Municipal High Performance Building Guidelines
City of Philadelphia

Version 1.4
02/06/2023

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Background

The City's Office of Sustainability is responsible for administering Philadelphia's Greenworks initiative, zero waste initiatives, the citywide energy benchmarking program, the Building Energy Performance Program (BEPP), and the municipal § 17-111 Energy Efficiency and Environmental Design in Construction of Buildings ordinance, or LEED (Leadership in Energy and Environmental Design) ordinance. The Energy Office works within the Office of Sustainability to procure energy for the city government and provide various supporting roles in leading municipal energy efficiency efforts. Capital Project managers are encouraged to reach out to the Energy Office for project support when available regarding:

- LEED Ordinance compliance
- Energy conservation programs, such as
  - the Building Monitoring Program,
  - Demand response and load management, and
  - BEPP compliance for municipal buildings.
- Energy retrofit project support, such as
  - Energy performance and project design services,
  - Capital funding available through the Greenworks Sustainability Fund, and
  - Energy efficiency rebate applications.

In 2017, the Office released the Municipal Energy Master Plan for the Built Environment (MEMP) to establish and measure progress towards carbon emission reductions. The MEMP outlines four goals for the City's Municipal Buildings and Streetlighting, including:

- Reduce greenhouse gas emissions from City operations 50% by 2030;
- Reduce City operations' energy use 20% by 2030;
- Generate or purchase 100% of all electricity for City operations from renewable resources by 2030, and
- Maintain or reduce the City's operational cost of energy.

Additionally, the City of Philadelphia has a goal to become carbon neutral by 2050. The broad strategies to achieve these goals include the following:

- Lower energy use in City operations
- Transition from fossil-fuel based systems to all electric systems (building electrification)
- Clean the City's energy supply

These goals should guide investments in improvements to existing buildings and new construction projects for municipal buildings. To support this alignment, this guidance document provides actionable strategies to prioritize and implement energy efficient technologies and operational considerations to maintain occupant comfort, streamline building system controls, and minimize maintenance requirements.

For questions or additional information, please reach out to the Energy Office directly:

City of Philadelphia
Energy Office
1515 Arch St., 18-024
Philadelphia, PA 19102
Email: energy@phila.gov

New Construction and Major Renovation Standards

LEED Certification Requirement

Since 2009, the City of Philadelphia requires all new construction of City-owned buildings and major renovation projects over 10,000 square feet to achieve a minimum LEED Silver certification. Beginning in July 2023, the beginning of fiscal year 2024 (FY24), municipal new construction and major renovations over 10,000 square feet will be required to achieve a minimum of LEED Gold certification. The appropriate LEED Rating System will be selected based upon project type and scope.

LEED is a framework comprised of nine credit categories that rewards projects based on performance related to Integrative Process, Location & Transportation, Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, Indoor Environmental Quality, Innovation in Design, and Regional Priority. No later than the end of schematic design, applicable projects should have held LEED goal-setting sessions and be registered for LEED certification with USGBC (United States Green Building Council). This facilitates a project's success by integrating the LEED process, milestones, and goals early to minimize missed sustainable strategies, maximize cost/benefit opportunities, and ensure alignment between all responsible parties.

The City of Philadelphia's *Municipal High Performance Building Guidelines* should be referenced by capital fund project managers for information related to prerequisite and credit guidance and credits typically pursued by City projects. Beginning with new projects in FY24, the LEED Ordinance will require projects to pursue 10 prioritized credit points below, in addition to LEED category prerequisites, as part of LEED Gold certification. Guidance on best practices related to achieving the prioritized credits for City projects are notated in this document using symbols corresponding to the credit categories.

- IP Integrative Process: 1 point
- LT Electric Vehicles: 1 point
- SS Site Assessment: 1 point

LEED Category Symbol Key

Integrative Process (IP)

Location & Transportation (LT)

Sustainable Sites (SS)

Energy & Atmosphere (EA)

Water Efficiency (WE)

Materials and Resources (MR)

Indoor Environmental Quality (EQ)

Innovation (IN)

Regional Priority (RP)

- EA Optimize Energy Performance: 10+ points
- EA Enhanced Commissioning: 2+ points
- EA Advanced Energy Metering: 1 point
- WE Outdoor Water Use Reduction: 1+ points
- WE Indoor Water Use Reduction: 2+ points
- EQ Enhanced Indoor Air Quality Strategies: 1+ points
- EQ Indoor Air Quality Assessment: 1 point

Additional credit-by-credit LEED guidance can be found in the Appendix.

Building Codes/Net-Zero Energy

Philadelphia currently follows the 2018 International Energy Conservation Code (IECC) as its building energy code, which has improved the baseline for energy performance on a broad scale. Meanwhile, the City aims to continue implementing above-code, energy-efficient improvements and construction to reduce use of fossil fuels, while simultaneously increasing renewable energy procurement. These efforts make municipal net-zero buildings, where the amount of energy used by the buildings is equal to the amount of energy generated by on- or off-site renewable resources, more attainable within the near future.

LEED projects with excellent performance in reducing and offsetting carbon emissions, energy use, and water use should consider LEED Zero certification. This is a certification for existing LEED buildings that can be achieved after at least 12 months of performance data demonstrating a net-zero impact.

More information can be found here: https://www.usgbc.org/programs/leed-zero

Consult the Energy Office if you would like to consider pursuing LEED Zero or another net-zero rating for a building you manage.

Building Performance for Existing Buildings

Energy Benchmarking Requirements

The Energy Benchmarking and Disclosure Law (Philadelphia Code Section 9-3402) requires commercial and multifamily buildings 50,000 square feet or larger to report their energy and water usage annually to the City of Philadelphia using EPA's ENERGY STAR Portfolio Manager. This platform is a free and reputable resource to measure the energy performance of a building, with eligible building types receiving an ENERGY STAR Score from 1-100. A score of 50 represents median energy performance, while a score of 75 or higher is eligible for ENERGY STAR Certification.

The Energy Office manages the energy benchmarking for the eligible buildings (about 40 in total). The Energy Office aims to bring the average ENERGY STAR Score for municipal buildings to above 50. For a snapshot of the ENERGY STAR Scores for municipal buildings, visit the Municipal Energy Use Dashboard (http://bit.ly/philamunienergyuse).

Building Energy Performance Policy and Compliance

To build on the awareness of energy use developed through the Benchmarking Program, the City of Philadelphia passed the Building Energy Performance Policy (BEPP) (Philadelphia Code Section 9-3404). This policy requires commercial buildings over 50,000 square feet to perform a building "tune-up" every five years. The "tune-up" is an evaluation of operational and maintenance practices to identify adjustments and opportunities to conserve energy and water use in the building.

These evaluations are operationally focused and capital projects are not required for compliance. However, there are high-performance pathways available to comply with the BEPP and can be pursued as an alternative to performing a "tune-up". Capital projects can be used to comply through a high-performance pathway, and the Energy Office should be informed of the potential projects for the respective buildings.

The high-performance pathways include the following, and more information on the BEPP can be found through this link (https://www.phila.gov/programs/building-energy-performance-program/).

- Gold rating under USGBC's LEED for Building Operations and Maintenance V4
- Net-Zero Energy Certification
- Participate in and complete a utility retro-commissioning program
- Complete a full retro- or recommissioning procedure, with documentation that building performance was optimized
- Demonstrate energy savings of at least 15%
- Conduct an energy audit (ASHRAE Level II or stricter) and implement all the no/low-cost EE measures
- Low Site EUI (less than 20 kBTU/sqft)
- ENERGY STAR Certification (75 or greater)
- Demonstrated continuous commissioning/active optimization

Retro-Commissioning

Retro-commissioning is valuable to any existing building and as a pathway to comply with BEPP or satisfying LEED O+M certification requirements. In addition to energy efficiency gains, retro-commissioning can also improve comfort, operations effectiveness and efficiency as well as indoor air quality.

Retro-commissioning is a holistic process, involving investigation, review, and analysis of the function of systems from a whole system point of view. The purpose of retro-commissioning services is to evaluate, test, adjust, and correct facility systems to meet the owner's current facility requirements, optimize operations and efficiency, and assist with the basis of design (BOD) for any remedial repair or replacement projects.

Retro-commissioning can be a direct consulting service, which provides discovery and recommendations with no repair, or a turnkey service which includes remedial repair and a scope of work for any capital improvement projects. City departments seeking to retro-commission a building or building system should work with a National Environmental Balancing Bureau (NEBB) certified commissioning firm who is independent of the design professionals and contractors on any project.

