energy, freezers should be ENERGY STAR qualified. See the 'ENERGY STAR Appliances' page of this guide.

The US Office of Energy Efficiency and Renewable Energy (EERE) states the following tips for managing freezer energy use:

- Only turn on anti-sweat heaters when ambient conditions cause condensation on the display doors. Try installing adaptive controls for these devices so they turn on and off automatically when necessary.
- Check door gaskets and auto closers to make sure they are in good condition. If these aren't working properly, warm, humid air can enter refrigeration compartments.
- Make sure the refrigeration system is clean and dust-free, especially the coils. This can help improve heat transfer within the system.
- Make sure the refrigeration system has enough space around it to ensure good airflow over the heat exchange coils to help reduce energy waste.
- Install motion sensors for case lighting systems. This will turn lights on only when needed.

Related Measures

ENERGY STAR or equivalent appliances

Recommendation for Implementation

Design team to evaluate the availability of ENERGY STAR qualified freezers and follow EERE tips when considering design aspects of the system. Ensure adequate space is provided around the condensing coils if air-cooled.

Design team could also consider water-cooled condensers, which could tie into the mechanical chilled water system and reduce the heat rejected to the space. This would also reduce the space needed around the condensing coils.

Design team should require use of CO_2-based refrigerant systems where available and otherwise use non-CFC, non-HCFC and non-HCF requirements for refrigeration systems.

Design team to explore monitoring and optimized control.

https://www.manufacturing.net/energy/article/13165386/how-to-save-energy-with-a-walkin-cooler-or-freezer

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

LEEDv4/4.1: EA Fundamental Refrigerant Management

LEEDv4/4.1: EA Enhanced Refrigerant Management

Applicable Building Types

- [ ] Office
- [x] Laboratory
- [ ] Distribution
- [x] Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Re-purpose / extract waste heat, or vent to outside to minimize burden on HVAC
- May have higher upfront cost

Active | Equipment
Plug Load Management

Most office, distribution, lab and warehouse appliances and electronic devices (including computers, monitors, printers, task lights, cell phone chargers, coffee makers and vending machines) continue to draw power even when in sleep mode.

This invisible electricity consumption is referred to as phantom loads; it is estimated that they constitute 47% of energy consumption in commercial buildings. Current Plug Load Management technologies have the potential to reduce plug loads by 30%.

Plug load controls can be incorporated to turn off based on occupancy, activity or schedule. New energy-efficient devices and appliances may come with built-in plug load controls or energy management strategies.

Recommendation for Implementation

- Enable low-power / sleep settings when devices are inactive
- Install advanced power strips that can turn off certain outlets based on timer, activity sensor or the main outlet's activity
- Use smart outlet systems, which plug into existing outlets and measure energy usage. They wirelessly transmit data and can be controlled to turn power on or off.
- Install automatic receptacle controls, which can be controlled to shut off power based on schedule or occupancy (as required under ASHRAE 90.1, California Title 24, Washington State Energy Code and International Energy Conservation Codes)

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Low installation cost
- May interfere with regular "push" software updates to computers that are turned off

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Related Measures

ENERGY STAR or equivalent appliances

Active | Equipment

Industrial Laundry Efficiencies

Industrial laundry equipment includes large capacity washers / extractors, dryers and combination washer / dryer units (combo units are often smaller than dedicated industrial laundry equipment). Industrial laundry equipment is designed to process laundry at higher volumes, faster speeds and higher temperatures than commercial equipment. There are no universal efficiency standards for this type of equipment; ENERGY STAR rating in the United States is limited to equipment with up to 25 lbs. of capacity, whereas industrial laundry equipment can range from 30-700 lbs. for washers and 50-500 lbs. for dryers).

Laundry operation efficiency is affected by the equipment selection but also by operational factors. Consider equipment operational factors such as availability of controls, appropriate programming and monitoring of leaks and failures. Also consider user operational factors such as user training for efficient choice of cycles and appropriate use of chemicals.

When choosing laundry equipment, always consider the total cost of ownership. First costs constitute less than 15% of total cost of ownership.

Related Measures

Laundry appliances

Recommendation for Implementation

For industrial washers / extractors, choose equipment that has at least 300 G-force extraction to allow for effective water removal, shorter drying time and lower drying fuel costs. The equipment should be set on eco mode (cold wash cycle, water saving cycle, etc.) as default, so that the user can choose more energy-intensive settings as necessary. Additionally, the equipment should have a variable frequency drive motor and water leak detection. Electrification is not a direct concern for washers / extractors as they operate on electricity but depend on a water heater or boiler for hot water / steam. Washers / extractors use hot water or steam as input, so pairing the equipment with an efficient water heater and reducing hot water use as much as possible will reduce the equipment's environmental impact.

For industrial dryers, choose equipment that has over-dry protection and hot air reclamation. Industrial dryers can run on gas, steam or electricity. However, currently electric industrial dryers are offered for up to 200 lbs. capacity. Most larger dryers currently only run on gas or steam as input fuel.

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

LEED v4/4.1: WE Indoor Water Use Reduction

Applicable Building Types

- ☐ Office
- ☑ Laboratory
- ☐ Distribution
- ☐ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Lower unexpected process equipment downtime (through advanced features such as monitoring and leak detection)
+ Lower linen replacement costs (through effective use and application of chemicals)
- Electric large capacity dryers (>200 lbs.) are currently not widely available.
- New, efficient equipment may have high upfront costs. This can be balanced with lower total cost of ownership.

Active | Equipment
Vertical Transportation

Vertical transportation primarily consists of elevators, also called lifts. Until recently, the energy required to power elevators was exempted from LEED, but now this energy must be included. This has spurred more innovative solutions.

There are a multitude of software or scheduling optimization solutions to reduce elevator / lift energy, such as turning a car off during light traffic times, using two cars on one track in tall buildings to reduce wait times, using double-deck elevators, or using smart elevator systems that direct passengers going to the same floor to one elevator.

Furthermore, almost 60% of energy used in elevators is during standby mode. Therefore, utilizing control strategies and sensors to reduce ventilation and lighting while the elevator is in standby mode can save a lot of energy.

Another key new technology is regenerative drive systems. These systems produce energy and recover it for the building's energy or sell it back to the grid. In some cases, they can produce more energy than they consume. This technology is readily available from popular elevator companies.

There are two main types of elevators: traction and hydraulic. Traction tend to be more energy-efficient, ride smoother and be more cost effective in mid- to high-rise buildings. Hydraulic elevators are less expensive to maintain and install, and are better at transporting heavy loads but they are only used in buildings up to five stories.

Recommendation for Implementation

Design team to look for regenerative elevator drives to significantly reduce elevator energy use. Design team should also prioritize using smart elevator systems that turn the cars off or 'put them to sleep' when not in use.

Carefully select between hydraulic and traction elevators. Considerations for choosing traction include: potential efficiencies and elevator use, enables use of regenerative drives, programming and controls, machine room-less (MRL) elevators, availability of LED lighting for elevators.

Hydraulic elevators are most often found in buildings that serve up to five stories because they operate at slower speeds than other types of elevators — typically 150 ft / min. or less. They do not have regenerative drive capabilities.

Try to promote taking the stairs or reducing the amount of unnecessary elevator rides whenever possible through the addition of signage for building occupants and co-locating elevators and stairs.

Source: https://www.smithsonianmag.com/innovation/elevators-are-going-green-180968907/

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Produces energy for building or the grid
- May have higher upfront cost

Active | Plumbing
Low-flow Fixtures

Heating water and maintaining water pressure throughout a building requires energy. Low-flow fixtures reduce water consumption, thereby reducing associated emissions.

WaterSense labeled products (or equivalent standards) include toilets, urinals, lavatory faucets and showerheads; they are independently certified based on water efficiency and performance criteria. On average they are 20% more efficient than their counterparts.

Reducing energy use is associated with fixtures that require heating the water including lavatory faucets, kitchen faucets and showerheads.

Recommendation for Implementation

Design team should regulate water consumption through limitations on fixture flow rates. Projects located in water scarce areas (identified as having a water scarcity score of greater than 3.4 by WWF Water Risk Filter Tool) must demonstrate at least a 30% reduction, and all other sites must demonstrate at least a 20% reduction, compared to the LEED v4/4.1 baseline. Additionally, consider specifying WaterSense labeled fixtures or those compliant with an equivalent local standard.

Maximum allowable flow rates based on referenced standards are as follows:

	Gallons	Liters	Reference
Toilets	1.28 gpf	4.8 L/flush	IgCC-2021
Urinals	0.5 gpf	1.9 L/flush	IgCC-2021
Public lavatory faucets	0.5 gpm	1.9 L/min	IgCC-2021
Kitchen faucets	1.5 gpm	5.7 L/min	USEPA
Showerheads	2.0 gpm	7.6 L/min	USEPA

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Reduces water consumption and cost

Source: stevemungroup.com

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

LEEDv4/4.1: WE Indoor Water Use Reduction

Related Measures

Sustainable Operations Policy

ENERGY STAR or equivalent appliances

3 options

Active | HVAC
Air Source Heat Pump

Air source heat pumps (ASHPs) are a significant building block for electrification. Their appropriate use must be examined through the project design process.

ASHPs are primary mechanical equipment that can heat or cool air or water using the air as a heat sink or source. They use refrigerants to transfer the heat from the air to the water or air.

Because they extract heat from ambient air, ASHPs are more efficient in temperate climates than cold climates. In cold climates, the heat pump will likely need to be backed up with a boiler for extremely cold days. Heat pumps can also be paired with heat recovery chillers and thermal energy storage tanks to decrease load on the heat pumps and increase resiliency. Other HVAC efficiency measures like demand-controlled ventilation also support designing for heat pumps.

The ASHP plant size needs to be coordinated for sufficient space allowance.

For air-to-water heat pumps, the delivered water temperature can be lower than for conventional products. Design teams should explore the use of lower temperature hydronic systems.

Related Measures

Space heating

Ground source heat pump

Water source heat pump

Water-cooled chiller

Heat recovery chillers

Recommendation for Implementation

Heat pumps are recommended, with three options: air source, ground source and water source. To reduce costs, use the same heat pump plant for heating and cooling for cooling capacities under 500 tons. A backup boiler may be needed in cold climates. Above 500 tons, it may be more efficient to use a water-cooled chiller plant for cooling. It is also important to design the systems for low temperature hot water and high temperature chilled water. Example minimum efficiency values from IECC for air source heat pumps include:

	Heating (COP)	Cooling (EER FL)
Efficiency requirements	≥1.95	≥9.595

These efficiencies assume a medium hot water temp of 120°F.
See all requirements in IECC table C403.3.2

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Electric solution to space heating
+ Opportunity for heat recovery
+ Coordinate with lower overall heating and higher overall cooling temperature distribution levels
+ Design lower temperature hydronic systems for compatibility with heat pumps
+ Coordinate with spatial requirements
+ Search for technologies with low emission refrigerants
- Efficiency tends to drop in colder climate zones so a backup electric boiler may be needed in certain scenarios.

3 options

Active | HVAC
Ground Source Heat Pump

Ground source heat pumps (GSHPs) are a significant building block for electrification. Their appropriate use must be examined in the energy design.

GSHPs are primary mechanical equipment that can heat or cool water using the ground as a heat sink or source. They use refrigerants to transfer the heat from the ground to the water. Then the hot or cold water is distributed for heating or cooling. The system can gain efficiencies during simultaneous heating and cooling by using heat recovery chillers from the chilled water loop. Because they extract heat from the ground, GSHPs can be used in most climates.

A ground source heat pump plant uses boreholes that are ~200 ft deep to exchange heat with the ground. They need sufficient open land for the total borehole area. It is possible to build a parking lot over the borehole area but putting a building on top becomes more complicated with the increased load. Design calculations must account for warming and cooling of the earth and balance the hours for heating vs. cooling.

Drilling the boreholes is capital intensive, so this technology typically requires longer ownership to realize the efficiency payback.

Related Measures

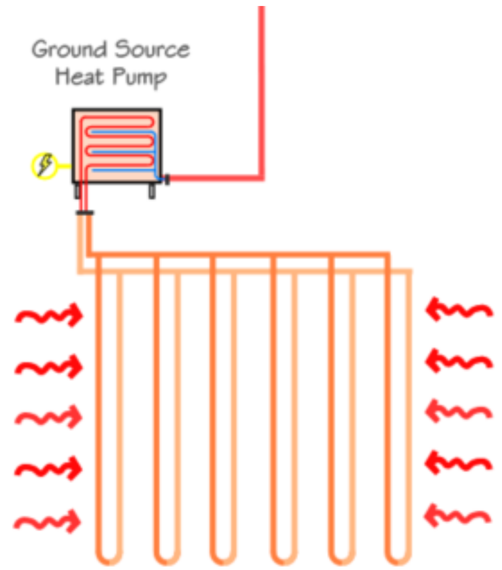
Space heating
Air source heat pump
Water source heat pump
Water-cooled chiller
Heat recovery chillers

Recommendation for Implementation

Heat pumps are recommended, with three options: air source, ground source and water source. It is recommended to use the same heat pump plant for heating and cooling and maximize the heat recovery. The piping will all manifold to one location. It is also important to design the systems for low temperature hot water and high temperature chilled water. Example minimum efficiency values from IECC for ground source heat pumps:

	Heating (COP)	Cooling (kW/ton FL)
Efficiency requirements	≥3.96	≤0.5895

These efficiencies assume a medium hot water temp of 120°F.
See all requirements in IECC table C403.3.2



Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

- \+ Promotes energy efficiency
- \+ Electric solution to space heating
- \+ Opportunity for heat recovery
- \+ Coordinate with lower overall heating and higher overall cooling temperature distribution levels
- \+ Search for technologies with low emission refrigerants
- \- Higher upfront and replacement cost
- \- Life expectancy averages 20+ years for the heat pump and 25-50 years for the underground infrastructure
- \- Applicable only when land is viable
- \- Typically requires local permission

3 options

Active | HVAC
Water Source Heat Pump

Water source heat pumps (WSHPs) are a significant building block for electrification. Their appropriate use must be examined in the energy design.

WSHPs are primary mechanical equipment that can heat or cool water using bodies of water such as a lake or river as the heat sink or source. They use refrigerants to transfer the heat from the water to a hot or chilled water loop. Then the loop is distributed throughout the building or to multiple buildings for heating or cooling. The system can gain efficiencies during simultaneous heating and cooling by using heat recovery from the chilled water loop.

It is important to understand and consider the impact that heating or cooling the body of water will have on the ecosystem. The design can also aim to balance the hours of heating vs. cooling throughout the year to minimize the impact. Heat pumps can also be paired with heat recovery chillers and thermal energy storage tanks to decrease load on the heat pumps and increase resiliency.

Related Measures

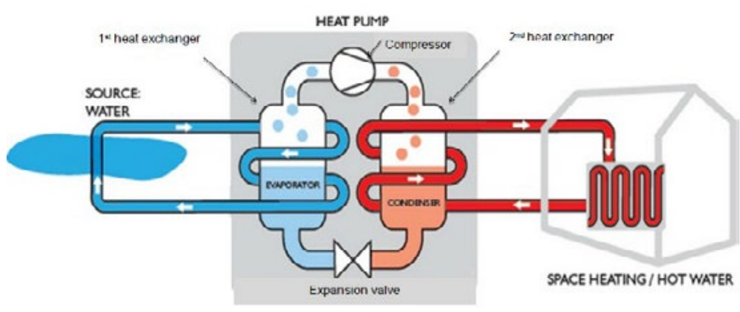
Space heating
Ground source heat pump
Air source heat pump
Water-cooled chiller
Heat recovery chillers

Recommendation for Implementation

Heat pumps are recommended, with three options: air source, ground source and water source. It is recommended to use the same heat pump plant for heating and cooling and maximize the heat recovery. It is also important to design the systems for low temperature hot water and high temperature chilled water. Example minimum efficiency values IECC for water source heat pumps:

	Heating (COP)	Cooling (kW/ton FL)
Efficiency requirements	≥3.96	≤0.5895

These efficiencies assume a medium hot water temp of 120°F.
See all requirements in IECC table C403.3.2



Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.researchgate.net%2Ffigure%2FA-typical-diagram-of-a-water-source-heat-pump_fig2_286358619&psig=AOvVaw3nig8YpuXQenT9QfUxSz1M&ust=1648596066014000&source=images&cd=vfe&ved=0CAsQjRxqFwoTCKjivY_56fYCFQAAAAAdAAAAABAX

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Electric solution to space heating
+ Opportunity for heat recovery
+ Coordinate with lower overall heating and higher overall cooling temperature distribution levels
+ Search for technologies with low emission refrigerants
- Needs body of water
- Typically requires local permission
- Need to evaluate environmental implications on source water body

Active | HVAC
Water-cooled Chiller

Water-cooled chiller systems work by rejecting heat to a condenser water loop. The condenser water loop pumps water to a cooling tower, where the heat is rejected to ambient air.

Water-cooled chiller systems offer higher efficiencies compared to air-cooled chillers but have higher upfront costs because more equipment and piping are required. Over the lifecycle, water-cooled chillers tend to be less costly than air-cooled chillers. Maintenance costs tend to be higher for water-cooled chillers because there is more equipment for maintenance and a need for water treatment processes.

Water consumption is important to consider for water-cooled chillers. Water in the condenser loop can evaporate or be lost at the cooling tower and must be replenished with makeup water. As a result, water-cooled chiller systems might not be the best fit in regions with water shortages or where water is very expensive. Hybrid cooling towers are also available; a hybrid combines both dry and evaporative cooling elements, helping reduce water consumption.

Water-cooled chillers take longer to construct, because of the additional mechanical equipment that must be installed. By comparison, air-cooled chillers usually come pre-packaged and ready for installation.

Related Measures

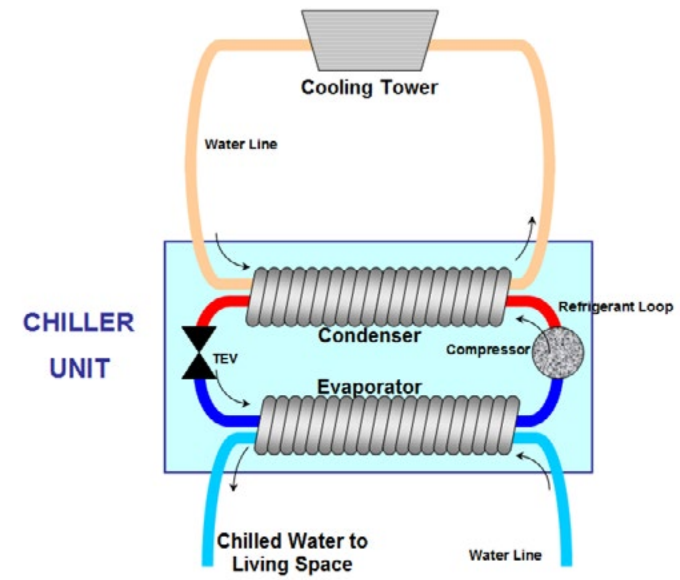
Air source heat pump
Ground source heat pump
Water source heat pump
Heat recovery chiller

Recommendation for Implementation

Design team to analyze water-cooled chillers vs. heat pumps. Example minimum efficiency values from International Energy Conservation Code (IECC) for water-cooled chillers:

	Chiller (kW/ton FL)	Cooling Tower (gpm/hp)
Efficiency requirements	≤0.56	40.2

These efficiencies assume a centrifugal chiller >600 tons and propeller or axial fan open-circuit cooling towers. See all requirements in IECC table C403.3.2.



Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

☑ Office ☑ Laboratory
☑ Distribution ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Higher efficiency of HVAC system
+ Lower lifecycle cost compared to air-cooled chiller system
- Increased water consumption, but that can be mitigated using non-evaporative cooling towers
- Cooling tower space requirements
- First costs include both chiller and cooling tower equipment
- Additional maintenance and enhanced level of sophistication needed to operate

Active | HVAC
Heat Recovery Chiller

Heat recovery chillers allow waste heat from the chilled water loop to be used for heating, offsetting some demand from the boiler system.

Heat recovery chillers transfer heat from the chilled water return to the heating hot water supply system. The heat in the chilled water return loop would otherwise be rejected to the outside air by the cooling towers. As a result, the heating provided is free.

Performance is best when there are simultaneous heating and cooling demands on the systems. This is because a cooling demand is required to return chilled water at a high enough temperature for the heat recovery chiller to be able to produce hot water and fulfill the building's simultaneous heating demand. In these conditions, the heat recovery chiller usually operates more efficiently than a boiler.

Since heat recovery chillers remove waste heat from the chilled water loop, the chillers reject less heat into the condenser water loop. As a result, less heat is rejected by the cooling towers. This also reduces the cooling tower capacity.

Recommendation for Implementation

Design team to analyze heat recovery opportunities with simultaneous heating and cooling loads. Example minimum values from International Energy Conservation Code (IECC) for heat recovery chillers:

	COP
Efficiency requirements	≥6.98

These efficiencies are assuming a medium HW temp of 120°F and a chiller capacity of >600 tons. See all requirements in IECC table C403.3.2

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Key electrification strategy
+ Saves energy costs
+ Reduces boiler / heat pump sizes
+ Reduces heat rejected by cooling towers
- Additional upfront cost
- Adds to space requirements
- Requires additional maintenance

Source: Arup Staff

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Related Measures

Air source heat pump
Ground source heat pump
Water source heat pump
Water-cooled chiller

Active | HVAC
Variable Air Volume System

Variable air volume systems (VAVs) are most popular in large building HVAC systems. Automatic controls are connected to each zone's thermostat to provide only the necessary supply airflow to meet the demand at a constant temperature, supplied from an air-handling unit (AHU). VAVs work best for spaces dominated by part loads, like cafes, meeting rooms and other spaces with changing occupancy patterns.

A single AHU can serve multiple thermal zones. Each zone will have a VAV terminal unit, which uses a modulating damper to control the amount of conditioned air that enters each zone.

AHU fan motors should be variable speed to ensure the system does not become over-pressurized as the terminal units turn down to a lower flow. It is ideal to use electrically commutated (EC) motors or variable speed motors. Design teams should ensure code-minimum fresh air requirements are maintained during low occupancy. This code minimum may differ depending on the region.

Recommendation for Implementation

Design team should minimize pressure drop through duct mains to VAVs to reduce fan load on AHU and use direct-digital controls (DDC) for VAV control.

Efficiency and controls recommendations and code limits from International Energy Conservation Code (IECC) below:

	VAV Heating
Re-heat limit	20% of the zone design peak supply for systems with DDC, 30% for others

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

\+ Promotes energy efficiency
\+ Saves energy costs
\+ Provides more control over zone temperature
\+ Equipment has less wear from not constantly running and can ramp down to a minimum speed
\+ Most effective in multi-zone buildings
\+ VAV systems' AHUs can be fitted with an economizer, which provides "free" cooling
\+ Potentially downsized equipment due to the ability to diversify the peak load
\- Space needed for airflow through overhead ducts and vertical shafts
\- No built-in redundancy. If one AHU is offline, all rooms it serves will be down.

Related Measures

Fan pressure drop review
Premium efficiency motors
Demand control ventilation
Temperature control adjustment
Chilled beams

Active | HVAC
Chilled Beams

Chilled beams are terminal cooling units. They can be used for cooling and heating, but not where heating loads are significant. Chilled beams have a primary air connection for fresh air and induce room air over the cooling coil. The primary air is served from a dedicated outdoor air unit, which is sized only for this primary air. This reduces main fan energy usage. The chilled beams can respond to the load in the space, providing a higher level of room control than VAVs. The coils non-condensing so are best for high sensible loads, not latent loads. This can work well for laboratories where the load is mostly from equipment.

Chilled beam systems require significant piping and the beams themselves are only in fixed sizes with a load per linear foot. This can make renovations more challenging when the load in a space changes significantly from the initial design.

Related Measures

Fan pressure drop review

Variable air volume system

Recommendation for Implementation

Design team should compare this technology with other terminal cooling equipment such as fan coil units and variable air volume units. The right equipment will depend on the building construction and loads.

In the right application, chilled beams can save significant amounts of energy by reducing or eliminating the need for large centralized fans.

Chilled beams may be less compatible in locations that use operable windows. Evaluate the humidity of outside air and deploy control strategies to ensure chilled beams are not active when windows are open during times of high humidity, to avoid condensation at the coil of the chilled beams.

https://www.trane.com/content/dam/Trane/Commercial/

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

- \+ Promotes energy efficiency
- \+ Saves energy costs
- \+ Reduces central fan energy usage
- \+ Room level temperature controls
- \+ Smaller ductwork
- \- Less flexible for future retrofits
- \- No latent load capacity
- \- Low heating capacity

Active | HVAC

Premium Efficiency Motors and Variable Speed Fans

Using best-in-class motors can reduce the power demand of mechanical equipment. The premium efficiency motor performance designation is based on horsepower, motor enclosure and the number of poles, and is given by the National Electrical Manufacturers Association (NEMA).

Be sure to select appropriately sized motors. If a premium efficiency motor is oversized, it will operate at a smaller percentage of its full load and at reduced efficiency. This will eliminate any efficiency improvements from using a premium efficiency motor.

It is also recommended to install variable speed drives (VSD) for motors that control changing loads. This can reduce the energy usage with the load. The VSD will need to be integrated with the building management system.

Recommendation for Implementation

Design team to specify premium efficiency motors and variable speed drives where possible. Variable frequency drives (VFD) are required for each fan system powered by 5 hp or more. Any fans used for cooling shall not have a horsepower that exceeds the IECC limit below. If greater than the specified limit, team must design fittings and accessories to minimize pressure drop.

	Fans ≥5 hp
Fan hp limit	Fan motor nameplate hp </= CFM x 0.0011

See all requirements in IECC table C403.8.1

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Higher efficiency selection
+ Longer lifespan
+ Wastes less heat
- May have higher upfront cost

Source: Arup Staff

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Related Measures

Variable primary flow pumping system

Active | HVAC

Fan Pressure Drop Review

To reduce fan motor energy consumption, minimize pressure drops throughout the design. This includes designing ductwork and fittings for smooth turns and transitions, and appropriately selecting coils or louvers for low pressure drops.

Including these design items will cause minor cost increases but will provide value in keeping fan motor size and energy usage down.

Recommendation for Implementation

Design team to follow best practice ductwork design as suggested in the table below.

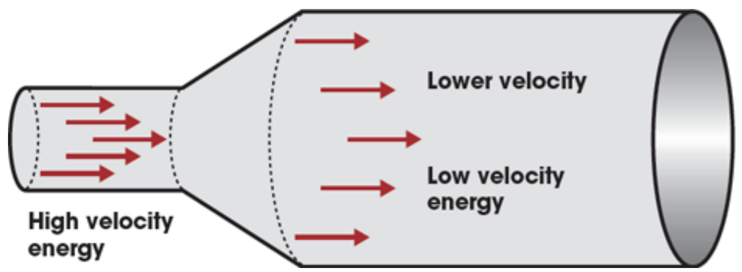
	Ductwork sizing	Over coils	Through louvers	Through diffusers
Pressure drop allowed	0.08 in wg/100 ft	0.30 in wg	0.08 in wg	0.08 in wg

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Reduces fan energy usage



Source: https://www.cibsejournal.com/cpd/modules/2011-08/

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Related Measures

Variable air volume system

Active | HVAC

Variable Primary Flow Pumping System

Variable primary flow pumping systems pump the hot and chilled water through a building with just one set of pumps per system. This allows the pumps and main equipment to respond directly to reduced loads in terminal units.

This differs from primary / secondary pumping where there are primary pumps for the main heating and cooling equipment and secondary pumps for the building loop—two sets of pumps per system per building. The primary set pumps through the main equipment and the secondary pump varies the flow to the terminal equipment. This configuration works best when the hydronic loops are long runs or large vertical distances such as campus distribution or high-rises. Since pump motors have efficiency limits, the inefficiencies multiply when using multiple pumps in series like this.

When designing single smaller buildings, a variable primary flow system is typically more efficient because it uses just one set of pumps.

Related Measures

Water-cooled chiller

Heat recovery chiller

Air source heat pump

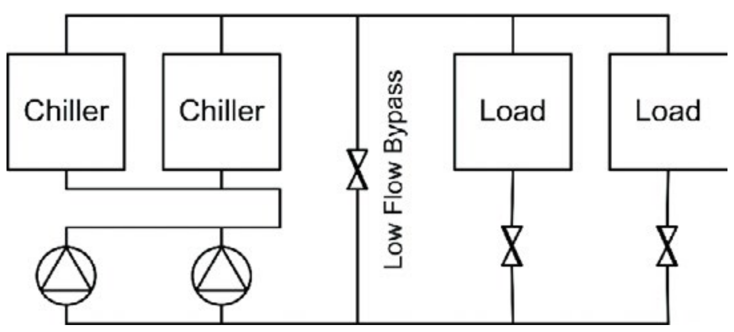
Water source heat pump

Ground source heat pump

Recommendation for Implementation

Design team should study the heating and cooling plant system sizes and analyze whether variable primary can provide efficiency gains by using one set of pumps.

This design should also include smart metering to understand how the system is performing and have the ability to easily commission.



https://www.researchgate.net/profile/William-Bahnfleth/publication/268127296/figure/fig1/AS:553699740663808@1509023713631/Schematic-of-typical-variable-primary-flow-system.png

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Requires less infrastructure
+ Better for shorter vertical systems
+ Consider chiller sequencing and bypass automation to minimize run time of multiple units vs. outside temperature, time-of-use and balance unit operation hours
- Potentially more complex controls

Active | HVAC
Airside Heat Recovery

Airside heat recovery works by transferring heat from one airstream to another. For this application, this means transferring heat between exhaust air leaving the building and outside air entering the building.

When the temperature of the outside air is higher than the temperature of the exhaust air, the outside air is pre-cooled by transferring heat to the exhaust air. When the temperature of the outside air is lower than the exhaust air, it can be pre-heated.

One common airside heat recovery method is using energy wheels. Energy wheels have a wheel with half its surface area exposed to each airstream. The wheel rotates, transferring heat between the airstreams. These are often installed in AHUs and take up a large amount of space. Square cores (shown) are available, too.