Retro-commissioning should be performed with the following objectives in mind:

- Identify equipment and system deficiencies, and correct issues that have developed throughout the building's life.
- Optimize how equipment and systems operate and function together, according to their current use.
- Develop and implement recommendations to improve operational or energy efficiency.
- Assist facility management with standard operating procedures moving forward, to minimize future cost events.

Specific retro-commissioning steps may vary from project to project but standard phased approach outlined below should be followed for any customized program.

A. Discovery Phase: Site Investigation and Development of Retro-Commissioning Plan
B. Implementation/Improvement Phase: Form Retro-Commissioning Team and Functional Performance Testing
C. Verification Phase: Verify Corrective Actions and Performance

Timing of individual phases may be performed at the direction of the project team and scope might also be limited to a portion of a project, by phase or system.

Retro-commissioning should include reviewing the appropriate design and operations and maintenance (O&M) documentation of an existing facility to understand the intent of previous designs and actions; conducting interviews with management, facilities staff, and occupants to determine their perspective on current facility conditions; investigation; and testing of conditions that could influence or relate to a perceived problem. Recommended solutions should focus on achieving the current facility requirements (CFR), while improving overall building operational and energy performance.

Project teams seeking to retro-commission should explore Energy Efficiency Rebates that may be available for the project.

Energy Project and Building Guidelines

Pre-Design

Integrative Process

This section contains guidance for meeting the requirements of the following LEED prerequisites and credits:

IP Credit: Integrative Process

Though particularly relevant in building a LEED project, the integrative process is valuable to incorporate into any major renovation or construction to encourage early and active collaborations between all parties, from users to architects to engineers and facilities maintenance staff.

Beginning in pre-design and continuing throughout the design phases of the project, identify and use opportunities to achieve synergies across disciplines and building systems described below. Use the analyses to inform the Owner's Project Requirements (OPR), Basis of Design (BOD), design documents, and construction documents.

Discovery:

Perform a preliminary "simple box" energy modeling analysis before the completion of schematic design that explores how to reduce energy loads in the building and accomplish related sustainability goals by questioning default assumptions. Assess at least two potential strategies associated with each of the following:

- Site conditions. Assess shading, exterior lighting, hardscape, landscaping, and adjacent site conditions.
- Massing and orientation. Assess massing and orientation affect HVAC sizing, energy consumption, lighting, and renewable energy opportunities.
- Basic envelope attributes. Assess insulation values, window-to-wall ratios, glazing characteristics, shading, and window operability.
- Lighting levels. Assess interior surface reflectance values and lighting levels in occupied spaces.
- Thermal comfort ranges. Assess thermal comfort range options.
- Plug and process load needs. Assess reducing plug and process loads through programmatic solutions (e.g., equipment and purchasing policies, layout options).
- Programmatic and operational parameters. Assess multifunctioning spaces, operating schedules, space allotment per person, teleworking, reduction of building area, and anticipated operations and maintenance.

Perform a preliminary water budget analysis before the completion of schematic design that explores how to reduce potable water loads in the building and accomplish related sustainability goals. Assess and estimate the project's potential nonpotable water supply sources and water demand volumes, including the following:

- Indoor water demand. Assess flow and flush fixture design case demand volumes, calculated in accordance with WE Prerequisite Indoor Water-Use Reduction.
- Outdoor water demand. Assess landscape irrigation design case demand volume calculated in accordance with WE Credit Outdoor Water-Use Reduction.
- Process water demand. Assess kitchen, laundry, cooling tower, and other equipment demand volumes, as applicable.
- Supply sources. Assess all potential nonpotable water supply source volumes, such as on-site rainwater and graywater, municipally supplied nonpotable water, and HVAC equipment condensate.

Implementation:

Document how the above analysis informed design and building form decisions in the project's OPR and BOD and the eventual design of the project, including the following, as applicable:

- Building and site program;
- Building form and geometry;
- Building envelope and façade treatments on different orientations;
- Elimination and/or significant downsizing of building systems (e.g., HVAC, lighting, controls, Exterior materials, interior finishes, and functional program elements); and
- Other systems.

Document how the above analysis informed building and site design decisions in the project's OPR and BOD. Demonstrate how at least one on-site nonpotable water supply source was analyzed to reduce the burden on municipal supply or wastewater treatment systems by contributing to at least two of the water demand components listed above. Demonstrate how the analysis informed the design of the project, including the following, as applicable:

- plumbing systems;
- sewage conveyance and/or on-site treatment systems;
- rainwater quantity and quality management systems;
- landscaping, irrigation, and site elements;
- roofing systems and/or building form and geometry; and
- other systems.

Project Site Assessment

This section contains guidance for meeting the requirements of the following LEED prerequisites and credits:

- SS Credit: Site Assessment

To evaluate sustainable options and inform related decisions about site design for new construction or major renovations, project teams should complete and document a site survey or assessment that includes details about the following characteristics of the site:

- Topography
- Hydrology
- Climate
- Vegetation
- Species
- Soils
- Human use
- Human health effects

A worksheet form that outlines the site details needed for the Site Assessment LEED credit is available on the USGBC website here: https://www.usgbc.org/credits/new-construction-core-and-shell-schools-new-construction-retail-new-construction-data-ss104?view=resources

Design

Energy Efficiency Rebates

Capital projects that improve energy efficiency should maximize utility incentives through the PECO Energy Efficiency Solutions Program, as the Energy Office reinvests the money collected from this program towards more capital projects. The rebates are collected from installing high-efficiency, electric equipment. There are eligibility requirements for this equipment, and project managers should reach out to the Energy Office at the early stages of the project to ensure these requirements are met. The Energy Office can complete the rebate application on behalf of the capital project managers.

For more information on the rebate program and the equipment requirements, see the link below:

https://www.peco.com/WaysToSave/ForYourBusiness/Pages/Incentives.aspx

https://webtools.dnv.com/projects/Portals/12/PECO_Application_Manual.pdf?ver=0pWbIYNEZG81puuK_9Ik3g%3d%3d

Energy Modeling

This section contains guidance for meeting the requirements of the following LEED prerequisites and credits:

- EA Prerequisite: Minimum Energy Performance
- EA Credit: Optimize Energy Performance

Building Energy Modeling (BEM) is a general term used for an analytical model of a building's energy consumption, ranging from simple spreadsheet calculations to full-scale, whole-building hourly simulations with advanced software. BEM is a versatile, multi-purpose tool that is used in new building and retrofit design, code compliance, green certification, qualification for tax credits and utility incentives, as well as code development and policy decisions. Current Philadelphia Energy Conservation Code, which follows 2018 International Energy Conservation Code, requires energy modeling for compliance.

As with any model, the goal is to predict the outcome of various design decisions quickly and inexpensively, from building envelope and orientation to HVAC and lighting systems. Performing this analysis early in the schematic design phase can be a powerful tool to optimize energy performance and cost and continuing to develop the model as the project moves from design to construction and occupancy can ensure long-term energy performance and facilitate quick decision-making.

Software Options for Energy Modeling

To encourage uniformity and maximize compliance with the City's current building energy code (the 2018 International Energy Conservation Code or 2018 IECC), rebate programs, and LEED prerequisite and credit requirements, it is recommended to model a building's energy use with one of the following software programs:

- DOE-2/eQUEST
- Carrier Hourly Analysis Program (HAP)
- Trane TRACE 700

Using spreadsheet-based calculations exclusively or EnergyPlus for energy modeling is not recommended.

Design Standards for Energy Modeling

Energy modeling can take many forms, so it is important to maintain a consistent level of quality across different scopes, projects, and design teams.

ASHRAE establishes the industry standard for energy performance calculation methods referenced in building energy code (2018 IECC), rebate programs, and LEED. The above recommendations for energy modeling software all have capability to perform calculations using ASHRAE 90.1-2016.

The preferred option (Option 1) to achieve the Optimize Energy Performance credit in LEED v4.1 specifically requires use of the ASHRAE 90.1-2016, Appendix G Performance Rating Method calculation.

Savings Targets

As the City building code already requires whole-building energy modeling, energy modeling is recommended over the prescriptive options for the LEED EA prerequisite Minimum Energy Performance and EA credit Optimize Energy Performance. Current 2018 energy code requirements are an 8% energy savings over the baseline used by LEED and will earn 2 points for new construction and 3 points for major renovations in EA credit Optimize Energy Performance. In accordance with the LEED ordinance regulations, teams should pursue 10 or more points within this credit. In fact, this may be the single most important LEED credit available to projects and should be a primary focus for achieving additional points.