Energy wheels require a motor to turn the wheel. As a result, any energy savings from transfer of energy must exceed the power demand of the motor. Energy wheels can transfer a percentage of air between the exhaust and outside airstreams. As a result, **energy wheels should not be used if the exhaust airstream has any toxins. Alternative products like the plate heat exchanger shown to the right are more compatible with laboratory situations.**

Related Measures

Premium efficiency motors

Temperature control adjustment

Humidity control adjustment

Recommendation for Implementation

Design team should consolidate exhaust where possible to increase heat recovery potential. Energy recovery mandates by code differ for different climates. The table below shows an example when ventilation heat recovery is required for some climates and airflows:

	Hot	Cold	Humid	Temperate
% Outside Airflow	50-60%	10-20%	10-20%	Not required
Total Airflow (CFM)	26,000	26,000	26,000	Not required

See all requirements in IECC table C403.7.4.2

Source: Renew Aire ERV

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Reduces capacity of air handling units
+ Captures energy from exhaust that would otherwise be wasted
+ Provides free heating
+ Provides free cooling
- Uses larger fans because of the added pressure drop through the energy wheel
- Cross-leakage between outside air and exhaust airstreams
- Requires additional space in air handling units

Active | HVAC
Wastewater Heat Recovery

Wastewater heat recovery captures waste heat in the drain line from showers, kitchens and laundry. The reclaimed heat is used to preheat cold water before it enters the water boiler through a heat exchanger. Preheating the water heater for domestic water helps to increase the water heater's capacity. This system is most effective in high-rise residential and hotel type buildings or buildings with high domestic hot water demands.

Drain wastewater heat recovery systems also need storage capacity, otherwise there will only be useful heat exchange when there is simultaneous flow of cold water and heated drain water. They are most popular in colder climates, where the incoming ground water is much colder.

Recommendation for Implementation

Design team will analyze domestic hot water heating load to determine if heat recovery would be a significant benefit.

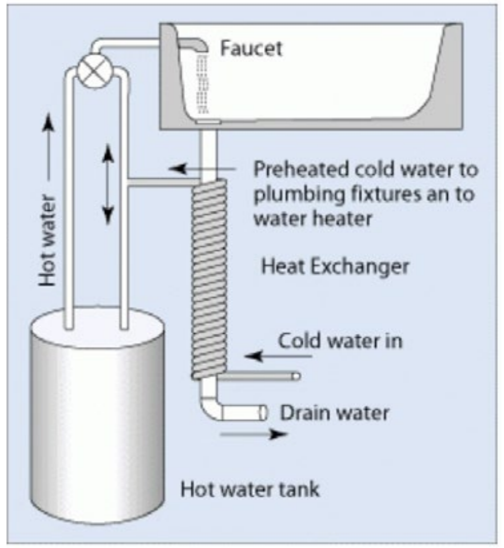
For IECC additional efficiency credit C406.7.2, no less than 30% of the building's annual hot water requirements shall be recovered from service hot water, heat recovery chillers or building equipment, or shall be from renewable hot water heating.

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ No need for increased maintenance or training of staff because there are no moving parts to the system
+ Drain wastewater heat recovery systems are made of mostly copper, which has a longer expected lifespan (30–50 years) than the hot water heaters. Reducing demand may also prolong the hot water heaters' lifespan.
- Capital cost for each heat exchanger installed



Source Dept of Energy (DOE)

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Related Measures

Low-flow fixtures

Active | HVAC
Waterside Economizer

Waterside economizers utilize free cooling from the cooling tower to produce chilled water, which reduces demand on the chillers and saves energy.

When the condenser water supply temperature is low enough, it transfers heat from the chilled water return pipework through a heat exchanger. The heat exchanger is placed upstream of the chillers. This way, the chilled water supply is cooled before reaching the chillers. As a result, the chillers need to supply less cooling to reach the desired chilled water supply temperature.

Since the waterside economizer reduces the chiller cooling load, the chillers operate less frequently. The reduced demand allows the chillers to have a longer lifespan.

Waterside economizers can increase the resiliency of the chilled water system. If a chiller fails, the waterside economizer will provide some or all of the lost cooling capacity.

ASHRAE 90.1 requires waterside economizers in certain climate zones based on the cooling capacity of the mechanical equipment. Generally, waterside economizers should be considered when the wet bulb temperature is below 55 degrees Fahrenheit for at least 3,000 hours per year.

Related Measures

Heat recovery chiller

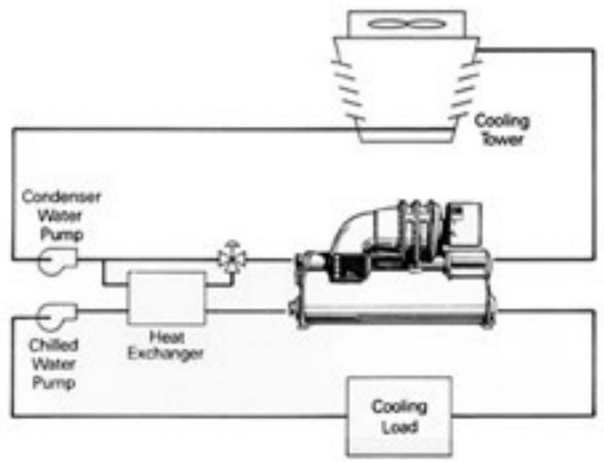
Water-cooled chiller

Recommendation for Implementation

Design team should review viability of waterside economizer based on location and total chilled water load. See table from IECC, below, showing when a waterside economizer is required:

	Hot	Cold	Humid	Temperate
Chilled-water system capacity (btu/hr)	≥960,000	≥1,320,000	≥960,000	≥720,000

See all requirements in IECC table C403.5



Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

- \+ Promotes energy efficiency
- \+ Saves energy costs
- \+ Reduces cooling required by chillers
- \+ Increases lifespan of chillers
- \+ Increases resiliency
- \- First costs
- \- Space requirements
- \- Periodic cleaning of heat exchanger

Active | HVAC
Airside Economizer

Airside economizers use free cooling from outside air instead of mechanically heating and cooling to condition spaces.

Airside economizers work by modulating the outside air dampers to change the amount of outside air entering the air handling units (AHU). The outside air is mixed with the return air to create supply air that will not require any cooling or heating from the coils within the AHU. As a result, the AHUs consume less energy.

During periods of "cool" weather (30-50 degrees Fahrenheit), all cooling demands can be met with the outside air. In warmer weather (50-70 degrees Fahrenheit), the outdoor air can only meet part of the cooling demand. In these warmer conditions, additional mechanical cooling is still required. When the outside air temperature exceeds the high-limit shutoff temperature, the outside air dampers shut and only allow the minimum amount of outside air required for ventilation purposes.

Airside economizers are required per IECC, depending on the climate zone and cooling system capacity.

Related Measures

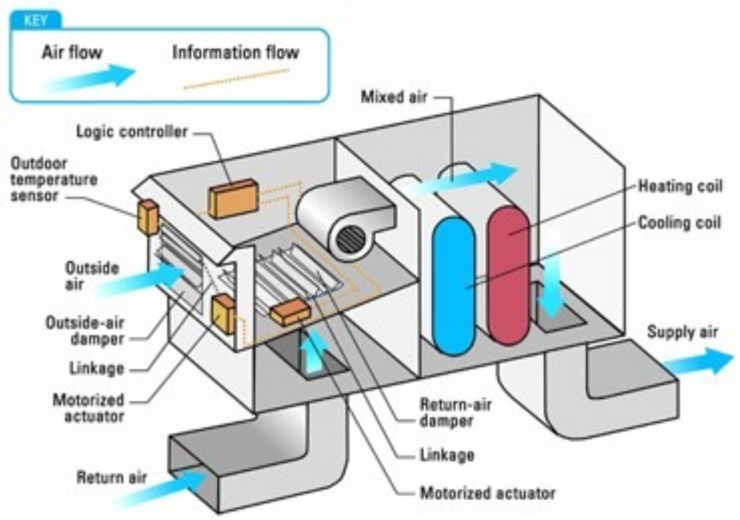
Variable air volume system

Recommendation for Implementation

Design team will review viability of airside economizers, based on location and total cooling capacity and implement if viable. Review the number of annual hours where outdoor conditions are viable for the airside economizer and whether humidification or dehumidification are required. Enthalpy-based economizer may also be used when Outside Air Enthalpy is lower than Return Air Enthalpy. The table from IECC, below, shows when an airside economizer is required:

	All Fan Systems
Cooling capacity (btu/hr)	≥54,000

See all requirements in IECC section C403.5



Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves significant energy in some climate zones
+ Reduces mechanical cooling by air handling units
+ Reduces heat rejection by cooling towers
+ Increases lifespan of air handling units
+ Improves indoor air quality
- Increased outside air filter maintenance
- Larger opening for outside air intake. Could impact building aesthetics
- Humidification or dehumidification might be required

Active | HVAC
Temperature Setbacks

To reduce energy use, HVAC systems should be programmed for temperature setbacks. Temperature setbacks are the controls sequence applied outside business hours that allows the building temperature to go up to a certain temperature, typically 85°F, in the summer, and down to a certain temperature, typically 55°F, in the winter. This is sometimes dictated by code, as seen to the right. This strategy reduces heating and cooling energy used when people are not using the building.

A morning warm-up or cool-down period, such as 2 hours before scheduled occupancy, brings the temperature to the comfort range before the building is occupied. This method can also support sizing and controls of heat recovery chillers by smoothing out peaks depending on the design.

It can be beneficial to break out the 24/7 cooling needs onto a separate system, so it stays on while allowing the occupied spaces to setback overnight.

Recommendation for Implementation

Design team should reference IECC 2021 for temperature setback controls (referenced below) or obtain Thermo Fisher approval for exceptions. Design team should consider separating 24/7 loads if it would allow for more turndown during off hours. Morning warm-up or cool-down period should be described in the project sequence of operations specification sections or as part of the control drawings.

IECC 2021: Thermostatic setback controls shall be configured to set back or temporarily operate the system to maintain zone temperatures down to 55°F (13°C) or up to 85°F (29°C).

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

- \+ Promotes energy efficiency
- \+ Saves energy costs
- \+ Little to no upfront cost
- \- Not feasible for 24/7 cooling or heating requirements

Source: https://www.acuitybrands.com/products/detail/947884/distech-controls/eclypse-connected-thermostat---ecy-stat-series

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Related Measures

Temperature control adjustment

Active | HVAC

Temperature Control Adjustment

Temperature control adjustment can be achieved in many different ways. In large high-performance spaces, typically the temperature adjustment is not at the local thermostats but is at the central BMS control, based on temperature sensors in the space. The BMS controls the supply temperature for the central supply of air and / or water.

Owners could also opt in to have controllable thermostats that occupants control up or down. This can lead to larger swings in cooling and heating demand on one system.

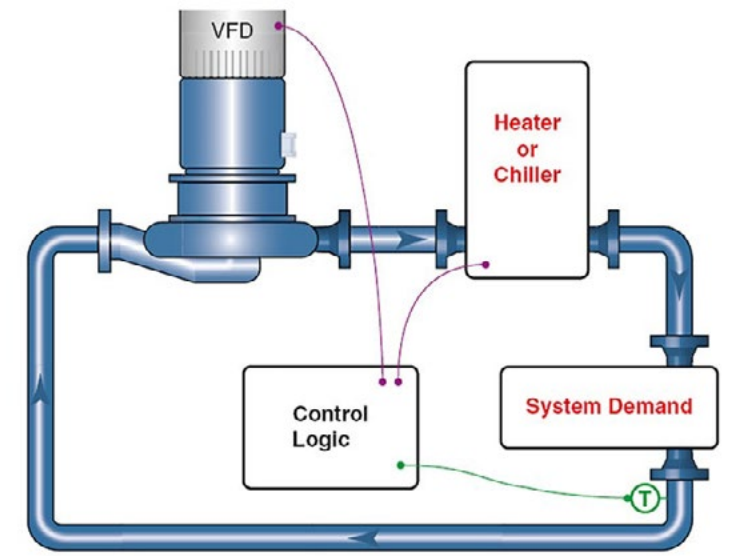
Another option is to offer a user app that occupants can vote cooler or warmer to produce a weighted average temperature for the central equipment to control to.

For VAV systems, since the VAVs control local temperature by changing the airflow, the central AHU supply temperatures only start resetting when a certain number of zones are calling for more or less cooling / heating.

Recommendation for Implementation

Design team should discuss desired level of temperature control at occupant level. Design team should also reference ASHRAE Guideline 36 standard for controls sequence guidance. All mechanical controls should use the same language so they can talk to each other and be integrated to the head BAS seamlessly.

IECC requires control such as:
Multiple-zone HVAC systems shall include controls that are capable of and configured to automatically reset the supply air temperature in response to representative building loads or to outdoor air temperature (or humidity in certain climate zones).



Source: www.pumpsandsystems.com/control-temperature-hvac-systems

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

LEEDv4/4.1: EQ Thermal Comfort

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Clear controls sequences can help the system perform efficiently throughout operations
+ Little to no upfront cost delta

Related Measures

Building Management System (BMS)

Active | HVAC
Demand Controlled Ventilation

Demand Controlled Ventilation (DCV) is the process of regulating the amount of outside air (OA) delivered to occupied spaces to save air conditioning (heating and cooling) and fan energy.

The technologies that can be used to regulate air to spaces include relying on predicted occupancy schedules through the building management system (BMS), people counters and occupancy sensors. The most common method is via space CO_2 sensors that can sense whether the quality of indoor air is becoming polluted and fix that by quickly pumping fresh OA into the building. Sensors measure CO_2 concentrations in values of parts per million (ppm), which are compared against the system setpoints. The greatest savings are realized in buildings where occupancy fluctuates significantly throughout the day compared to the maximum design conditions.

In buildings with large airflow volumes such as labs, air management systems like Aircuity can be economically viable. In these systems, piped air samples from the spaces are continuously assessed to allow differential measurements between zones and airstreams to inform the corresponding modulation of the air system.

The goal of this measure is to save energy, not improve indoor air quality. By helping monitor and maintain the quality of the air, though, a DCV strategy can keep concentrations of allergens, chemical fumes, dust and other pollutants at low enough levels to avoid drops in occupants' happiness and productivity associated with poor air quality.

Related Measures

Air change rates review

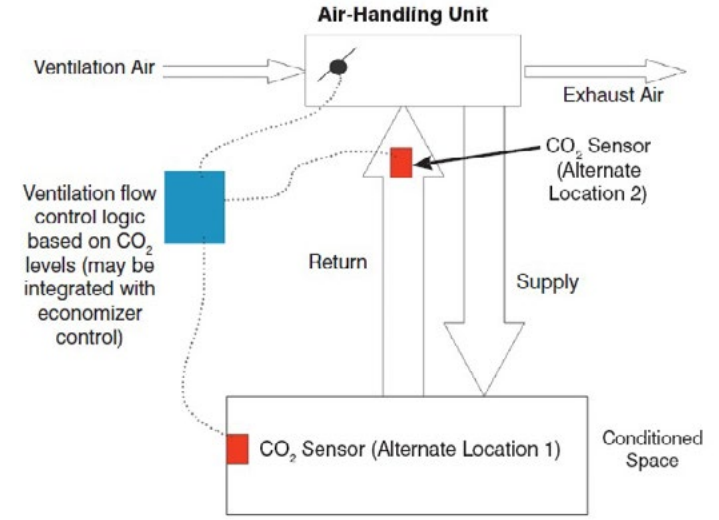
Recommendation for Implementation

The mechanical / controls engineer should determine if a DCV system is appropriate and cost-effective based on the building's ventilation requirements and primary ventilation system, as well as installation costs and energy savings associated with the DCV system.

Deploying DCV in a building with multiple ventilation zones on single air handling systems typically requires the BMS to monitor all DCV sensors and either adjust the outside air damper enough to satisfy the ventilation requirements of all zones or regulate the OA fraction to each zone. Alternately a single sensor in the return air duct can be used, but this can lead to some zones being over-ventilated and some under-ventilated.

Following installation, a building commissioning agent is required to test and verify that the building's DCV system is performing correctly and complies with minimum outdoor airflows.

ASHRAE recommends keeping indoor CO_2 levels to within 700ppm of the outdoor CO_2 concentration.