As recent examples, Public Safety projects have been able to achieve between 7 and 14 points with mainstream insulation and mechanical systems. Ten points should be an achievable minimum target on projects.

The use of energy modeling during the design process to evaluate design decisions is highly encouraged as it produces better and more cost-effective outcomes. This should be included in the design Request for Proposals to ensure that designers include multiple models in their proposals. ENERGY STAR's Target Finder tool is useful for comparing model results to real-world buildings.

Consider strategies that use very high levels of insulation to reduce mechanical system sizes on future projects.

Commissioning

This section contains guidance for meeting the requirements of the following LEED prerequisites and credits:

- EA Prerequisite: Fundamental Commissioning and Verification
- EA Credit: Enhanced Commissioning

The commissioning process tests and verifies that building systems perform according to the design intent and owner's requirements and can be operated and maintained effectively. For a new building, commissioning begins in the design development phase and continues through construction until at least 10 months post-occupancy.

The focus of commissioning is on systems accessibility, testability, and maintainability. The commissioning process should follow the ANSI/NEBB Standard S110-1019, Second Edition: Whole Building Technical Commissioning of New Construction and to satisfy LEED requirements, follow ASHRAE Guideline 0-2013, and ASHRAE Guideline 1.1–2007 for HVAC&R Systems. The commissioning firm should be a National Environmental Balancing Bureau (NEBB) Certified commissioning firm and should be independent of the design professionals and contractors on a project.

Current Philadelphia code requires commissioning, but LEED includes more detailed requirements. Completing the standard scope below satisfies EA Prerequisite: Fundamental Commissioning and Verification as well as Option 1, Path 1 of EA Credit: Enhanced Commissioning (3 points). Including building envelope in the scope is not required by LEED for the prerequisite but is recommended for projects with a substantial envelope component and can earn a LEED project 2 points through Option 2 of EA Credit: Enhanced Commissioning. See Building Enclosure section for additional guidance.

Additionally, to earn maximum points for Option 1 of EA Credit: Enhanced Commissioning, Path 2 can be considered for larger buildings. This requires a monitoring-based approach to be developed to assess energy and water performance of the building. This must be included in the commissioning plan and details on all requirements can be found in the LEED v4.1 manual. Refer to Building Automation Controls and Sub-Metering sections or contact the Energy Office directly for additional guidance.

Standard Commissioning Scope

Building Systems to be Commissioned, as applicable:

- HVAC: Boiler and chiller plants, air handling equipment, building automation and controls
- Electrical: Lighting and lighting controls, generators and uninterruptible power supply (UPS) systems, power distribution, emergency and redundant A/B power supply systems
- Plumbing: Domestic water heating systems, domestic water return systems, lab water systems
- Life safety: Fire sprinkler, fire alarm
- Renewable energy: Solar, wind
- Specialty: Security, voice / data, audio / visual, telecommunications
- Building Envelope

During the commissioning process, equipment and systems should not be statistically sampled. All equipment and systems should be tested and verified.

Scope of Work:

Following is an outline summary of tasks that should be performed by the commissioning firm for new construction/new systems.

<u>DESIGN PHASE</u>

- Develop Owner's Project Requirements (OPR)
- Review Basis of Design (BOD)
- Develop preliminary commissioning plan
- Develop commissioning specifications
- Design Development review
- Construction Document progress back-check and review
- Final Document back-check and review

<u>CONSTRUCTION PHASE</u>

- Develop commissioning plan
- Kick-Off meeting
- Review equipment submittals
- Field installation verification
- Witness start-ups
- Functional testing
- TAB (Testing, Adjusting and Balancing) verification
- Maintain issues log

<u>PERFORMANCE PHASE</u>

- Develop and conduct performance verification tests
- Optimize systems

<u>POST-OCCUPANCY PHASE</u>

- Review operation and maintenance manuals (O&Ms) and record drawings
- Coordinate training seminar for operators and occupants
- Develop systems manual
- Commissioning report
- Opposite-season testing
- 10-month warranty visit
- Lessons learned seminar

The commissioning firm should be responsible for data and information gathering as part of the commissioning process, not the contractors/sub-contractors. This includes any LEED Online documentation.

Lighting

The City's plan for lighting renovations and efficient design in new construction generally takes a holistic approach, ranging from installation of efficient light-emitting diode (LED) fixtures to smart automation features using occupancy sensors, smart dimmers, and/or daylighting implementation in the design phase, when available. LED fixtures are more cost-effective to control and dim than traditional fluorescent and HID fixtures. Compared to linear fluorescent lamps, LED lamps and fixtures are 50% more efficient than their T12 fluorescent counterparts and 10% more efficient than their T8 counterparts without reducing the lumen output. Municipal buildings are also required to install LED fixtures as a part of major construction projects under Philadelphia Code Section 16-307 (LED Lighting in City Buildings).

Existing Project Evaluation

Each project needs to be evaluated on an individual basis. Preferably, new, solid-state LED luminaires should replace existing luminaires to take full advantage of long-life expectancies, thermal properties, and optical performance.

Some older facilities have existing plaster ceilings and/or vandal-proof luminaires. In these cases, removing the entire existing luminaire can be difficult so LED retrofit lamps or LED retrofit kits are recommended.

Due to labor costs, a one-for-one fixture replacement strategy is often the most economical solution. Light levels should be calculated so that spaces are not too bright or too dark. Task lighting should also be installed or replaced when possible so that ambient light levels can be reduced for further energy savings and to allow occupants to set their own preferred light levels. LED lighting systems offer better light distribution so reducing the number of fixtures should be considered when possible.

Facility managers should be interviewed to determine problem areas or areas where the use of a space has changed. Request hours of operation and observe conditions where specialty light fixtures may be required such as vandal-proof or vapor-tight luminaires.

When exterior areas are part of the project, ask the building manager if the existing lighting seems sufficient for the facility's use and surroundings. LED area lights offer better light uniformity over traditional sources so simply doing a one-for-one fixture replacement can greatly improve the illumination in an area. At times, extending the power to an additional pole or wall location would make a facility more secure.

Exit signs and emergency lighting: If the buildings does not have a generator then fixtures with battery backup or inverters should be included in the upgrade.

Sensors and control systems: Occupancy, vacancy, and daylight sensors provide additional energy savings, convenience, and additional rebate opportunities. Control systems for larger buildings offer greater opportunities for energy savings, lighting control and energy data collection.

Interior Lighting Considerations

1. Reference Technical Section 265100 and related sections.
2. Provide lumen output as required by the design and application criteria.
3. Confirm all voltages.
4. Verify all mounting hardware required.
5. Determined emergency lighting requirements.
6. If finish options are available, finish selection must be approved by the Project Manager.

Optics: As required
Color Temperature: 3000K- 4000K
Minimum Color Rendering Index: 80
Minimum Lumens per Watt: 90 Lumens/Watt
Minimum Warranty for LEDs and Drivers: 5 years
Life: 50,000 Hours L70
Certification: Should be ENERGY STAR Certified or on the Design Lights Consortium Qualified Product List to ensure utility rebate eligibility.

Exterior Lighting Considerations

- Refer to Technical Specification Section 265600 and related sections.
- Provide lumen output as required by design and application criteria.
- Confirm all voltages.
- Verify all mounting hardware required.
- If finish options are available, finish selection must be approved by Project Manager

Optics: Light above 90 degrees should be avoided
Color Temperature: 3000K-4000K
BUG (backlight, uplight, glare) Ratings
Minimum Color Rendering Index: 70
Minimum Lumens per Watt: 100 Lumens/Watt
Minimum Warranty for LEDs and Drivers: 5 years

Life: 50,000 Hours L70
Certification: Wet Rated*, Should be ENERGY STAR Certified or on the Design Lights Consortium Qualified Product List to ensure utility rebate eligibility.

* Wet Rated light fixtures are UL Listed products that have the distinction Suitable for Wet Locations, as their electrical components frequently come in contact with liquid.

Lighting Controls- Interior and Exterior

- All controls must be commissioned before acceptance by the owner.
- Refer to section 260923- lighting control devices for additional requirements.
- Lutron Electronics switches, dimmers, occupancy sensors or equal should be used.

Interior Controls

- Occupancy and vacancy sensors should be considered for restrooms, closets, mechanical spaces, offices, kitchens, remote corridors, and any other space that would benefit from automated controls. Sensors come with overrides and can replace existing switches. Ceiling and wall mounted wireless sensors simplify installation.
- Bi-level occupancy sensors should be considered for stairwells. Luminaires with integrated sensors are recommended.
- Preset dimming control systems should be considered for multi-purpose rooms, auditoriums, conference rooms and community rooms. These systems allow for lighting scenes to be created and recalled depending on the lighting requirements for specific activities.
- Daylight sensors should be considered for areas where adequate daylight is available during certain times of the day. These areas typically include open office areas, gymnasiums, and lobbies.

Exterior Controls

- Photocell sensors should be considered to automate all exterior/security lighting to come on at dusk and turn off at dawn. Astronomic electronic timer control devices can also be considered in scenarios that require more customized on/off schedules, such as turning off lights sometime during the night, as determined by the facility manager.
- A preset dimming control system with an astronomical timer should be considered for sports field lighting. This allows for different light levels- maximum light for games and organized activities, mid-level for typical evenings when recreational activities may occur, low level for security lighting after centers close until dawn.

Energy Analysis and Payback Period

Develop a Space-by-Space Energy Analysis to document the existing luminaire types, lamping, wattages, and hours of operation. Add the wattages of the proposed luminaires, to demonstrate the potential energy savings, and establish the rebate potential. In addition, obtain the purchase cost of the proposed luminaires and include that in the analysis to calculate the payback period.

LED LIGHTING UPGRADE CASE STUDIES

Municipal Office Space

PROJECT NAME- One Parkway Building, Department of Human Services

PROJECT SCOPE- Upgrade lighting in Corridors, Open Office Areas, Private Offices, Conference Rooms, Meeting Rooms, Waiting Areas, and Support Spaces.

PROJECT STRATEGY- All fluorescent troffers were replaced with high performance LED troffers with fully diffuse lenses and efficiencies of up to 120 lumens per watt. The existing compact fluorescent downlights were replaced with LED downlights that provide high color rendering and excellent glare control. In some areas, the light fixtures were reconfigured to work better with the current floor plan.

PROJECT IMPLEMENTATION- Upgrades were implemented in stages by the facility management staff.

PROJECT OUTCOME- There has been positive feedback from the staff working in these upgraded spaces. The brightness control and light distribution provided by the troffers and the downlights has created a comfortable and productive environment with better light uniformity, more visual comfort, and high color rendering. The LED troffers have been independently tested and have shown to produce 92% of their initial lumen output at 60,000 hours with an overall projected lifespan of nearly 500,000 hours. This will reduce maintenance efforts for years to come. The total watts were reduced to nearly one third of the original load with a payback period of less than 10 years.

Library/Public Assembly Space

PROJECT NAME- Free Library of Philadelphia, Roxborough Branch

PROJECT SCOPE- Upgrade lighting in Circulation Spaces, Open Office Area, Private Offices, Community Room, Staff and Support Areas and Perimeter Site Lighting. A New Electrical Panel, New Ceiling Tiles, Emergency Lighting and Exit Signs were also included.

PROJECT STRATEGY- All fluorescent troffers were replaced with high performance LED troffers in the public and staff areas, lower cost LED flat panels were used in support spaces and suspended linear fixtures were used in mechanical spaces. Cutoff LED wall-mounted fixtures with good color rendering were used around the perimeter to reduce light trespass in this residential area and create a safe, welcoming appearance after dark. Daylight sensors were added in the office areas where high windows and abundant daylight is available. Occupancy sensors were added in the community room, restrooms, and kitchen.

PROJECT IMPLEMENTATION- The building was closed for construction. The project was bid to prequalified electrical contractors. The low bid was selected, and work was performed in a timely manner.

PROJECT OUTCOME- The community is delighted with the library improvements. The high-performance LED troffers used throughout the public spaces have created a pleasing environment that is bright but visually comfortable. The optical control and high color rendering characteristics provide good light all the way down to the bottom of the stacks, bringing out the colors of the books. The LED fixtures will keep maintenance costs at a minimum for years with the LED troffers offering a 10-year warranty and 100,000 projected life. The total watts were reduced to nearly one third of the original load and the payback period is about 8 years.

Parking Garage

PROJECT NAME- Callowhill Street Parking Garage

PROJECT SCOPE- Upgrade lighting for Parking Decks, Stairwells, Elevator Lobbies, and Perimeter Site Lighting.

PROJECT STRATEGY- All high-intensity discharge (HID) and first-generation LED luminaires on the parking deck were replaced with specification grade, low-glare, LED parking deck luminaires with an optical system that improved the lighting uniformity along the ramps and drive aisles. Additional fixtures were added along the back wall where it was dark. The refractor wallpacks around the perimeter were replaced with cutoff luminaires around the perimeter of the building to reduce sky glow and glare while improving visibility. On the top deck, new cutoff LED luminaires were installed on existing poles. These luminaires are equipped with motion sensors that allow for dimming to 50% when the lot is unoccupied.

PROJECT IMPLEMENTATION- The building was closed for construction. A quote was obtained from the electrical contractor under contract. The project was approved, funded, and opened in 2021.

PROJECT OUTCOME- The wide light distribution from the new LED luminaires creates a welcoming environment with improved light uniformity and better visibility. By lighting the back walls of the ramps, the decks are perceived to be brighter and safer. The light levels were also increased in the stairwells and elevator lobbies with improved color rendering throughout making vehicles easier to identify. The long-life LED luminaires will reduce maintenance for years with the parking deck fixture having a rated life of 200,000 hours. The total watts were reduced to nearly one third of the original load with a 5-year payback period.

Building Enclosure

The Energy Office aims to establish an approach to modernizing building enclosures that allows for greater energy efficiency and climate resilience. Building enclosure, or building envelope, is defined as any portion of the building that has direct contact with unconditioned space, including walls, windows, doors, roofing, floors, and ceilings below unconditioned attic spaces.

Philadelphia is currently in the 4A climate region, as identified by IECC (International Energy Conservation Code) and ASHRAE (American Society of Heating, Refrigeration, and Air-Conditioning Engineers). Climate 4A is considered mixed-humid and defined as annual precipitation greater than 20 inches (50 cm), approximately 5,400 heating degree days (65°F basis) or fewer, and an average monthly outdoor temperature below 45°F (7°C) during the winter months. Climate models project that

Philadelphia's climate will become warmer and more humid as global warming continues. Increased humidity and cooling days should be considered in calculations and modeling for installations with longer useful lives.

The following are the City's goals, in order of importance, when designing enclosure assemblies or upgrading existing enclosure assemblies:

- Improved Occupant Comfort and Health
  - Reduce the unintentional transfer of heat through walls, windows, doors, flooring, and roof assemblies
  - Reduce air infiltration or exfiltration through enclosure penetrations
  - Maintain occupant health by preventing the growth of molds and mildews inside the weatherproofing system
- Reduced Operating Costs
  - Decrease energy usage for immediate cost savings and safeguarding against future energy cost spikes
  - Reduce unnecessary maintenance or building repairs through increased building durability related to water, air, vapor, and heat transfer
- Balanced Upfront Costs
  - Decrease heating, ventilation, and air conditioning (HVAC) loads and equipment sizes by decreasing heating and cooling demand
  - Selection of alternative HVAC systems that may be more cost-efficient when energy demand is low

Standard Design Processes

Building enclosure commissioning should include, at a minimum, review of the project's Owner's Project Requirements (OPR), Basis of Design (BOD), and enclosure design. Projects will engage a qualified, third-party professional to verify that the BOD reflects the OPR and that the design documents reflect with BOD and OPR. Project goals and design should prioritize preventing water, air, vapor, and thermal issues which can cause deficiencies related to energy performance, durability, health, and comfort.

Depending on project scope, budget, and complexity, LEED v4.1 credit Enhanced Commissioning, Option 2: Building Enclosure Commissioning should be considered for each project and can be an option for achieving the credit in standard compliance with the LEED Ordinance. Building Enclosure Commissioning (BECx) is a systematic process that verifies the building enclosure is designed and built to meet the OPR. BECx spans all phases of design and construction to influence both the design intent, details, and construction of enclosure assemblies.

Project-specific energy modeling and diagnostic testing should be implemented early in the design process. To identify and prioritize areas of improvement, the following tools should be used during the design process:

1. ***Energy Modeling***

Energy modeling is recommended to evaluate the cost-benefit of various energy conservation measures such as increased insulation or high-performance glazing. Modeling should be an iterative process, completed early in design and spanning the entire design process. Energy modeling can help find the ‘point of diminishing return’ at which investing in specific upgrades, such as additional insulation, may yield only minimal performance gains. Please see *Energy Modeling* section for more information.

2. ***Hygrothermal Modeling***

Hygrothermal modeling, through programs like WUFI, evaluates the movement of moisture (hygro) and heat (thermal) through building enclosure materials. Results of a moisture and heat movement simulation often include results showing potential moisture content of each enclosure component as well as the entire assembly. This analysis can help determine if moisture within an assembly and deterioration from hygrothermal movement is possible.