Source: Tom Lawrence and ASHRAE, https://designbuilder.co.uk/helpv4.5/Content/DCV.htm

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

LEED v4/4.1: EQ Enhanced Indoor Air Quality Strategies

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Locations for sensors should be chosen based on ventilation ductwork and zoning layouts.
+ Measure can be carried out as part of a more comprehensive controls upgrade to avail of economic synergies.
+ DCV should be disabled when airside economizing is enabled.
+ DCV may be required by local codes, depending on type / scope of building retrofit
+ Building pressure controls need to be integrated with the DCV control sequences.

Active | HVAC
Humidity Control Adjustment

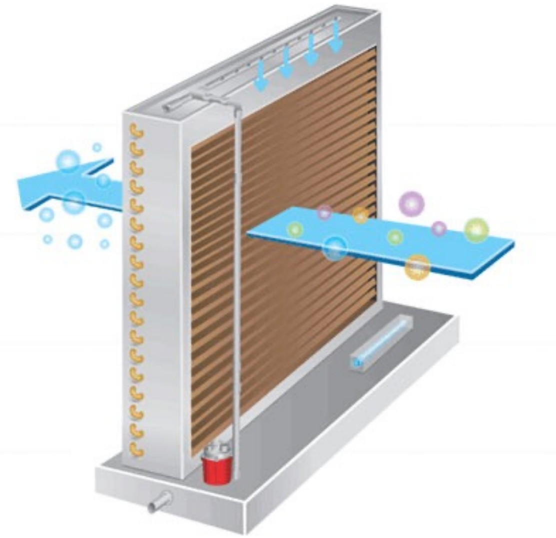
Humidity control adjustment is typically achieved by the central BMS controls sensing the humidity levels at the space and / or in the return air ductwork.

The BMS then adjusts the supply air temperature in the central air system—typically an AHU—to dehumidify the supply air with a chilled water coil or humidify it with filtered make-up water.

Recommendation for Implementation

Comfort humidity levels are between 30% and 70% relative humidity, but the space requirements may vary depending on use. Humidity level requirements might be especially sensitive in certain laboratories. Design team should understand all the space humidity requirements and consider only adding humidification to the spaces that require it. Reference ASHRAE 55 for thermal comfort standards and Guideline 36 for controls practices.

IECC requires control such as:
Multiple-zone HVAC systems shall include controls that are capable of and configured to automatically reset the supply air temperature in response to representative building loads or to outdoor air temperature (or humidity in certain climate zones).



Source: http://t-1.koreasme.com/hvac_system01.html

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

LEEDv4/4.1: EQ Thermal Comfort

Applicable Building Types

- ☐ Office
- ☑ Laboratory
- ☐ Distribution
- ☑ Manufacturing

Considerations

+ Actively managing humidity levels promotes energy efficiency.
+ Central control allows for easy facilities control / maintenance.
+ More stringent humidification requirements may have upfront cost.
- May not save energy if humidification is found to be required
- May require reheating of air streams following dehumidification
- Additional humidification equipment carries additional capital costs and can be maintenance intensive.

Related Measures

Building Management System (BMS)

Active | HVAC
Air Change Rates Review

Air change rates from a cooling or heating system will vary based on space type and heating and cooling loads. It is beneficial to review these in relation to [?] the exhaust and make-up air requirements and understand which requires more airflow. If possible, using the smaller requirement will save energy and still be in line with the code.

Less airflow will also require less infrastructure.

Recommendation for Implementation

Design team should review the air change, exhaust and make-up air requirements and recommend the smaller or dynamic airflow where possible. Careful coordination and review when designating space types for air change requirements, while following required codes, can be beneficial. This strategy reduces power usage for fans, heating, cooling, drying, humidifying, etc. when not needed and in several cases when discharged outside.

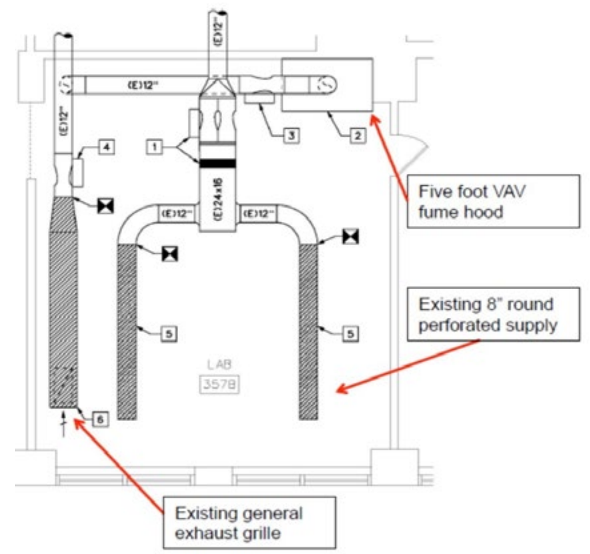
For manufacturing spaces with high containment requirements, consider designing a smaller space dedicated to this task in lieu of large facility air changes. This will reduce energy use for heating, cooling and humidity control. Another strategy is to consider robust HVAC controls for co-balanced zones that can setback from continuous large air changes when not in use. Attention is needed in initial design of the facility to 1) not cause unbalancing of adjacent zones and 2) follow all safety procedures.

Applicable Building Types

- ☐ Office
- ☑ Laboratory
- ☐ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Possibility of lower upfront cost
+ Higher air change rates may be required for laboratory spaces and high containment product manufacturing.



Source: Better Buildings Alliance

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Related Measures

Pressurization review

Active | HVAC
Pressurization Review

Building pressurization should be reviewed in the early stages of design. Pressurization can be especially complex for laboratories with lots of exhaust and make-up air requirements.

General areas such as lobbies, offices and corridors should be positively pressurized, while rooms with chemicals like laboratories and chemical storage areas should be negatively pressurized.

To reduce the amount of make-up air needed, the negatively pressurized rooms should use transfer air as much as possible.

Recommendation for Implementation

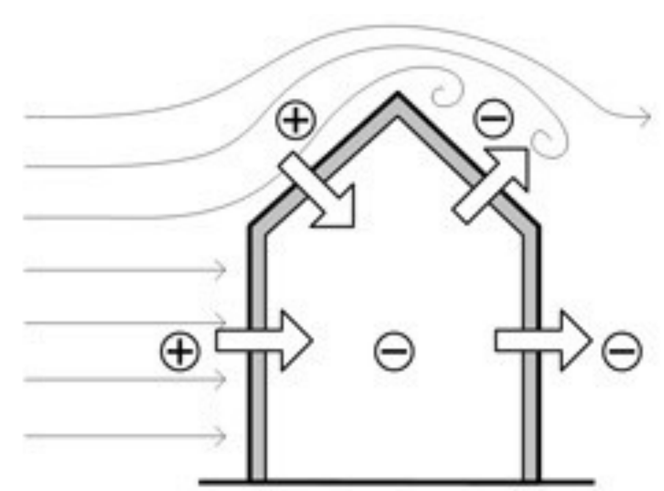
The design team should produce building pressurization diagrams to show the outside air, transfer air, return air and exhaust air pathways. This should be reviewed to ensure that 1) the transfer air is transferring from the positively pressurized to negatively pressurized rooms and 2) the negatively pressurized rooms have more exhaust flow than transfer and make-up flow.

Applicable Building Types

- ☐ Office
- ☑ Laboratory
- ☐ Distribution
- ☑ Manufacturing

Considerations

+ Ensures properly balanced airflow throughout the building
+ May have higher, larger ducts required for transfer air



Source: https://www.ssr-inc.com/pressroom/operating-pressure-importance-maintaining-building-pressure/

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Related Measures

Air change rates review

Active | HVAC

Efficient Fume Hood and Controls

Efficient fume hoods and controls turn off or turn down fume hoods and associated fans when they are not in use. To turn down, each fan uses variable speed control or an electronically commutated motor (ECM). Fume hoods can be turned off with a timeclock on the central controls or by requiring the user to turn them on. Requiring the users to shut the sash when they are not in use can also significantly reduce energy usage.

Less air exhausted requires less make-up air. This reduces the heating and cooling load for the make-up air.

Fume hood exhaust monitoring systems can also be deployed to enable energy efficiency. These can actively monitor particles and total volatile organic compounds in an air stream and optimize the flow of air to compensate.

Related Measures

Fume hood exhaust consolidation

Recommendation for Implementation

Design team should automate turning off fume hoods as much as possible. In areas where turning fans off overnight is not preferred, automate a minimum airflow if possible. Discuss the options to have user control off / on switch. Explore the viability of a demand-based control system to monitor air stream contaminants and match air flow to demand. Refer to My Green Lab for additional guidance.

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☐ Office
- ☑ Laboratory
- ☐ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Lowers heating and cooling demand
+ Little to no upfront cost
- User overrides could impact actual energy use.

Active | HVAC

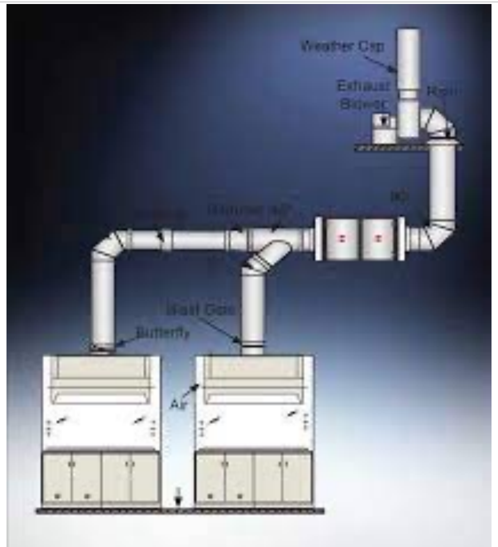
Fume Hood Exhaust Consolidation

Consolidating fume hood exhaust provides the opportunity for less infrastructure and fewer fan motors and controls. Consolidation means less exhaust ductwork. Reducing the number of fans reduces the points of maintenance for the facilities team.

Consolidation also allows for smaller overall exhaust fans, leveraging the diversity across fume hoods. This also results in higher efficiency motors and energy savings.

Recommendation for Implementation

HVAC design team should collaborate with architects and users to consolidate fume hoods onto centralized exhaust fans wherever possible.



https://encrypted-tbn0.gstatic.com/

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☐ Office
- ☑ Laboratory
- ☐ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Reduced infrastructure
+ Reduced upfront cost
- May have architectural impact on space planning
- Potential resiliency concerns if fan fails, but can be mitigated by using standby equipment

Related Measures

Efficient fume hood and controls

Active | HVAC
Refrigerant Management

Refrigerants are commonly used in HVAC equipment, including chillers and heat pumps. Refrigerant leaks can be dangerous to human health and the environment.

Global Warming Potential, or GWP, is essentially a measure of how damaging the refrigerant is to the environment due to its ability to trap heat in the atmosphere. The GWP of a refrigerant refers to the total impact on global warming resulting from the emission of one unit of that refrigerant relative to one unit of the reference refrigerant gas, CO_2, which has a GWP of one. Naturally occurring refrigerants are low impact with a GWP between 1 and 10, compared to historically typical refrigerant compounds with GWPs ranging from 1,000 to 3,000.

Regulations are beginning to cover the GWP of refrigerants. In Europe, the F-gas regulation will start to prohibit the use of refrigerants with a GWP potential of more than 750 by 2025. A similar bill by CARB in California seeks to do the same in early 2023. This is driving manufacturers to seek alternative refrigerants for their products, with R-32, R-452B, R-454B and carbon dioxide all being explored as low-GWP alternatives.

Related Measures

Centralized refrigeration

Recommendation for Implementation

Where possible, and depending on market availability, Design team should select equipment with CO_2 or HFOs refrigerants (R-744) or equivalent low-GWP refrigerants with a GWP below 750. Furthermore, team should ensure there is no use of CFCs or HCFCs. The European Union and North America have mandates regarding refrigerants. The Montreal Protocol has banned the use of CFCs and is phasing out the use of HCFCs.

Refrigerant	GWP*
HCFC-22	1,810
R-410A	2,088
R-407C	1,774
HFO Blends	<1,032
HFC-32	675
HFO-1234ze	6
HFO-1234yf	4
R-441A	4
Propane (R-290)	3.3
CO_2 (R-744)	1

Note: HCFC-22 is no longer used in new equipment because of its ozone depletion potential.

* GWP values are from the Intergovernmental Panel on Climate Change Fourth Assessment Report: Climate Change 2007.

https://www.epa.gov/sites/default/files/2015-09/documents/epa_hfc_residential_light_commercial_ac.pdf

Sustainability Certifications

LEEDv4/4.1: EA Fundamental Refrigerant Management

LEEDv4/4.1: EA Enhanced Refrigerant Management

Applicable Building Types

- [x] Office
- [x] Laboratory
- [x] Distribution
- [x] Manufacturing

Considerations

+ Low environmental footprint
+ May have higher upfront cost
- Low-GWP heating and cooling technologies are still developing

Active | HVAC
Centralized Refrigeration

Refrigerants are used in lots of HVAC equipment, including chillers and heat pumps. Refrigerant leaks are dangerous to human health and the environment, so it is beneficial to centralize all larger HVAC equipment with refrigerants and have a refrigerant leak detection, alarm and exhaust system that responds to detected leaks. This is required by code in some areas and is also best practice. When centralized, it is much simpler to monitor and respond to accidents.

Recommendation for Implementation

Design team should work with architect to centralize large HVAC equipment with refrigerants. Design team should include a refrigerant leak monitoring system.

Reference the International Mechanical Code (IMC) for ventilation requirements for rooms with refrigerant equipment. An excerpt of the code requirement follows:

Section 1105.6: Machinery rooms shall be mechanically ventilated to the outdoors. The free-aperture cross-section for the ventilation of the machinery room shall be not less than:

$F = \sqrt{G}$

Where:

F = the free opening area in square feet

G = the mass of refrigerant in pounds in the largest system, any part of which is located in the machinery room

Applicable Building Types

- ☐ Office
- ☑ Laboratory
- ☐ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Manages risk and maintenance of refrigerant leak to one location

Sustainability Certifications

LEEDv4/4.1: EA Enhanced Refrigerant Management

Related Measures

Refrigerant management

Active | Process

Process Efficiencies (i.e., Pipe / Equipment Insulation)

Insulation is critical to energy efficiency. Fittings, valves and vessels should also be insulated.

Jackets on insulation help preserve insulation integrity.

There are multiple process efficiency measures:

- Insulate. If insulation is not possible, consider and review insulating paint.
- Reduce temperatures and pressures
- Build and lay out routes and equipment to minimize losses
- Turn off or turn down energy use when possible

Recommendation for Implementation

Insulation specifications are well defined. Provide per codes and engineering recommendations.

When insulation is not possible due to complex shapes or for heated vessels, ceramic insulating paint may be a viable approach. See ThermaCels, Thermalmix or other products.

It can be costly to maintain hotter or colder than ambient temperatures, and high pressures or vacuums. Adjusting temperatures and pressures to values closer to ambient conditions saves money and may reduce energy consumption.

Distribution losses can be excessive and must be considered as equipment is located and as distribution systems are determined.

If something does not need to be on, ensure it can be turned off.