The following diagnostics should be completed during construction and specified early in the project:

1. ***Blower Door Testing***

A blower door test is a diagnostic tool for measuring airtightness of a building. Airtightness helps reduce energy consumption, avoid hot and cold drafts that affect occupant comfort, decrease space conditioning loads, and prevent moisture and indoor air quality issues.

2. ***Thermal Imaging***

Thermography involves the analysis of objects by detecting infrared energy emitted from those objects, and then converting that infrared information into apparent temperatures. Thermographic imaging of a building can identify air leaks, water infiltration and damage, and thermal deficiencies.

Testing Standards

Standards for performance testing commonly used in Building Enclosure Commissioning include the following as they relate to water, air, and thermal performance. This is simply a sample list and all testing should be reviewed on a project-by-project basis with a qualified commissioning provider or other team member.

<u>Water Penetration</u>

- ASTM E1105: Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference. [extreme weather condition testing]
- AAMA 501.1: Standard Test Method for Water Prevention of Windows, Curtain Walls, and Doors Using Dynamic Pressure

- AAMA 501.2: Quality Assurance and Diagnostic Water Leakage Field Check of Installed Store Fronts, Curtain Walls, and Sloped Glazing Systems [standard water tightness testing; "hose nozzle test"] Also [not appropriate for testing of operable windows and doors]
- AAMA 511: Voluntary Guideline for Forensic Water Penetration Testing of Fenestration Products [used to investigate if a fenestration product is defective as opposed to the installation of that product; includes "sill dam test"]. Same investigative techniques as ASTM E2128, except for sill dam test.
- ELD or EFVM for Roof Leak Detection: Electronic Leak Detection (ELD) is similar to Electric Field Vector Mapping (EFVM). Flood testing is not recommended due to weight concerns and water migration.
- ASTM C1153: Standard Practice for Location of Wet Insulation in Roofing Systems Using Infrared Imaging.

<u>Air Leakage</u>

- ASTM E1186: Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems
- ASTM E783: Standard Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors.
- ASTM E779: Standard Test Methods for Determining Air Leakage Rate by Fan Pressurization

<u>Thermal</u>

- ASTM C 1060: Standard Practice for Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings

For more information on building enclosure commissioning process and testing standards, teams should refer to the National Institute of Building Science (NIBS) Guideline 3: Building Enclosure Commissioning Process BECx, ASTM E2813 Standard Practice for Building Enclosure Commissioning, and ASTM E2947 Standard Guide for Building Enclosure Commissioning.

HVAC

A building’s heating/cooling system is a primary component of a building’s energy use and thus installing an efficient HVAC system is of the highest priority for project managers. In renovation projects, an initial equipment assessment should be conducted initially to confirm the age and quality of the existing systems. Often, older facilities’ mechanical systems will need to be replaced or serviced when renovating older buildings in the city. If the facility has no existing central HVAC system, i.e., is using window/wall cooling units or an older hot water coil heating system, removing this existing system, and installing a central HVAC system is highly recommended.

General HVAC Design Guidelines

When installing a new HVAC system, a project manager should adhere to the following general design guidelines:

- Reduce maintenance demands
- Increase automation within operations

- Ensure occupant comfort
- Maintain indoor air quality
- Avoid steam for heating - For new hydronic systems, hot water distribution lines are recommended for optimum high efficiency heat transfer and level of control. For existing systems using steam, it is recommended to replace with hot water.

The Energy Office is focused on building electrification for all newly constructed buildings and renovations to reduce the City's dependency on fossil fuels. It is recommended to explore and seriously consider electric heating systems in most applications, barring a special circumstance.

This will help building systems to:

- Support the Municipal Clean Fleet Plan and ability to expand EV charging infrastructure by modernizing electrical systems and enabling expansion of EV charging infrastructure.
- Provide redundancy to improve climate resilience and prevent service disruption through system backup solutions such as generators or batteries.
- Support municipal budget stability through reliability in electricity market and fuel source diversity.
- Ensure that we are investing in technology that advances our sustainability goals and will not be outdated in 10 years' time.
- Generate more Demand Response Program revenue.
- Reduce pollutants from on-site fuel combustion to improve indoor air quality and occupant health.

For all electric equipment, the efficiency ratings should comply with the PECO rebate program to maximize potential utility program incentives. The program manual with eligibility requirements can be seen here:

https://webtools.dnv.com/projects/Portals/12/PECO_Application_Manual.pdf?ver=0pWbIYNEZG81puuK_9Ik3g%3d%3d

Design Standards for Energy Efficiency and Performance

Many standards and guidelines exist to help designers and project planners incorporate energy efficiency and sustainability into both new and existing building projects. The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) provides excellent resources that are continuously updated to capture the most current understanding of energy-efficient design. Read-only versions of many ASHRAE resources can be found at the following link:

https://www.ashrae.org/technical-resources/standards-and-guidelines/read-only-versions-of-ashrae-standards

Early in the conceptual and schematic phases of design, consult the most current City-adopted editions of the following ASHRAE resources:

- ASHRAE Guideline 36: High Performance Sequences of Operation for HVAC Systems
  - The purpose of this guideline is to provide uniform sequences of operation and functional testing procedures for HVAC systems that are intended to maximize energy

efficiency and performance, provide control stability, and allow for real-time fault detection and diagnostics.

- ASHRAE Standard 55: Thermal Environmental Conditions for Human Occupancy
  - This standard specifies the combination of indoor thermal environmental factors and personal factors that will produce thermal environmental conditions acceptable to a majority of the occupants within a space.
- ASHRAE Standard 62.1: Ventilation for Acceptable Indoor Air Quality
  - Specifies minimum ventilation rates and other measures intended to provide indoor air quality that is acceptable to human occupants and that minimizes adverse health effects. It can also be used to guide the improvement of indoor air quality in existing buildings.
- ASHRAE Standard 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings
  - The purpose of Standard 90.1 is to establish the minimum energy efficiency requirements of buildings for design, construction, operation, and maintenance, as well as utilization of on-site renewable energy resources.
- ASHRAE Standard 100: Energy Efficiency in Existing Buildings
  - This standard provides criteria that will result in reduced energy consumption through improved energy efficiency in existing buildings, providing procedures and programs essential to energy efficient operation, maintenance, management, and monitoring; increasing the energy efficiency of systems and components; and upgrading the thermal performance of the building envelope.

Equipment Selection Guidelines

The Office of Sustainability’s desire to move away from fossil-fuel heating sources in favor of high-efficiency, all-electric systems will likely drive equipment selection decisions towards distributed heat pump solutions rather than large central plants for new construction and substantial renovations. The number of applications for heat pumps and the available system configurations are rapidly increasing and improving, generally making them suitable for all but the largest and most complex facilities.

This section identifies best practices for the selection of energy-efficient equipment in various applications, including distributed systems, hybrid distributed systems, and central plants.

<u>Distributed HVAC Systems</u>

A distributed HVAC system has no central plant, relying instead on smaller single-zone units installed throughout the building to provide both heating and cooling to individual spaces. Distributed systems are often ideal in small to medium-sized buildings with relatively few zones or larger multi-family residential and rehabilitation facilities, where individual room control and ease of maintenance are crucial. Drawbacks include the potentially large number of terminal units required, limited efficiency and control options, and potential over-sizing of the total system since terminal units are generally only available in nominal capacities. Examples of distributed HVAC systems include:

1. Packaged terminal heat pumps and air conditioners
   - Package terminal units are self-contained heat pumps (PTHPs) or air conditioners (PTACs) ranging from about one to two tons that are typically installed in through-wall penetrations underneath or between windows. Integral electric resistance heaters are a common option

for supplemental heat in the coldest weather. Controls are often built-in with a user access panel; however, advanced controls options are available from most manufacturers, including wall-mounted thermostats, occupancy sensors, and DDC integration. Regular maintenance is limited to changing filters, but PTHPs are not as robust as larger heat pumps or central plant equipment and have an expected service life of about 10-15 years.

  - ASHRAE 90.1-2016 minimum efficiency: 10.0-11.0 EER cool, 2.8-3.2 COP heat

2. Unitary air-source heat pumps and air conditioners
   - Split system or packaged unitary heat pumps and air conditioners are typically ducted units serving one or more zones, and ranging in size from about five tons to 60 tons. Efficiency ratings are similar to PTACs, although some multi-compressor and variable-speed compressor options can boost efficiency for a cost premium. Unitary heat pumps may also require supplemental heating such as electric resistance, a hot water coil, or a gas furnace. Increasingly, heat pumps are available with low-temperature heating capabilities, reducing or eliminating the need for supplemental heat. Expected service life is about 15 years.
   - ASHRAE 90.1-2016 minimum efficiency: 10.0-11.0 EER cool, 3.0-3.3 COP heat
3. Unit heaters
   - Unit heaters are heating-only devices that are typically suspended or cabinet-mounted and provide spot heating in vestibules, stairwells, storage areas, mechanical rooms, and garages. They can be electric, gas-fired, or hydronic. The largest commonly available electric unit heaters are about 50 kW (170 MBH), whereas gas-fired and hydronic units can be much larger. If selecting gas or hydronic unit heaters, consider condensing gas-fired units (up to 97% E_T) or low-temperature hydronic units that are designed for condensing hot water boilers. The expected service life of electric and gas unit heaters is about 13 years. Hydronic unit heaters may last up to 20 years.
   - ASHRAE 90.1-2016 minimum efficiency: 80% E_C

Hybrid Distributed HVAC Systems

Heat pump systems that feature a common water loop or condensing unit array can be considered a hybrid of distributed and central plant designs, requiring some common equipment to serve distributed single-zone units. These systems combine some of the scalability and high efficiency of central chiller plants with the City's goals of electrification and ease of maintenance, and may be the ideal solution in many applications. Examples include:

- Water-source or geothermal water-to-air heat pumps
  - Water-source or geothermal heat pumps function in much the same way as unitary air-source heat pumps except that heat is rejected to, and extracted from, a condenser water loop rather than the outside air. This greatly increases the efficiency of the heat pump and reduces or eliminates the need for supplemental heating. Water-source heat pumps require a boiler for heat extraction and a cooling tower for heat rejection, and geothermal heat pumps require a groundwater loop or geothermal well field. If considering water-source heat pumps, select a condensing boiler that is designed for low temperature hot water. If considering geothermal, carefully examine the building's total annual heating and cooling loads, as an imbalance could reduce the well field's effectiveness over time. The expected service life of water-to-air heat pumps is about 20 years.

- ASHRAE 90.1-2016 minimum efficiency: 13.0-18.0 EER cool, 3.2-4.3 COP heat
- Variable Refrigerant Flow (VRF) heat pumps
    - VRF heat pumps feature one or more variable-speed condensing units serving multiple indoor blower units, providing nearly unlimited flexibility, very high part-load efficiency, and heat recovery capabilities without the need for large circulation pumps. VRF is quickly becoming the global standard for high-efficiency, multi-zone HVAC systems, and both efficiency and affordability are expected to continue improving. Like other heat pumps, VRF can be either air-source, featuring an array of outdoor condensing units, or water-source, with indoor condensing units connected to a boiler/tower or geothermal loop. VRF systems have an expected service life of about 20-25 years.
    - ASHRAE 90.1-2016 minimum efficiency: 10.8-16.2 EER cool, 2.8-4.3 COP heat
- Dedicated outdoor air systems
    - Hybrid distributed HVAC systems are often designed with a Dedicated Outdoor Air System (DOAS) that conditions and distributes the outside air needed for ventilation separately from the rest of the system. This has several benefits. First, the main heating and cooling system can be sized for just the building envelope and internal loads, reducing its overall capacity and cost and making advanced high efficiency systems like VRF more affordable. Second, only a single source of outside air is needed, rather than routing each terminal unit to separate intakes. Third, the DOAS can employ energy recovery to dramatically reduce the ventilation conditioning load. Other benefits include advanced ventilation control, reduced maintenance related to condensate removal in the conditioned space, and decreased total project costs. DOAS units, like most outdoor equipment, have an expected service life of about 15 years. Consider manufacturer options that will extend the useful life, such as double-wall construction and corrosion resistance, and prioritize regular maintenance.

<u>Centralized HVAC Systems</u>

Traditionally, large buildings with many zones and diverse uses were designed with central hydronic boiler and chiller plants serving fan-coil units and/or Variable Air Volume (VAV) air handler systems. For very large buildings, a central plant may remain the most cost-effective way to provide heating and cooling. Heat pumps can also potentially play a role in a hydronic central plant, with air- or water-to-water heat pumps serving as the primary source of heating and cooling.

- Air-cooled or water-cooled chillers
    - Chillers use electricity to generate chilled water, generally in the range of 40-50F, which is circulated to hydronic coils in air handlers or other terminal units (e.g. fan-coil units or chilled beams) by a set of chilled water pumps. Heat is either rejected to the outside air (air-cooled chillers) or to a condenser water loop and cooling tower (water-cooled chillers). Chillers can handle very large cooling loads and have nearly limitless scalability. They also tend to be more efficient than smaller equipment and many have advanced energy-saving features. In large facilities with complex cooling demands, a chiller plant can simplify the mechanical design and reduce overall costs. However, chiller plants, especially water-cooled chillers with cooling towers, require substantial and frequent skilled maintenance and water treatment to ensure performance and longevity. Air-cooled chillers have an expected

service life of about 20 years. Water-cooled chillers can last for 25-30 years, and cooling towers can also last for 20-30 years with proper maintenance.

- ASHRAE 90.1-2016 minimum efficiency:
    - Air-cooled chillers: 9.7 EER, 16.1 IPLV EER
    - Water-cooled chillers: 18.8 EER, 30.0 IPLV EER

- Water-to-water heat pumps
    - Water-to-water heat pumps, sometimes referred to as reversible chillers, are relatively large, central plant equipment capable of providing both chilled and hot water from high-efficiency electric heat pumps. These units could potentially be tied to a boiler/tower condenser water loop, although it is more common and more energy efficient to use a geothermal or ground-water loop. Modular water-to-water heat pumps can be controlled together to provide substantial scalability and flexibility. Technology and availability are still improving, but most medium to large office buildings and other similar facilities that would traditionally have a chiller/boiler plant could potentially use water-to-water heat pumps instead. Like chillers, the expected life of a water-to-water heat pump is about 20-25 years.
    - ASHRAE 90.1-2016 minimum efficiency: 10.6-16.3 EER cool, 2.5-3.7 COP heat
- Air-to-water heat pumps
    - Air-to-water heat pumps are somewhat uncommon in this region, but they can be effective at generating chilled water for cooling and low-temperature hot water for radiant flooring and domestic water heating applications. Like other air-source heat pumps, performance will decrease as the outside air temperature decreases, so a supplemental heating source may be necessary. If considering this technology, look for heat pumps with low-temperature heating capabilities. Expected service life is about 15 years.
    - ASHRAE 90.1-2016 minimum efficiency: 10.0-11.0 EER cool, 3.0-3.3 COP heat
- Fuel-fired Boilers
    - Hot water and steam boilers, fueled by oil or natural gas, have been the standard choice for heating systems of all sizes for many years. The Office of Sustainability is making a focused effort to eliminate fuel oil from City buildings where possible, as it is less energy efficient and more polluting than natural gas, and unlike electric systems it does not facilitate the City's goals of increasing renewable energy. However, some critical City facilities are required to maintain fuel oil systems for resilience. In these facilities it may be possible to retain an oil-fired boiler for emergencies but rely on high-efficiency, natural gas or heat pump heating systems for normal use.
    - If electric options are infeasible and a fuel-fired boiler is required, select high-efficiency, gas-fired condensing boilers whenever possible. These can reach thermal efficiencies as high as 99% under part-load and low-temperature conditions, and are most effective when terminal units have multi-row heating coils and variable-speed fans and pumps. Condensing boilers tend to have smaller fluid passages, leading to higher pressure drop and potential maintenance difficulty. Cast iron condensing boilers are available from several manufacturers and offer reduced pressure drop and maintenance issues. The corrosive condensate generated by condensing boilers must pass through a neutralizer before entering the drain. The expected service life of fuel-fired boilers is about 35 years.
    - ASHRAE 90.1-2016 minimum efficiency: 80-82% E_T
- Electric boilers

  - In some limited applications, an electric boiler may be able to replace a fuel-fired boiler for light heating, domestic hot water, or process demands. Electric boilers are generally not designed to handle large space heating loads with substantial need for recovery and would require costly electric service upgrades in most facilities as well as greatly increasing utility expenses, as grid-sourced electricity is currently about three times more expensive than natural gas. Transitioning to renewable energy may provide more opportunities for small electric boilers to be cost-effective, but heat pump options are generally recommended if possible. The expected service life of an electric boiler is 15 years.
  - ASHRAE 90.1-2016 minimum efficiency: 1.0 COP

Controls Best Practices

Control of HVAC systems determines the difference between good and bad performance, comfort, and energy efficiency. The sophistication of HVAC controls varies dramatically from small, self-contained systems to large plants and distributed systems, and the project team must carefully consider the needs and abilities of the building operators when selecting control systems and specifying sequences of operation.