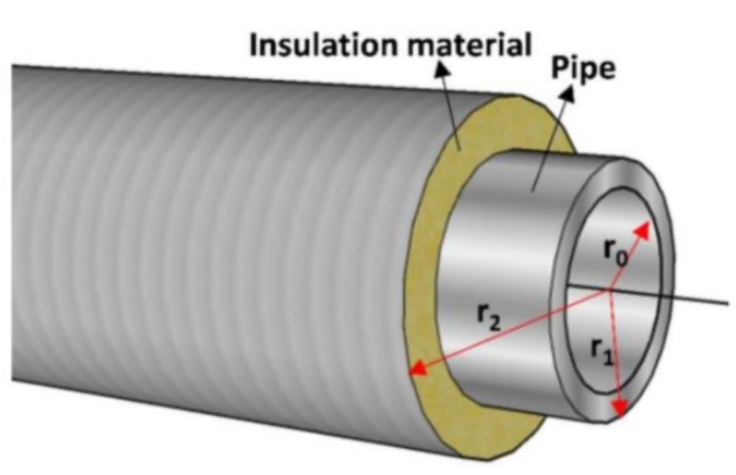
If something can be reduced, reduce it.

Applicable Building Types

- ☐ Office
- ☑ Laboratory
- ☐ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Lowers heating and cooling demand
+ Allows for flexibility in HVAC selection
+ May reduce HVAC equipment capacities saving cost
- May have higher upfront cost



Source: https://www.mdpi.com/2071-1050/14/1/549/htm

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Related Measures

Demand-driven process cooling

Water loops for purified water

Steam pressure and distribution

Active | Process
Cold Water for Injection Systems

Water for Injection (WFI) is manufactured at multiple Thermo Fisher facilities. Finding ways to make WFI without gas and with less energy helps achieve Thermo Fisher's decarbonization goals.

There are two suggested approaches:

1. **Cold WFI generation** using membrane-based WFI systems with vapor compression
2. **Heated vacuum vessel(s)** take advantage of water evaporation at lower temperatures when in a vacuum. See the chart on this page.

Related Measures

Process efficiencies

Demand-driven process cooling

Water loops for purified water

Recommendation for Implementation

Design team should consider lifecycle analysis, energy use and reliability, comparing existing approaches to WFI manufacture.

Key factors to consider with membrane-based WFI manufacture include: the cost of "membranes" and manufacturing process application of the membranes, along with the generator of the pressure needed for the membranes.

A moderate vacuum enables lower temperatures to "boil" the water. This approach uses less energy, reducing the nearly 1,000 Btu latent energy at standard atmosphere per pound of water.

All three process approaches (existing, membrane and vacuum) require and benefit from considering the water quality input to the process. All three processes have ongoing manufacturing concerns of residue from the process(es) and requirements for high quality WFI output from the process used.

	Temperature		Vapor Pressure	
Vacuum Inches Mercury (In Hg)	Degrees F	Degrees C	(MPa)	(kPa)
		0.01	0.000612	0.6
0.94	77	25	0.00317	3.2
3.65	122	50	0.01235	12.4
11.39	167	75	0.0386	38.6
29.94	212	100	0.1014	101.4
		150	0.4762	
		200	1.555	
		250	3.976	
		300	8.588	
		350	16.529	
		373.9	22.064	

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☐ Office
- ☑ Laboratory
- ☐ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Lowers heating and cooling demand
+ Must consider water volumes
- Will have higher upfront cost and will probably have increased maintenance and operating costs
- Compressors or vacuum generators may add contamination to process.

Active | Process
Water Loops for Purified Water

Purified water has several types:

- Sterilized by heating
- RO: Reverse Osmosis
- DI: De-Ionized

All of these types may be in use at new and existing Thermo Fisher facilities.

First costs, lifecycle costs, monthly service costs, staff costs, related energy costs and materials costs are all worthy of review.

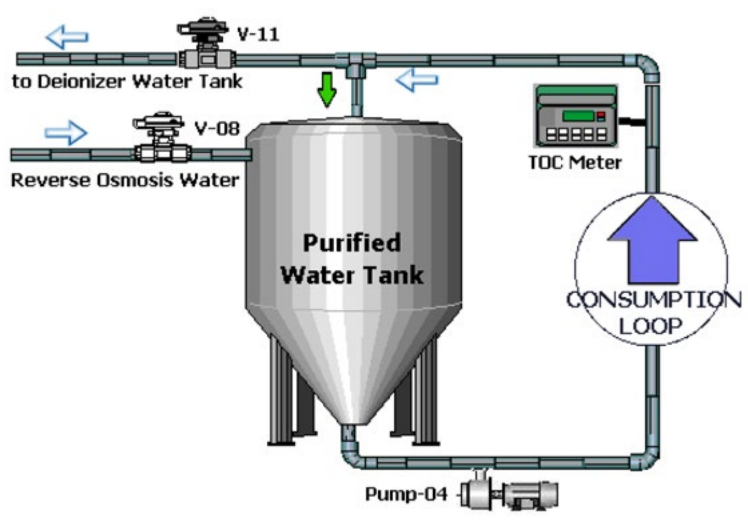
Recommendation for Implementation

Review first costs

Review for electrification potential

Review required supply temperatures and minimize re-heating, re-cooling and other excessive energy use

Recycle energy used in sterilization or when adjusting final product temperatures



Source: https://www.mdpi.com/1424-8220/19/20/4488/htm

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☐ Office
- ☑ Laboratory
- ☐ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Improves product control by isolating purified water loops by temperature required for purified water process and final product requirement
+ May reduce HVAC equipment capacities saving cost
- May have higher upfront cost
- May increase maintenance materials and staff costs

Related Measures

Process efficiencies

Demand-driven process cooling

Active | Process

Demand-driven Process Cooling

Process cooling is used within Thermo Fisher facilities to support lab spaces and to help cool processes associated with the manufacture of products.

Since the water temperature needs of some processes differ from the chilled water temperature needed for air conditioning, process cooling is often provided with separate chiller(s). The separate chillers run continually to provide process cooling when needed, driving up energy consumption.

Design teams should confirm process cooling needs within the facility under design and decide whether a separate process cooling system should be provided or whether process cooling can be included as a sub-circuit to the air conditioning chilled water system. The more efficient approach would be to combine systems into a common chilled water plant.

Team should also confirm the frequency of process cooling usage, and this, in turn, should help inform control strategies related to the process cooling system. Where process cooling is used intermittently, the serving chiller should have the ability to drop into standby mode, driven by a BMS schedule or based on process cooling demand, as sensed by differential pressure sensors and return temperature.

Related Measures

Process efficiencies

Building Management System (BMS)

Water loops for purified water

Recommendation for Implementation

Project team should confirm process cooling temperatures and the operational frequency of processes requiring cooling with Thermo Fisher, along with cooling demand of processes. Where compatible, explore combining process cooling with cooling for air conditioning.

Integrate process cooling system with building automation system. Specify sensors on process cooling circuit or specify schedule-based control to enable energy consuming process cooling equipment to move to standby mode when there is no demand.

Source: Better Buildings Initiative

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☐ Office
- ☑ Laboratory
- ☐ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Lowers heating and cooling demand
+ Reduces maintenance

Active | Process

Steam Pressure and Distribution Review

Steam may be used within Thermo Fisher buildings to help support process heating, sanitization of laboratory equipment and space heating.

Although steam distribution is efficient from a capital perspective, due to smaller pipes and higher energy density, these systems are challenging to maintain and difficult to decarbonize.

Before committing to a steam-based system, design teams must review whether alternative solutions might better meet the needs of the building.

This may involve discussions with Thermo Fisher on the proposed end uses for steam to understand whether there are alternate end use solutions that may avoid using steam.

Where steam is required, it may be better to use a localized electric steam boiler focused on the end use.

Recommendation for Implementation

Prior to committing to a steam-based system within Thermo Fisher facilities, Design team should rule out alternative, lower temperature water-based systems. Where steam is required for a process, engage with Thermo Fisher to investigate whether there are alternate end uses compatible with a non-steam approach.

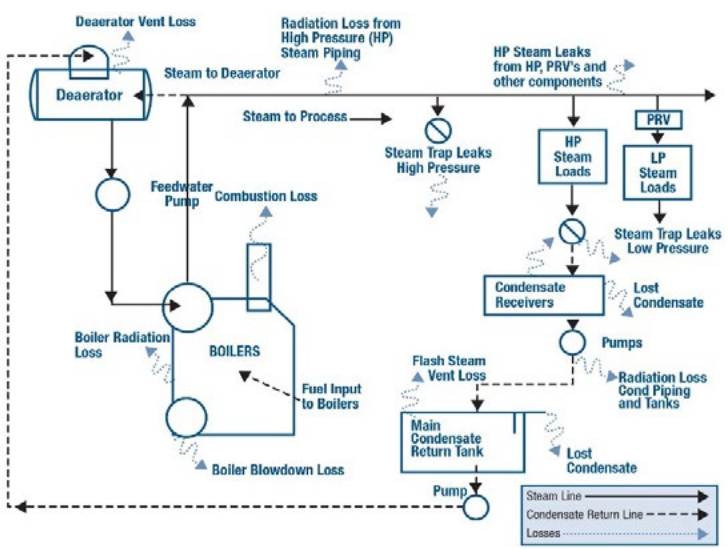
Where steam is required by an end use, consider the local production of steam near the end use, utilizing an electric steam generator.

Applicable Building Types

- ☐ Office
- ☑ Laboratory
- ☐ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Reduces maintenance costs



Boiler & Steam System Losses. Source: energy.gov

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Related Measures

Process efficiencies

Compressed air and distribution review

Active | Process

Compressed Air and Distribution Review

Compressed air systems can be the most expensive "utility" for a facility.

Piping and fittings leaks must be found and corrected.

Compressed air receiver tanks must be strategically located and sized to keep compressor "on" time to the lowest amount reasonable and to minimize short-cycling.

Multiple air compressors may be cascaded to minimize and reduce electrical peak demands.

Compressed air systems' piping topology should also be reviewed. Piping should be segregated for loads served and valved to facilitate zoned maintenance and repairs.

Recommendation for Implementation

Provide multiple, cascaded compressors where feasible and shown to benefit the compressed air system.

Provide suitable air dryers. Specify dryers that utilize compression heat to minimize energy required for drying.

Locate and size compressed air receiver tanks to minimize compressor short-cycling and compressed air supply to loads.

Provide isolation valves and piping layout to segregate major loads for type, pressures and maintenance.

Consider opportunities for heat recovery from air compressors.

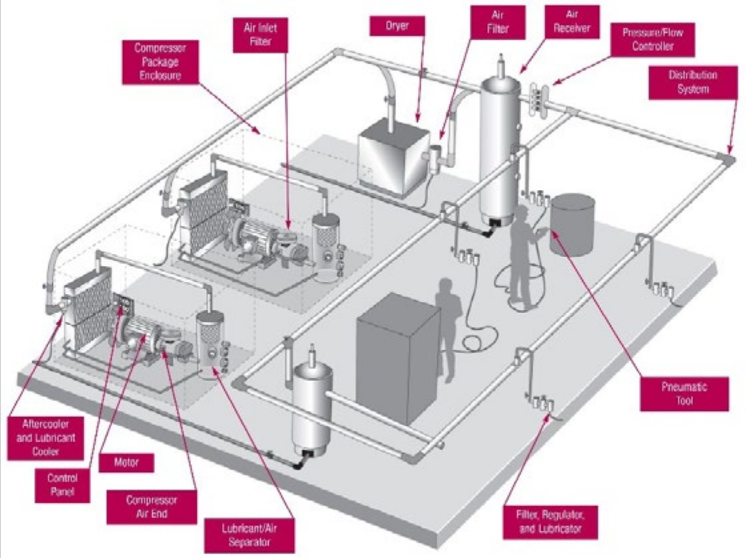
Explore the benefits of oil-free compressors compared to oil-based compressors.

Applicable Building Types

- [ ] Office
- [x] Laboratory
- [ ] Distribution
- [x] Manufacturing

Considerations

\+ Promotes energy efficiency
\+ Saves energy costs
\+ Reduces operating compressed air pressures to the lowest pressure operable
\+ Reduces system failures
\- Higher first cost



Source: energy.gov

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Related Measures

Steam pressure and distribution review

Active | Process

Optimized Compressed Air Control Settings

Compressed air requires significant energy when maintained at higher pressures. Reducing air pressure to lower values will save electrical demand costs and electrical energy costs.

New control sequences and appropriate system sensors can help maintain lower, floating, appropriate compressed air pressures. These systems also help analyze system leakage and provide alarms when leakage or usage is excessive and beyond expected values.

Multiple air compressors may be cascaded to minimize and reduce electrical peak demands.

Also consider compressed air systems' piping topology. Piping should be segregated for loads served and valved to facilitate zoned maintenance and repairs.

Periodic preventative maintenance should be ensured to seek out and correct any compressed air leaks.

Recommendation for Implementation

Provide multiple, cascaded and parallel air compressors for large systems. Provide variable speed drives on large compressors.

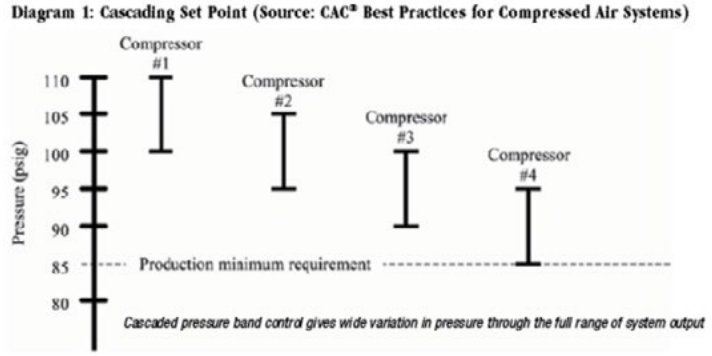
Provide remote sensors indicating remote air pressures and relate these with Sequences of Operations (SOO) and Fault Detection and Diagnostic (FDD) logic to control compressed air systems to optimal pressures and to provide leak detection.

Size compressed air receiver tanks for optimal system performance.

When possible, choose compressed air utilization equipment that uses lower pressures. Install sectionalizing valves to enable maintenance without full system shutdown. Provide adequate and efficient air dryers for compressed air systems. Choose equipment that leverages compressor heat (i.e., heat recovery) to offset air dryer energy needs.

Operate systems to reduce compressor short-cycling.

Diagram 1: Cascading Set Point (Source: CAC® Best Practices for Compressed Air Systems)



Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☐ Office
- ☑ Laboratory
- ☐ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Reduces operating compressed air pressures to the lowest pressure operable
+ Provides remote pressure sensors and additional BMS or compressed air controls to optimize the system pressure
+ Reduces systems failures
- Higher first cost

Related Measures

Building Management System (BMS)

Fault Detection and Diagnostics (FDD) analytics

Active | Electrical Infrastructure

Electrical Transformers

Transformers are a critical infrastructure component within a building's electrical system; all electrical power passes through them to step-up or step-down voltage to serve end loads.

During operation, transformers consume energy due to losses associated with heat generation and vibration. Transformer efficiency varies significantly and non-linearly, based on the amount of power flowing through them. This efficiency varies by product, but maximum efficiency is typically achieved when transformers are loaded to between 30% and 50% of their power rating. Efficiency typically drops off significantly when transformers are either under-loaded or loaded to the upper end of their capacities.