This section describes the different levels of control recommended for projects of varying sizes, and the sequences of operation that should be implemented to maximize performance and energy efficiency. For further information regarding control sequences, consult ASHRAE Guideline 36: High Performance Sequences of Operation for HVAC Systems.

<u>Distributed HVAC Systems</u>

Smaller facilities with distributed single-zone systems generally require only space temperature control. Individual thermostats are often sufficient, and the project team should consider models that can be networked together for remote monitoring and control. Larger unitary heat pumps and air conditioners can feature more advanced built-in controls for ventilation and economizer. For larger facilities with distributed HVAC systems comprising numerous terminal units, a lightweight, open-source Building Automation System (BAS) may be necessary and cost-effective.

- Space temperature control
  - Thermostats should have 7-day programming capabilities and a facility-wide policy on temperature setpoints and schedules is recommended, with space temperatures setting back by 5-10F during unoccupied hours whenever possible.
- Minimum ventilation control
  - Minimum ventilation rates should be calculated according to ASHRAE Standard 62.1: Ventilation for Acceptable Indoor Air Quality. Outside air dampers should be set to this minimum position during occupied hours, and should close completely during unoccupied hours.
- Air-side economizer
  - On larger unitary systems, select economizer control options where available. The economizer controls the mixed air dampers to allow additional outside air for “free cooling” when weather permits. Consider dual-enthalpy controls to maximize energy savings, and in facilities with winter cooling demands, make the low-limit setpoint low enough to take advantage of the cold outside air without leading to freezing conditions.

- Supply fan differential temperature speed control
  - Single-zone systems with variable-speed fans can take advantage of "single-zone VAV" control, saving energy by varying the fan speed to maintain room temperature as the first stage of control, before heating and cooling coils are activated.

Hybrid Distributed HVAC Systems

In addition to the control sequences described above, hybrid distributed HVAC systems often feature water circulation loops with pumps and associated controls. The often large number of terminal units and more sophisticated heating/cooling equipment also tends to require more advanced controls than single-zone systems and a BAS is recommended.

- Pump differential pressure speed control and reset
  - For systems with water circulation loops, pumps are typically controlled by differential pressure, maintaining a constant pressure that is calculated to ensure adequate flow at the furthest and worst-case terminal unit coils. If coils have two-way shutoff valves rather than three-way diverting valves, the pumps will be able to slow down and save energy as space temperatures are satisfied and coil valves close.
  - The differential pressure setpoint can also be reset incrementally down until only the critical zone's valve is wide open, further reducing pump speed and energy consumption.
- Pump differential temperature speed control
  - An alternative, or complement to pump pressure control is temperature control. In this sequence, the pump speed is controlled to maintain a constant temperature difference, increasing speed if the difference becomes too large and slowing down if the difference becomes small. This is a more direct reflection of the loads on the system and can maximize energy efficiency, but it is important to maintain the minimum required system pressure and ensure that all coils and primary equipment have adequate flow.
- Optimal start/stop
  - Warm-up and cool-down routines are commonly used to bring space temperatures to the occupied setpoint in time for the scheduled occupancy. "Optimal start and stop" algorithms conserve energy by predicting the shortest required morning warm-up period and longest possible evening coasting period based on weather and past system performance.
- Demand-Controlled Ventilation (DCV)
  - Larger unitary systems may also have DCV options by incorporating CO_2, VOC, or other environmental quality sensors into the occupied space or return duct. DCV can reduce ventilation conditioning loads by allowing only the outside air required to maintain an Indoor Air Quality (IAQ) setpoint, usually around 750-1,000 ppm CO_2. DCV can also be used to temporarily increase ventilation in conference rooms and lecture halls when they are fully occupied.
- Ventilation energy recovery
  - If using a DOAS in conjunction with distributed HVAC systems, consider a unit with energy recovery capabilities. Successful energy recovery depends on careful calibration and maintenance of temperature and enthalpy sensors. In heating mode, energy from the exhausted air should be transferred to the incoming fresh air; in cooling mode, the opposite should occur.
- Water-source heat pump and VRF energy recovery

- Hybrid distributed heat pump systems with common water or refrigerant circuits can utilize energy recovery when some units are in cooling mode and others are in heating mode. As cooling-mode units reject heat, heating-mode units can extract the same heat without using extra compressor energy.

Centralized HVAC Systems

Central plants and large HVAC equipment require the most sophisticated controls and offer the most opportunities for energy efficient control sequences, although frequent monitoring and maintenance are required for long-term performance. In addition to the control sequences described above, central plants and large air handling systems should incorporate the following controls:

- Supply air temperature reset
  - In VAV and large multi-zone systems, the supply air temperature in cooling mode can be reset up by as much as 5F under low-demand conditions without causing comfort or dehumidification issues.
- Supply air static pressure speed control and reset
  - VAV fan systems are typically controlled by a static pressure sensor located roughly 2/3 down the longest major run of ductwork. The setpoint is calculated to ensure that the furthest and worst-case terminal units have adequate airflow. The static pressure setpoint can be reset incrementally down until only the critical zone's damper is wide open, further minimizing fan power and energy consumption.
- Hot, chilled, and condenser water temperature reset
  - Similar to supply air temperature reset, the temperature setpoint of hot, chilled, and condenser water loops can typically be reset by 5-10F during periods of low demand.
- Cooling tower fan speed control
  - Modulate cooling tower fan speeds to maintain the condenser water temperature setpoint. Cooling tower fan and spray pump operation should be staged to maximize efficiency.

Building Automation Controls

The need for building automation systems to help manage the operation of the City's buildings have become an essential as mechanical systems become more sophisticated and more connected. As central plant mechanical systems (VFDs, Chillers, Boilers, AHUs) are easier to connect than ever before, the cost of installing and maintaining a Building Automation System (BAS) at each location has become simplified and less cost prohibitive.

The general guidance on mechanical systems is that they must be capable of BACNET/IP integration. Although MODBUS is an acceptable open protocol, it does require additional labor for point mapping and integration. This applies to a variety of systems that includes but is not limited to:

- Lighting and Lighting Control Systems
- Chiller Controls
- Pump Controls (VFDs)
- Boilers
- AHUs

- RTUs
- VAV's
- Primary Electrical Switchgear
- Security - Card Access Systems
- Security - CCTV (IP Camera Systems)
- Elevator Systems
- Fire Alarm Systems

As these systems are integrated into the site's building automation system, this simplifies ease of access for facilities management personnel and should reduce long-term operating costs for the systems that are integrated into the BAS System.

The need for building automation systems (BAS) to help manage the operation of the city's buildings has become essential as mechanical systems become more efficient yet more sophisticated. BAS also allows older mechanical equipment to operate more efficiently through precise scheduling, optimized start-up algorithms, high-performance sequences of operations, and environmental monitoring. In addition to utility savings realized through efficient use of HVAC equipment, the equipment has a longer functional life span and requires less maintenance, generating even more savings.

Facilities staff benefit from continuous access to web-connected building automation systems. This allows for critical alarms to be sent to on-call staff via e-mail or SMS text and for those alarms to be addressed remotely. Troubleshooting equipment failures is made easier when accessing controls from a tablet or smart phone, as is quickly overriding comfort settings and schedules.

The BAS also enables continuous commissioning (CCx), which satisfies the Philadelphia Building Energy Performance Program (BEPP) high-performance pathway of Automated Active Optimization, with minimal added cost or time spent by operations staff. Because mechanical, electrical, and physical building assets deteriorate over time, in terms of both performance and efficiency, operations, and maintenance costs rise along with energy consumption while occupant comfort often declines. BEPP requires building owners to "tune-up" these systems every 5 years to reduce energy waste. A monitoring-based commissioning system integrated with the BAS aims to keep the building tuned, lowering the cost and reporting burden of complying with the new policy.

New BAS deployments should utilize open protocol communication networks with BACnet/IP being the preferred protocol and BACnet MS/TP being used when IP networks are not permitted. Integration of new equipment into existing automation systems should utilize the pre-existing network but be capable of future conversion to an open protocol when a proprietary protocol is being used.