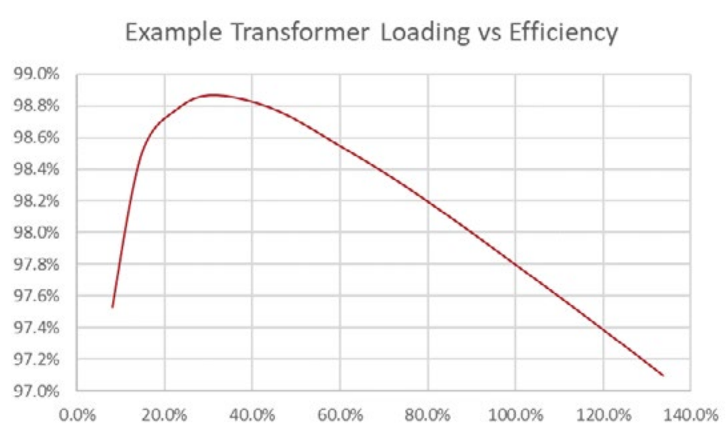
Studies have documented that transformers are often significantly under-loaded, leading to wasted energy. A 2006 study analyzed 86 transformers in 43 commercial, industrial and institutional buildings and found the average loading varied from 14.1% to 17.6%. Because transformers serve multiple end uses, they are often not able to be de-energized because they are always servicing a load somewhere in the building.

Poor transformer selection can result in lost energy for the life of the equipment. The trend of electrification will increase these losses.

Recommendation for Implementation

When selecting transformers, team should consider and evaluate the following:

- Where feasible, consider serving loads with similar usage times on the same transformer, with the aim of de-energizing transformers when loads are not in use.
- Evaluate the realistic loading of the transformer, including diversities where applicable. Match the "typical" loading with the highest efficiency performance of the transformer.
- At a minimum, comply with the required transformer efficiencies listed in the latest version of the International Energy Conservation Code.
- Consider oil-filled transformers, which tend to operate at higher efficiencies with a smaller footprint. Explore products that contain biodegradable transformer oil as a substitution for mineral oil.
- Consider using copper-based coil windings, which are more efficient than aluminum.



Source: Arup

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

☑ Office ☑ Laboratory
☑ Distribution ☑ Manufacturing

Considerations

\+ Optimally specified transformers offer significant energy savings over the life of the asset.

\+ Consider efficiency curve of transformer at different loadings. Selecting when transformer operates at peak efficiency can prolong lifespan.

\+ Transformer efficiency is expected to be a significant energy saving opportunity as more electricity is used within buildings due to electrification.

\+ Consider copper coils for more efficiency.

\+ Oil-filled transformers can be more efficient and more compact. Consider environmentally friendly cooling mediums.

\- Oil-filled transformers require additional maintenance and may require special fire containment.

Active | Data Centers

Data Center Energy Efficiency

Data centers use about 70 billion kWh of energy per year in the United States, which is nearly 2% of the nation's electricity use. Energy in data centers is primarily used for server power (60%) and cooling loads (40%).

A few energy efficient methods for data centers include hot-aisle / cold-aisle containment (shown in the image below), power monitoring, temperature / humidity / pressure monitoring, LED lighting and control, computer room air conditioner (CRAC) and monitoring with SynapseSense or similar data center infrastructure management tools.

Containment means the hot or cool air is fully ducted or routed in an enclosed soffit between the AC unit and the servers. There are pros and cons to hot-aisle vs. cold-aisle, but it is generally understood that hot-aisle containment is more energy efficient for most cases.

Data center infrastructure monitoring can help balance airflow by keeping track of room pressure, environmental monitoring and live imaging, energy use monitoring and asset health monitoring.

CRAC is used for general temperature and humidity control in data centers.

Energy is lost when data center volumes are not sealed around cables / cable tray entry points. Identify these during construction.

Related Measures

LED lighting

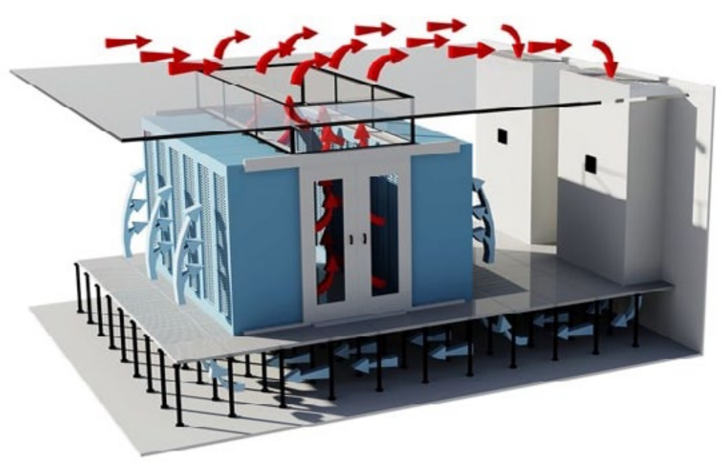
Recommendation for Implementation

Design team should compare hot-aisle vs. cold-aisle benefits and coordinate underfloor and overhead plenum spaces with architect. Also discuss maintenance access for server units and specify front-access units if possible.

Design team should consult the Data Center Environmental Policy section of ASHRAE TC9.9 for further guidelines.

Design team should implement Data Center Infrastructure Management (DCIM) tools, which monitor with installed sensors every rack inlet and outlet at low, medium and high points for room temperature and air pressure.

Data centers should be designed to achieve a power usage effectiveness (PUE) of less than 1.5. The lower the PUE, the more energy efficient the data center is; 1.2 is very efficient and 3.0 is very inefficient.



https://www.colocationamerica.com/blog/hot-vs-cold-aisle-containment

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Certified Energy Manager® - CEM®

Energy Efficiency Practitioner - EEP™

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

- \+ Promotes energy efficiency
- \+ Saves energy costs
- \+ Hot-aisle ensures colder environment for all equipment in room
- \+ Can increase equipment lifespan and reduce maintenance costs and downtime caused by equipment overheating
- \- May have higher upfront cost
- \- May have architectural impact

Operations | Commissioning
Owner's Project Requirements (OPR)

The OPR provides the project owner and project teams with considerations and constraints related to the design, construction, acceptance and operation of a facility. It is typically produced and used in conjunction with the Basis of Design (BOD) developed by the design team, as well as the Commissioning Plan.

The OPR is written by the owner, Commissioning Provider (CxP) or Agent (CxA). It should be circulated and agreed upon by related parties. Typical sections of the report include:

- Scope
- Internal design standards or manuals
- General specifications
- Team directory
- Project schedule
- Project description
- Training
- Warranty information

Note: The OPR is not required for every project, but it is a required piece of documentation for LEED project submissions.

Recommendation for Implementation

An OPR should be written toward the beginning of a project's design stage. It is not uncommon for it to be revised and updated as the project progresses. It is recommended for the Commissioning Provider to host an OPR Workshop with the owners, designers, facilities team and any other related parties to agree on terms and requirements. In the workshop, the Commissioning Provider should ask questions and gather information that will help to better evaluate the design and progress of the project.

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ OPR Workshops with the owner / owner representatives and the facilities team (upon occupancy) are not required but are recommended.
+ Having an updated OPR keeps the CxP accountable and facilitates the process of writing the final Commissioning Report.

Sustainability Certifications

LEEDv4/4.1: EA Fundamental Commissioning and Verification

LEEDv4/4.1: EA Enhanced Commissioning

Related Measures

Commissioning design review

Operations | Commissioning
Commissioning Design Review

A Commissioning Review is completed by a commissioning agent (CxA – an entity not involved with the project design). It is conducted at various stages of the construction process, typically at 30%, 60% and 90% Design and / or whenever the contract obligates.

The purpose of this review is to find and raise issues that should be addressed during the design stage, prior to incurring expensive changes that can result if issues are not identified until construction. The design review will focus on ensuring the energy systems can be commissioned and are designed to work together. It will also verify the maintainability of the systems. Another focus is making sure the control strategies are meeting the intent of each space and helping meet any environmental performance requirements for the project.

The commissioning review also helps ensure the design meets all requirements specified in the OPR.

Recommendation for Implementation

Conducting a commissioning review early in the process can lead to time and cost savings. It is also helpful if the project has an Owner's Project Requirement (OPR), as the CxA can use that to check if the design meets the criteria specified. Examples of items raised via a Commissioning Review include:

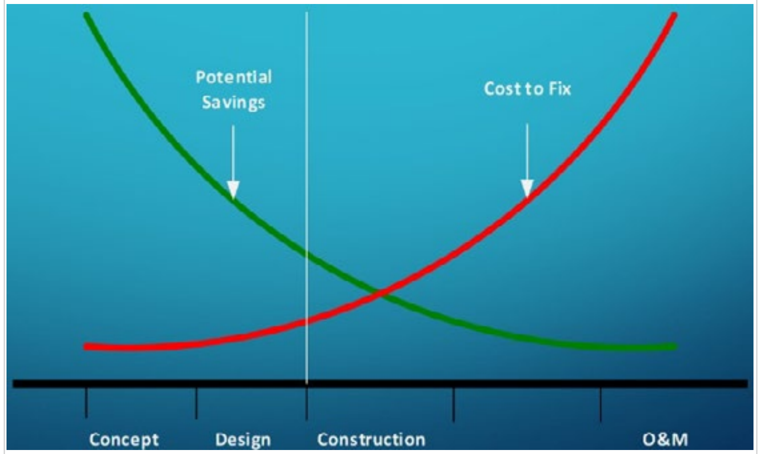
- Code Compliance: Ensuring the design meets all code requirements
- OPR Compliance: Ensuring the OPR criteria are met, and highlighting any missing design criteria
- Coordination Items: Ensuring that ducts do not overlap, equipment has sufficient compliance and access, and maintenance can still be done
- Cost Savings: Removing redundancies in equipment and controls
- Design: Ensuring that requirement components are present and unobstructed

Applicable Building Types

☑ Office
☑ Laboratory
☑ Distribution
☑ Manufacturing

Considerations

+ The CxA must not be affiliated with the project design.
+ Some elements of commissioning are now required by building codes.
+ Required for LEED Fundamental Commissioning and Verification Prerequisite
+ More commissioning reviews can lead to more impactful changes.



Source: Arup

Sustainability Certifications

LEEDv4/4.1: EA Fundamental Commissioning and Verification

Related Measures

Owner's Project Requirements (OPR)

Operations | Commissioning
Witness and Verification

Witness and verification, sometimes referred to as "testing and balance" (T&B), is a process to verify that systems are functioning as designed. Typically, only a percentage of systems go through the testing and balancing process; that percentage could be either a percentage of the total number, a representative percentage or a statistically-derived percentage. Often, the number of systems to be tested is included in the project contract or OPR.

The following systems may be tested:

- 15% of all VAV boxes
- 1 test on each AHU of the same type and control logic
- 10% of thermostats
- All cooling towers

Testing requires the Commissioning Agent (CxA) to be onsite to oversee testing by the contractor. Typically, this testing focuses on the balancing of hydronic and air systems, to ensure that air volumes and water volumes reaching each end use are aligned with the design intent.

Related Measures

Owner's Project Requirements (OPR)

Recommendation for Implementation

The testing and balancing process commences after start-up tests are conducted by the contractor(s) to ensure the equipment is functioning. This T&B process can consist of measuring the supply air velocity and flowrate into select rooms and comparing those measurements to the design values. It can also consist of measuring flowrates, pressures, differentials, or voltages of VAVs, motors, fans and other equipment.

Source: energy.gov

Sustainability Certifications

LEEDv4/4.1: EA Fundamental Commissioning and Verification

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ The CxA must not be affiliated with the project design.
+ Required for California projects (Title 24)
+ Required for LEED Fundamental Commissioning and Verification Prerequisite
+ More commissioning reviews can lead to more impactful changes.
+ Additional cost per visit for CxA to conduct testing

Operations | Commissioning
Enhanced Commissioning

Enhanced commissioning is a more extensive commissioning process. Building on the standard process, enhanced commissioning typically includes post-occupancy seasonal testing and development of a systems manual to capture warranty and maintenance requirements. It also includes the review of key contractor submittals and delivery of building operation training following construction.

Undergoing an enhanced commissioning process can lower operational costs in the long run. Small issues related to mechanical, electrical and control systems can accumulate and lead to other, larger issues. Identifying these issues through the enhanced commissioning process offers better returns by amending heating and cooling demand while improving thermal comfort.

Recommendation for Implementation

Enhanced commissioning requires the commissioning authority to do the following:

- Review contractor submittals
- Check to ensure requirements for facilities and occupant training are included in the construction documents
- Verify that the facilities and occupant training is effective
- Verify that construction documents include system manual requirements and are updated as necessary
- Review building operations 10 months after occupancy
- Develop an ongoing commissioning plan
- Verify that seasonal testing takes place

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Requires a commissioning authority with appropriate equipment and training (and not affiliated or involved with the design)
+ Enhanced commissioning earns LEED credits for EA Enhanced Commissioning
+ Can achieve LEED Enhanced Commissioning credit
+ Costs money for each visit made by the CxA

Source: energy.gov

Sustainability Certifications

LEEDv4/4.1: EA Enhanced Commissioning

Related Measures

Commissioning review

Witness and verification

Monitoring-based commissioning

Envelope commissioning

Operations | Commissioning
Envelope Commissioning

Envelope commissioning is used to validate that the building envelope meets the Owner's Project Requirements (OPR). The process consists of observing, testing and verifying that systems, assemblies, materials and components meet the OPR. This process can avoid costly design changes during the construction process. Different types of envelope system tests could include:

- Infiltration (water and air)
- Thermal performance
- Building envelope pressure and air leakage
- Daylight glare control
- Condensation resistance
- Moisture control
- Water penetration
- Acoustic performance
- Wind load testing
- Blast / impact testing
- Vibration testing
- Durability
- Security performance

Related Measures

Optimized insulation

Optimized glazing

Recommendation for Implementation

Envelope commissioning can catch errors with infiltration, glare and solar heat gains to help improve occupant comfort. Before construction:

- Incorporate envelope requirements into the Owner's Project Requirements (OPR)
- Have a kickoff meeting to identify project objectives and decide on the project's commissioning agenda
- Develop a commissioning plan

During the design phase, the commissioning agent (CxA) reviews drawing sets to verify that the design meets the OPR. During construction, the CxA:

- Reviews the construction documents and submittals
- Conducts aesthetic and performance testing on design mock-ups
- Reviews the contractor / subcontractor performance implementation plans for the building envelope

The type of envelope and size of building will determine which types of tests are conducted. For example, a 10-story building with a curtain wall would be best tested by thermal imaging or a field mock-up, whereas a 3-story office would be better tested with a blower door test.

Sustainability Certifications

LEEDv4/4.1: EA Enhanced Commissioning, Option 2 Envelope Commissioning

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Requires a commissioning authority with appropriate equipment and training (and not affiliated or involved with the design)
+ Enhanced commissioning earns LEED credits for EA Enhanced Commissioning
- Costs money for each visit made by the CxA

Operations | Commissioning
Monitoring-based Commissioning

Monitoring-based commissioning (MBCx) consists of physical energy monitoring systems and real-time energy analysis. This information is used to identify unexpected or irregular patterns in energy consumption and / or faulty equipment. This, in turn, can lead to retro-commissioning of existing systems.

Monitoring-based commissioning offers three unique benefits that differ from retro-commissioning (RCx):

1. Initial savings from RCx can evaporate over time. MBCx can identify when the initial savings begin to evaporate, thus offering savings by identifying problems through metering and data trending.
2. Savings from measures that were identified during the initial commissioning process
3. New energy-saving measures that materialize through continuous monitoring of data and systems

Related Measures

Enhanced metering

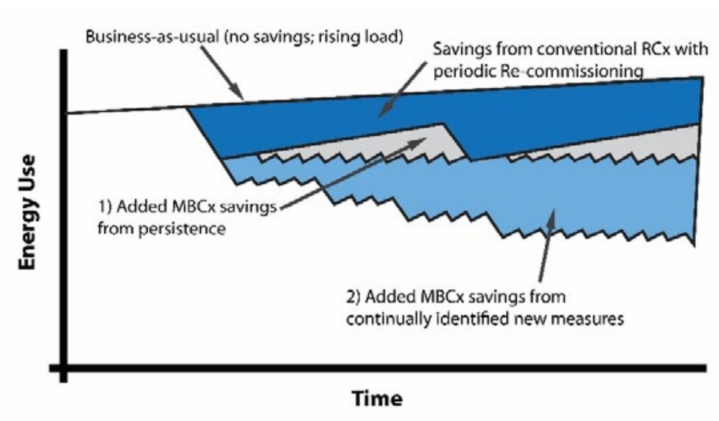
Building Management System (BMS)

Recommendation for Implementation

Monitoring-based commissioning could reduce operating costs by roughly $0.25/SF/year with a simple payback time of 2.5 years (based on a study of 24 buildings in the University of California and California State University systems).

MBCx also requires the following additions to the commissioning plan:

- Monitoring requirements (number of meters, data points to be tracked and any supporting software and hardware)
- Thresholds of acceptable data values
- Updated metric for quantifying system performance
- Operator training on system use and error tracking
- Frequency of analyses during the first year of occupancy
- Ongoing functional performance testing



Sustainability Certifications

LEEDv4/4.1: EA Enhanced Commissioning Ongoing Commissioning (OCx) and Monitoring-based Commissioning (MBCx)

Applicable Building Types

☑ Office ☑ Laboratory
☑ Distribution ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Monitoring-based commissioning is most cost-effective when the energy metering and analysis software are included in the initial building design.
+ Requires a commissioning authority with appropriate equipment and training (and not affiliated or involved with the design)
+ Required for California projects (Title 24)
+ Utilities can offer rebates.

Operations | Energy Management
Enhanced Metering

Whole-building energy metering tracks energy consumption over time, and analysis of the collected metering data can prevent overconsumption, as well as overbilling, while also providing the opportunity to take advantage of off-peak utility rates.

Submetering is the installation of metering devices that measure energy usage downstream from the whole-building meter or primary utility meter. It offers the ability to monitor energy usage for individual tenants, departments, pieces of equipment, process loads, etc., and it can provide insights on usage patterns to develop tailored energy conservation measures (Measures) throughout the building's lifespan.

Metering data and submetering data are useful when collected, analyzed and communicated to users. Building automation systems can be used for this purpose but Thermo Fisher's preference is to utilize a cloud-based system for data collection and reporting. This approach ensures the data is accessible at the enterprise level, allowing for centralized benchmarking and facility comparisons to be made over time.

Related Measures

Building Management System (BMS)

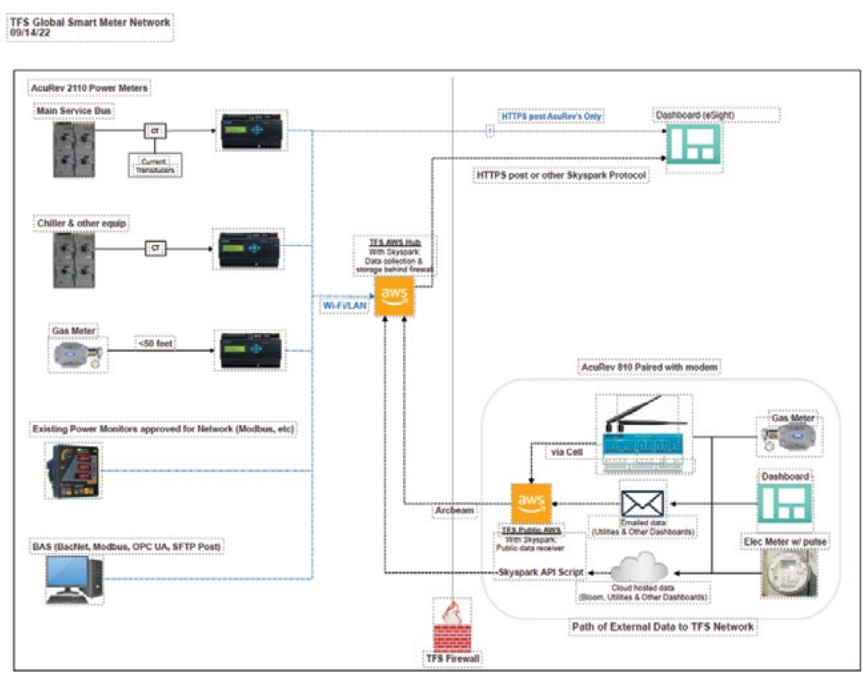
Fault Detection and Diagnosis (FDD) analytics

Monitoring-based commissioning

Recommendation for Implementation

Design team should identify and meter all sources of energy delivered to the building (electricity, gas, district chilled water, onsite renewables, etc.) and implement a submetering strategy appropriate for project type and goals. Steps to inform submetering strategies may include using a building energy simulation model to identify practical systems or end uses. Example end uses for a commercial office building may include receptacle loads, interior / exterior lighting, space heating / cooling, etc.

To support energy management and identify opportunities for additional energy savings at the system level, install submeters for any end use that represents 10% or more of the total annual energy consumption.



Source: https://www.accuenergy.com/wp-content/uploads/AcuLink-810-data-aquisition-server-brochure.pdf

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Saves energy costs
+ Owners and tenants can cross-check the accuracy of energy bills
+ Helps monitor energy consumption with real-time reporting
- May have higher upfront cost
- May require budgeting for maintenance and energy manager analysis

Sustainability Certifications

LEEDv4/4.1: EA Advanced Energy Metering

Operations | Energy Management

Building Management System (BMS)

Building controls are critical to proper facility operation, energy efficiency and occupant comfort. Building Management Systems (BMS) and Building Automation Systems (BAS) are synonyms.

User interface with computer display graphics properly representative of the systems controlled and monitored must be provided and confirmed through commissioning (Cx). Sensors must be confirmed accurate; damper and valve actuators must be properly operating and properly indicated on BMS displays.

Sequences of Operation (SOO) provide occupied and unoccupied modes of HVAC operations. Resets reduce energy use. When outside air temperature and humidity are comfortable, economizers allow use of that air and reduce energy use.

A BMS with trending capability enables better energy efficiency and systems optimization.

Related Measures

Fault Detection and Diagnostics (FDD) analytics

Recommendation for Implementation

Confirm with Thermo Fisher whether a particular BMS product should be specified. Design team must check with Thermo Fisher's Global Energy Management team during the planning stage for approval and recommendations.

BMS shall be commissioned to ASHRAE Guidelines and Standards.

Metering for electrical use, gas use, water use and renewable energy must be collected in the BMS.

Provide trending of all metering; all sensors; all commands and changes of states, space and outdoor temperatures and humidity.

Training must be provided to Owner operating staff for the BMS.

Source: https://www.mlncompany.com/wp-content/uploads/2016/10/Bldg-Mangt.png

Sustainability Certifications

LEEDv4/4.1: EA Enhanced Commissioning Ongoing Commissioning (OCx) and Monitoring-based Commissioning (MBCx)

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Lowers heating and cooling demand
+ Improves comfort in all spaces
+ Fault Detection and Diagnostics (FDD) may be added
- May have higher upfront cost
- Requires well-trained staff for maximum benefits and greater zero net energy savings / reductions potential

Operations | Energy Management

Fault Detection and Diagnosis (FDD) Analytics

FDD analytics provide a BMS platform that will help the facilities team keep the building running well. The platform alone does nothing; FDD requires dedication and follow up from the facility maintenance team.

The FDD platform must be set up as early as possible, prior to commissioning. It uses programming algorithms to supplement FPTs. The FDD platform can serve as a tool to gauge the readiness of the building.

Features / requirements with some examples:

- Building level meters – water meters, gas meters, electric meters
- Water meters
- Domestic hot water boiler – supply temperature
- VAV boxes – supply air temperature, CO_2 levels
- Chilled water system – supply temperature, return temperature, chiller kW, BTU meter (BTU in and out of building)
- Heating hot water – supply temperature, return temperature
- AHUs – CFM, supply temperature, return temperature, filter status

Related Measures

Building Management System

Recommendation for Implementation

FDD is provided with the BMS or by a separate service provider that interfaces with the BMS. Design team must check with Thermo Fisher's Global Energy Management team during the planning stage for approval and recommendations.

Design phase

- Incorporate monitoring into specs
- Incorporate MBCx process in Cx plan

Construction phase

- Incorporate monitoring points, limits, logic into controls system
- Verify performance of controls system

Post-occupancy

- Monitor / review (continuous)
- Analyze / report (at least quarterly)

Blue dots represent optimal or calculated building performance.
Red dots are measured building or equipment performance possible to be improved.

Sustainability Certifications

LEEDv4/4.1: EA Enhanced Commissioning

Applicable Building Types

☑ Office ☑ Laboratory
☑ Distribution ☑ Manufacturing

Considerations

+ Promotes energy efficiency
+ Saves energy costs
+ Lowers heating, cooling and ventilation energy use while improving comfort for occupants
+ May reduce HVAC equipment capacities saving cost
+ Requires well-trained staff for maximum benefits
- May have higher upfront cost

Renewables | Power
Onsite Solar Photovoltaics

Onsite solar photovoltaic (PV) systems are now common in new construction. Some cities have mandated that all new buildings must have PV on the roof or be designed as solar-ready.

Solar technology has been advancing and become more efficient. Thermo Fisher recommends monocrystalline silicon panels as opposed to polycrystalline silicon due to higher efficiency ranges. The team should select the most efficient panels available.

Beyond rooftops, carports offer potential to include onsite solar photovoltaics. Proper site planning should allow for the inclusion of carports with conveniently located driveways and drive aisles.

Recommendation for Implementation

Any new build must enable onsite solar photovoltaics covering at least 40% of roof surface in line with IECC 2021. Design team should review the local code for onsite solar photovoltaic requirements as well. Design team should properly plan site for current or future inclusion of carports with solar photovoltaics.

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Reduces energy costs by producing energy for the building or for export
+ Visibly promotes commitment to sustainability efforts and social responsibility
+ Financing options available, including owning and operating the system through a capital purchase that pays back within the lifetime of the system or power purchase agreements (PPA) where a third-party owns, operates and sets rates for electricity purchase
- Increases maintenance

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

LEEDv4/4.1: EA Renewable Energy

Related Measures

Solar thermal water heating

Onsite wind generation

Renewables | Power
Onsite Wind Generation

Though widely used at the utility scale, wind energy is utilized less on buildings or within the site of specific facilities. This is mainly due to the lower wind speeds available in more urban environments.

Unlike photovoltaics, onsite wind turbines can provide a steadier source of energy across 24 hours (day and night), but turbines generate less total energy than solar.

A typical wind turbine for onsite energy generation should be at least 80 feet tall in an area with average wind speeds of at least 12 mph. Smaller turbines are sometimes used for supplemental energy generation.

Onsite wind turbines usually serve as a supplemental power source; they are often unable to meet a whole building's needs.

There are two main types of wind turbines: horizontal axis and vertical axis. Horizontal axis turbines are most common (pictured below on the left). However, vertical axis turbines (pictured below on the right) generally take up less space and are becoming increasingly popular in low space availability areas such as cities.

Related Measures

Onsite solar photovoltaics

Solar thermal water heating

Recommendation for Implementation

Design team should review the local code for wind energy requirements.

Highly recommend reviewing average wind speeds to determine if there is a favorable cost to benefit ratio for utilizing onsite wind turbines.

Typically, onsite wind generation is located on the ground in an open area with higher average winds. Technologies that mount to roof systems are also available and may be considered.

Source: zoro.com

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

LEEDv4/4.1: EA Renewable Energy

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Reduces energy costs by producing energy for the building or for export
+ Visibly promotes commitment to sustainability efforts and social responsibility
- May have higher upfront cost
- Increases maintenance, especially since it has moving parts that can result in more wear and tear
- Can be visually and aurally unappealing
- Have height requirements and operate best in an open, unimpeded environment

Renewables | Power
Solar Thermal Water Heating

Solar thermal water heaters use a series of panels or tubes to collect thermal energy from the sun and transfer it to heat water for building domestic hot water (DHW) use.

There are two types of solar thermal water heater systems:

1. **Active solar thermal water heaters**
   - Direct circulation system: pumps water directly to the solar collectors and heats the water
   - Indirect circulation system: uses a heat transfer fluid and a heat exchanger to heat the water instead of pumping all the water to the collectors
2. **Passive solar thermal water heaters**
   - Integral collector storage system: cold water passes through the solar collector and is pre-heated, then goes into the conventional water boiler for a reliable source of hot water
   - Thermosyphon system: the collector is installed below the storage tank and utilizes that warm water rises into the tank. Roof design must be evaluated because of the heavy load of the tank.

Related Measures

Solar photovoltaics

Recommendation for Implementation

Solar thermal water heating has the potential to significantly reduce domestic hot water energy use, but also competes with solar PV for roof space. Compare the energy saved vs. space required for each system.

Regions with freezing temperatures should be careful of exposed piping.

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Reduces DHW energy use
+ Reduces water heating load and HVAC equipment sizes
+ Visibly promotes commitment to sustainability efforts and social responsibility
- May have higher upfront cost
- May have architectural impact on roof
- May require lots of maintenance
- Almost always requires a backup conventional water heater for when the weather is cloudy or demand is too high

Renewables | Grid Management

Demand Response Program

Demand response programs are run in conjunction with the utility company, where the building can receive a demand response signal and then reduce its electricity consumption strategically. This reduction usually takes place in stages with the smallest impact to occupants staging first. This could include slight increases or decreases to temperature setpoint or lighting reductions.

For this strategy to work, the HVAC and lighting controls must be designed to respond to the demand response request. This often requires more advanced metering and a central BAS controls system.

The utility company often offers rebates or discounts for participating in a demand response program – including tariff structures that provide a financial benefit for participating in demand response events.

To supplement the reduced utility consumption during the demand response period, the building could use battery storage energy.

Recommendation for Implementation

Design team should review utility benefits for participating in demand response and, if chosen, design the controls to reduce equipment loads appropriately.

Source: energy.gov

Sustainability Certifications

LEEDv4: EA Demand Response or LEEDv4.1: EA Grid Harmonization

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Reduces energy cost
+ Reduces strain on the utility
- Demand response requests may be sporadic
- More complex controls

Related Measures

Battery energy storage

Microgrid controls

Renewables | Grid Management
Thermal Storage

Thermal storage is typically the storage of hot water or chilled water in thermal energy storage (TES) tanks. By storing the thermal energy, it can be produced in off-peak electricity hours and held in the tank until needed. This can help reduce electric demand. It can also reduce the HVAC equipment capacities needed because the equipment can work less for longer durations as opposed to harder for shorter durations.

The tanks can be above ground vessels or excavated in the ground. The above ground tanks are recommended because they are cheaper than excavation.

Recommendation for Implementation

With rising electricity rates and electrification of thermal systems, it is strongly advised to investigate the use of thermal energy storage. The design team should determine the optimal size of TES tank(s) needed for the project and how the upfront cost compares to the annual energy savings produced.

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

+ Reduces HVAC equipment capacities saving cost
+ Reduces electricity demand and costs
- May have higher upfront cost
- Space impact for tank location

Arup Project

Sustainability Certifications

LEEDv4/4.1: EA Optimize Energy Performance

LEEDv4.1: EA Grid Harmonization

Related Measures

Air source heat pumps
Water source heat pumps
Ground source heat pumps
Water-cooled chiller

Renewables | Grid Management
Battery Energy Storage

Battery energy storage systems (BESS) can store energy from renewable sources such as onsite solar photovoltaics for later use. BESS can also charge off the utility grid when prices are lowest and discharge during peak demand, high-cost times to save on energy cost if applicable to the location's utility bill structure. Furthermore, BESS can be coordinated with the utility to serve the purpose of grid harmonization. There are a variety of financing mechanisms that may be available depending on location.

While costs are decreasing year to year and incentives when paired with renewables may be available, BESS is a high-cost technology. Design also must be coordinated to accommodate its footprint. Therefore, the sizing needs to be optimized by the design team for best cost-benefit.

This technology can also be paired with demand response or peak demand management.

Related Measures

Demand response

Microgrid controls

Recommendation for Implementation

Design team should perform study on optimal BESS sizing to support grid harmonization and reduce electricity demand costs.

https://d1jbg4la8qhw2x.cloudfront.net/wp-content/uploads/2021/10/ABSA-pg42.jpg

Sustainability Certifications

LEEDv4.1: EA Grid Harmonization

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

- \+ Grid harmonization
- \+ Can reduce electricity peak demand
- \- Higher upfront cost
- \- Size impact
- \- May have more complex controls
- \- Must be mindful of installation locations

Renewables | Grid Management
Microgrid Controls

Microgrids are small-scale local electricity grids that produce and share electricity among connected buildings, generally on the same campus or located nearby.

Microgrid controls are an added layer of electricity metering and controls, on top of the utility metering. These are complex and direct where the onsite generated electricity, typically from solar PV, goes.

Microgrids are becoming more popular because they increase the connected buildings' resilience to power outages. The microgrids can be self-sufficient, but the amount of electricity generated onsite is not always enough to support the buildings' typical energy use. In this case, it can be beneficial to pair microgrid controls with demand response controls to reduce the buildings' energy use when solely sourcing from the local grid.

When crossing property lines, microgrids must receive city approval. There are some codes that restrict buildings from using energy that is not from a regulated utility.

Related Measures

Demand response

Battery energy storage

Recommendation for Implementation

Design team should assess onsite electricity generation and microgrid connection feasibility to increase campus resiliency. Engage with utility and microgrid controls companies to discuss the implementation.

Design team must check with Thermo Fisher's Global Energy Management team during the planning stage for approval and recommendations.

Source: National Renewable Energy Laboratory (nrel.gov)

Sustainability Certifications

LEEDv4.1: EA Grid Harmonization

Applicable Building Types

- ☑ Office
- ☑ Laboratory
- ☑ Distribution
- ☑ Manufacturing

Considerations

- \+ Increases building / campus energy resiliency
- \+ May reduce energy usage and bills from utility
- \- Higher upfront cost
- \- More complex controls

Renewables | Electric Vehicles
Electric Vehicle Charging

Tailpipe emissions from vehicles with an internal combustion engine (ICE) can be categorized in two forms:

1. air pollutants that harm respiratory heath and sensitive ecosystems
2. greenhouse gases that contribute to climate change

Incorporating electric vehicle (EV) charging into parking design for fleet vehicles and employee commuting provides an opportunity to eliminate harmful exhaust and reduce transportation sector emissions.

© James Prestage/Arup

Recommendation for Implementation

Design team should provide appropriate location(s) with electrical infrastructure for Level 2 electric vehicle (EV) charging stations. A typical quantity used for EV stations is 10% of total parking spaces, although some jurisdictions may require more, per local building code requirements. *Design team must check with Thermo Fisher's Global Energy Management team during the planning stage for approval and recommendations.*

Incorporating an Automated Load Management System (ALMS) for EV charging stations is also recommended to share power across multiple stations—allowing a full charge to a vehicle when the parking lot is empty and optimized charging for multiple vehicles simultaneously when the parking lot is full. An ALMS will maximize the number of EV plugs, while minimizing site electrical infrastructure needs. The SAE J1772 standard is common among U.S.-based electric vehicle supply equipment (EVSE) manufacturers. The IEC 62196 of the International Electrotechnical Commission is an equivalent standard that is common outside the U.S.; the GB/T is the standard common among Chinese-based facilities.

The details of the recommended electric vehicle supply equipment (EVSE), an 11kW Level 2 unit, is outlined as follows:

	Voltage	Voltage Type	Charging Speed	Maximum Load
Level 2	208-Volt to 240-Volt	AC	12 to 80 miles per hour	~7.5kW

Applicable Building Types

☑ Office ☑ Laboratory
☑ Distribution ☑ Manufacturing

Considerations

+ Visibly promotes commitment to sustainability efforts and social responsibility
+ Supports emerging technologies and showcases the business as innovative
+ EV fleets are cheaper to run (fuel cost), cheaper to maintain (fewer moving parts) and more akin to a circular economy than vehicles with an internal combustion engine (ICE)
+ EV adoption is increasing

Related Measures

Onsite solar photovoltaics
Battery energy storage
DC power distribution

Sustainability Certifications

LEEDv4: LT Green Vehicles or
LEEDv4.1: LT Electric Vehicles

4.0
Opportunities Checklist

Opportunities Checklist

The Opportunity Checklist indicates which measures are mandatory (i.e. required to implement), recommended (i.e. required to evaluate and recommended to implement upon feasibility study), or stretch (i.e. applicable in unique applications or emerging technology). It also identifies measures that overlap with LEED credits as well as the applicable space types (i.e. office, distribution, laboratory, manufacturing). The impact criteria columns are a qualitative review intended to be informational at a high-level and studied further through the performance modelling. A solid dot represents "best" for each category striving for low complexity (i.e. ease of design and installation), low capital cost (i.e. incremental expense to implement), and high energy reduction (i.e. potential to conserve effectively).

○	◑	●	M	R	S
Good	Better	Best	Mandatory	Recommended	Stretch

	Opportunities Checklist	Tier: Mandatory / Recommended / Stretch	Impact: High Energy Reduction	Metric: Measures Evaluated	Metric: Measures Included in Design	Comments
Performance	**Did Project add Fossil Fuels**	M			No	
Performance	30% Design Performance Model	M			Yes	
Performance	60% Design Performance Model	M			Yes	
Performance	90% Design Performance Model	M			Yes	
Performance	Energy consumption savings @90% design > baseline.	M			20%	
Electrification	Space Heating	M		N/A	N/A	
Electrification	Domestic Hot Water Heating	M		Yes	Yes	
Electrification	Process Loads	M		Yes	Yes	
Electrification	Cooking Appliances	M		Yes	Yes	
Electrification	Laundry Appliances	M		Yes	Yes	
Envelope	Cool Roof [Climate Dependent]	R	◑	Yes	Yes	
Envelope	Optimized Insulation	M	●	Yes	Yes	
Envelope	Optimized Glazing	M	●	Yes	Yes	
Envelope	Thermal Breaks	R	◑	Yes	Yes	
Envelope	Weatherization / Air Tightness	R	◑	Yes	Yes	
Envelope	Green Roof	S	○	Yes	Yes	
Envelope	Thermal Mass	S	◑	Yes	Yes	
Envelope	Electrochromic Glass	S	◑	Yes	Yes	
Passive	Exterior Shading	R	◑	Yes	Yes	
Passive	Optimized Building Orientation	R	●	Yes	Yes	
Passive	Skylights / Solar Tubes	R	○	Yes	Yes	
Passive	Light Shelves	S	○	Yes	Yes	
Passive	Outside Air Solar Preheating	S	◑	Yes	Yes	
Passive	Thermal Labyrinth	S	○	Yes	Yes	

Opportunities Checklist

○	◑	●	M	R	S
Good	Better	Best	Mandatory	Recommended	Stretch

	Opportunities Checklist	Tier	Impact	Metric		Comments
		Mandatory / Recommended / Stretch	High Energy Reduction	Measures Evaluated	Measures Included in Design	
Active	LED Lighting	M	●	Yes	Yes	
	Advanced Lighting Controls	M	●	Yes	Yes	
	DC Power Distribution	R	◑	Yes	Yes	
	Energy Star or Equivalent Appliances	M	●	Yes	Yes	
	Industrial Freezer Efficiency	M	●	Yes	Yes	
	Plug Load Management	M	●	Yes	Yes	
	Industrial Laundry Efficiencies	R	◑	Yes	Yes	
	Vertical Transportation	R	◑	Yes	Yes	
	Low-flow Fixtures	M	●	Yes	Yes	
	Systems					
	Heat Pump (Air/Ground/Water Source)	M	●	Yes	Yes	
	Water Cooled Chiller	R	●	Yes	Yes	
	Heat Recovery Chiller	R	●	Yes	Yes	
	Variable Air Volume System	R	●	Yes	Yes	
	Chilled Beams	R	●	Yes	Yes	
	Distribution					
	Premium Efficiency Motors and Variable Speed Drives	M	●	Yes	Yes	
	Fan Pressure Drop Review	M	◑	Yes	Yes	
	Variable Primary Flow Pumping System	R	◑	Yes	Yes	
	Heat Recovery and Economizers					
	Airside Heat Recovery	R	●	Yes	Yes	
	Wastewater Heat Recovery	R	◑	Yes	Yes	
	Waterside Economizer	R	◑	Yes	Yes	
	Airside Economizer	R	●	Yes	Yes	
	Controls					
	Temperature, Setbacks	M	●	Yes	Yes	
	Temperature Control Adjustment	R	●	Yes	Yes	
	Demand Controlled Ventilation	R	●	Yes	Yes	
	Humidity Control Adjustment	R	◑	Yes	Yes	
	Air Change Rates Review	M	◑	Yes	Yes	
	Pressurization Review	M	◑	Yes	Yes	
	Fume Hoods					
	Efficient Fume Hoods and Proximity Controls	M	●	Yes	Yes	
	Fume Hood Exhaust Consolidation	R	◑	Yes	Yes	
	Refrigeration					
	Refrigerant Management [for EU and NA]	M	●	Yes	Yes	
	Centralized Refrigeration	R	◑	Yes	Yes	
	Process Efficiencies (i.e. Pipe/Equipment Insulation)	M	●	Yes	Yes	
	Cold Water for Injection Systems	R	◑	Yes	Yes	
	Water Loops for Purified Water	R	◑	Yes	Yes	
	Demand-driven Process Cooling	R	●	Yes	Yes	
	Steam Pressure and Distribution Review	M	◑	Yes	Yes	
	Compressed Air and Distribution Review	M	◑	Yes	Yes	
	Optimized Compressed Air Control Settings	R	◑	Yes	Yes	
	Electrical Transformers	R	◑	Yes	Yes	
	Data Center Energy Efficiency [<1.5 PUE]	M	●	Yes	Yes	

Opportunities Checklist

	Opportunities Checklist	Tier: Mandatory / Recommended / Stretch	Impact: High Energy Reduction	Metric: Measures Evaluated	Metric: Measures Included in Design	Comments
Operations	Owner's Project Requirements Document [if > 25,000 sf]	M	●	Yes	Yes	
Operations	Commissioning Review [if > 25,000 sf]	M	●	Yes	Yes	
Operations	Witness and Verification [if > 25,000 sf]	M	●	Yes	Yes	
Operations	Enhanced Commissioning [if > 25,000 sf]	M	●	Yes	Yes	
Operations	Envelope Commissioning	R	◑	Yes	Yes	
Operations	Monitoring Based Commissioning	R	◑	Yes	Yes	
Operations	Enhanced Metering	M	●	Yes	Yes	
Operations	Building Management System (BMS)	M	●	Yes	Yes	
Operations	Fault Detection and Diagnosis (FDD) Analytics	R	●	Yes	Yes	
Operations	Demand Response Program	S	○	Yes	Yes	
Power | Renewables	Onsite Solar Photovoltaics ["Solar Ready"]	R	●	Yes	Yes	
Power | Renewables	Onsite Wind	S	●	Yes	Yes	
Power | Renewables	Solar Thermal Water Heating	S	◑	Yes	Yes	
Power | Renewables	Thermal Storage	S	○	Yes	Yes	
Power | Renewables	Battery Energy Storage	S	○	Yes	Yes	
Power | Renewables	Microgrid Controls	S	○	Yes	Yes	
Power | Renewables	Electric Vehicle Charging ["EV Ready"]	M	●	Yes	Yes	

○	◑	●	M	R	S
Good	Better	Best	Mandatory	Recommended	Stretch

5.0

Glossary

Net-Zero Building Design

Glossary

Key Terms

Alternating current (AC) – An electric current that periodically reverses direction and changes its magnitude continuously with time, in contrast to direct current (DC), which flows only in one direction. Alternating current is the form of electrical energy provided through the electrical grid.

Automated Load Management System (ALMS) – A system designed to manage load across one or more Electric Vehicle Supply Equipment (EVSE) to share electrical capacity and/or automatically manage power at each connection point.

Chlorofluorocarbons (CFC) – Gaseous chemical compounds, commonly known as Freons, that are widely used as refrigerants, propellants (in aerosol applications) and solvents; their manufacture has been phased out under the Montreal Protocol, due to their high ozone depletion potential (ODP) in the upper atmosphere.

Circadian rhythms – Physical, mental and behavioral changes that follow a 24-hour cycle and respond primarily to light and dark environments.

Direct current (DC) – An electric current that flows in a constant direction, distinguishing it from alternating current (AC). Direct current may flow through a conductor such as a wire, but can also flow through semiconductors, insulators or even through a vacuum as in electron or ion beams.

Energy conservation measure (ECM) – Any improvement, repair, alteration or betterment of building systems, equipment, fixtures, furnishings, etc. designed to reduce energy consumption and/or operating costs.

Energy use intensity – Expression of a building's energy use as a function of its size, typically expressed as kBtu/sf/yr or kWh/sm/yr

Hydrochlorofluorocarbon (HCFC) – A type of gas used worldwide in refrigeration, air-conditioning and foam applications that is being phased out under the Montreal Protocol since they deplete the ozone layer.

Hydrofluorocarbon (HFC) – A type of gas introduced as non-ozone depleting alternative to support the timely phase out of CFCs and HCFCs. While these chemicals do not deplete the stratospheric ozone layer, some of them do have a high global warming potential (GWP).

International Organization for Standardization (ISO) – An international standard-setting body that develops and publishes worldwide technical, industrial and commercial standards.

Leadership in Energy and Environmental Design (LEED) – A green building certification program used worldwide. "LEED v4/4.1" indicates that LEED v4.1 is an update to LEED v4 made to streamline and amend requirements. Although project teams can register for LEED v4.1, it is recommended to allow flexibility between the versions by registering projects for v4 and implementing a v4.1 credit-to-credit substitution as deemed advantageous or meaningful. The reverse, a v4.1 project substituting for v4, is not permitted.

Light-emitting diode (LED) – A semiconductor diode that glows when a voltage is applied. LED bulbs are high-efficacy light sources, meaning that they possess a high lumens per watt efficiency.

Montreal Protocol – A landmark multilateral environmental agreement that regulates the production and consumption of nearly 100 man-made chemicals known to have ozone depleting potential (ODP).

Plan-Do-Check-Act (PDCA) – An iterative design and management method used in business for the control and continuous improvement of processes and products.

Power over Ethernet (PoE) lighting – Smart lighting that uses Ethernet cables to both provide DC power and enable network communication with lighting fixtures, sensors and devices that improve control.

Solid-state lighting (SSL) – A technology in which light-emitting diodes (LEDs) replace conventional incandescent and fluorescent lamps for general lighting purposes. An SSL device produces visible light by means of an electric current causing semiconductor material to glow.

6.0

Appendix

ThermoFisher
SCIENTIFIC