A BAS supervisor serves real-time graphical information to standard web-browser clients and performs essential functions such as analytics, centralized data logging/trending, archiving to external databases, alarming, dashboarding, system navigation, master scheduling, database management, and integration with other enterprise software applications. Moving these functions from field controllers to the supervisor frees up system resources for better performance while giving building owners and operators full control of their BAS through full access to the control software. This keeps the system open to future expansion and service by any contractor, not just the installing contractor.

Integration of building systems may extend beyond HVAC equipment to simplify ease of access for facilities management personnel and should reduce long-term operating costs for the systems that are integrated into the BAS. This applies to a variety of systems that includes but is not limited to:

1) Lighting and Lighting Control Systems
2) Central Chiller Plants
3) Boiler Plants
4) Pump Controls (VFDs)
5) Air Handling Units and Building Exhaust
6) Fire Alarm Systems
7) Water Monitoring
8) Security - Card Access Systems
9) Security - CCTV (IP Camera Systems)
10) Elevator Systems
11) Primary Electrical Switchgears and Power Monitoring

BAS programming should adhere to ASHRAE standards 62.1 – Ventilation for Acceptable Indoor Air Quality, 90.1 – Energy Standard for Buildings, and guideline 36 – High Performance Sequences of Operation for HVAC Systems. These documents are the basis for building codes and minimum energy efficiency requirements in many rebate programs.

Metering and sensing devices should adhere to the following guidelines:

Measured Variable	**Reported Accuracy** **(end to end)**
Outside air dry-bulb temperature	±0.27°C (±0.5°F)
Chilled and condenser water temperature at central plant mains only	±0.11°C (±0.2°F)
Chilled and condenser water temperature - general	±0.27°C (±0.5°F)
Hot water temperature	±0.27°C (±0.5°F)
Chilled, condenser or heating water ΔT for energy use calculation or heat exchanger evaluation	±0.08°C (±0.14°F) or 2.0% uncertainty at design ΔT

Relative humidity - tower control	±1.7%RH
Water and gas flow	±1% of reading
Electrical power meter	±1% of reading
Water pressure	±2% of reading
Water Differential pressure	±1% of reading

1) Temperature measurement equipment used for thermal energy calculations shall comply with ASHRAE 41.1 Table 1. Instrument requirement is for water or non-volatile refrigerant temperature difference. End to end differential temperature accuracy of not greater than ±0.18°F over the typical chilled water, condenser water and hot water operating range should be delivered.
2) Power measurement should be made with a revenue grade three phase power meter with an end-to-end accuracy complying with ANSI C12.1-2008, Class 1 ±1%.
3) Chilled water flow rate, end to end accuracy of 1% of reading throughout the entire operational range (range to be defined by the engineer of record). Careful consideration of meter end device location is mandatory and must follow manufacturer's recommended installation requirements.
4) Condenser water flow rate, end to end accuracy of 1% of reading throughout the entire operational range (range to be defined by the engineer of record).
5) Combined outside air temperature measurement with an accuracy of ±0.36°F between 35°F and 105°F and relative humidity measurement with an accuracy of ±1.7% RH between 10% and 95%. Outside air measurement device should be equipped with a solar and rain shield cover.
6) All data collection input/output hardware should be supplied with a minimum 14-bit resolution.
7) Makeup and tower blow down water flow measurement end to end accuracy of not greater than 1%.

HVAC and lighting systems consume 40-60% of a commercial building's total energy spend. Automating these systems to perform optimally presents the biggest opportunity for energy savings in most buildings. The following building-wide and system-specific strategies should be employed whenever possible.

Building-wide strategies

- Space-specific schedules should be implemented alongside building and/or equipment schedules wherever appropriate.

- Spaces with repetitive, but not uniform loads such as cafeterias and kitchens should be scheduled to meet peak loads while standby temperatures in between peaks.
- The BAS should trend all sensor readings, occupancy states, control signals, and feedback signals locally, and retain the data for no less than 2 weeks, to aide in diagnostic troubleshooting.
    - Numerical points should be trended at 15-minute intervals (or shorter if system memory is available).
    - Enumerated and boolean points should be trended by change of value and retain at least 500 records.
    - Where possible through BAS supervisor connection, trends histories should retain at least 2 years of data.
- Occupancy sensors provide much tighter lighting and climate control than wall switches and schedules. Occupancy sensors for lighting should be used wherever possible. Occupancy/vacancy sensors should be given priority for HVAC control over daily schedules.
    - Less frequently used spaces such as storage rooms, warehouses, auditoriums, and conference rooms should typically be scheduled unoccupied, with motion sensors overriding their lighting and climate control on-demand.
- Demand Controlled Ventilation (DCV) reduces outside air requirements to the minimum needed to satisfy ASHRAE standard 62.1. This reduces fan energy as well as heating and cooling energy needed to pre-treat ventilation air.
    - In buildings with similar space uses throughout, CO2 sensors should be placed in the return air stream of air handling units.
    - In buildings with dissimilar space uses or densely populated areas, zone sensors are recommended.
    - CO2 setpoints should follow default values provided in ASHRAE guideline 36 Table 3.1.1.3 or be within 700 ppm of outside air levels where no setpoint is provided.
- Nighttime pre-cooling (night purge) reduces daytime mechanical cooling requirements by lowering the temperature of the building mass. This strategy should only be used where free cooling (economization) is available.
    - Pre-cooling should be part of an optimized start-up algorithm which includes load forecasting by weather service integrated to the BAS.
    - Local weather stations (outside air and humidity mandatory, air speed optional) should be used when weather service data is not available.
- Variable speed control of all motors larger than 1.5 HP is recommended.
    - Variable frequency drives should always be integrated to the BAS where possible and never set to hand (manual) except during equipment maintenance.
    - The BAS should alarm when a VFD is not in Auto for more than 3 hours.
    - Variable speed fans and pumps controlling to a flow and/or pressure setpoints should have speed signal and VFD output trended in the BAS along with the value of the corresponding control point.

System-specific strategies

- Lighting and Lighting Control Systems
    - Existing Lighting Control Systems that are not integrated to a BAS should be integrated.
    - Motion (occupancy) sensors should replace wall switches and scheduled lighting.

  - Sensors should be integrated to the BAS where possible, or to stand-alone HVAC systems, when necessary, to control local HVAC in addition to local lighting.
    - Only sensors with built-in control contacts should be deployed.
    - Where pre-existing sensors are currently controlling lighting but not HVAC, a control relay should be installed and integrated to the BAS to provide local occupancy indication to the proper HVAC system.
  - Daylighting should be employed wherever natural light is adequate to reduce a space's internal lighting load by at least 20% for 4 hours (average) or more per day.
  - Light level sensors should be integrated to the BAS whenever possible.

- Chiller Plants
  - Chiller controls should be integrated to the BAS to provide a full range of operating setpoints, signals, and diagnostics, including instantaneous power draw and cooling capacity. Minimal chiller control (consisting of only start/stop signal, sequencing, and CHW setpoint) is strongly discouraged.
    - Chillers that do not provide instantaneous power and efficiency metrics (kW/ton) should be sub-metered.
  - A base lead/lag strategy should be used to manage multiple chillers to optimally match load while decreasing energy consumption.
  - Plants employing cooling towers should monitor and trend make-up water flow and consumption.
  - Pump and cooling tower motors should be controlled via VFD as noted in the building-wide strategy for all motors over 1.5 HP.
    - VFD controls should be integrated to the BAS to receive speed control signals as well as provide feedback and energy metrics.
  - Modulating valves should provide the BAS with feedback signals.
  - Total plant power should be calculated by the BAS, which should be capable of implementing demand-limiting, curtailment, and predictive optimization algorithms.
  - Chiller isolation valves should be integrated to the BAS to prevent flow through shutdown chillers.
  - Chilled water reset logic and loop pressure control should prioritize building load signals over outside air temperature.
  - Larger capacity central utility plants (< 400 tR) operating 24 hours / 7 days a week should consider a dedicated program providing an optimized sequence of operation that complements the base automation sequencing. The optimization platform should provide a fully modeled, simulation-based approach utilizing equipment performance data with pre-established rules of operation.
    - Optimization systems should be capable of adapting to equipment revisions and availability due to repair or system maintenance.
    - The programming should not be embedded within the base sequence of operation. Solution sequencing must maintain a method of separation from the base sequence of operation for reliability and redundancy.
    - These systems generally include a visual display or dashboard to provide metrics indicating real-time performance and historical data.

        - Optimization systems must maintain compatibility to open/non-proprietary architecture as outlined in this document.

- Boiler Plants
    - Boiler controls should be integrated to the BAS wherever possible. Standalone controllers are not recommended as they have limited inputs and do not have access to weather services.
        - At a minimum, boiler status, setpoint temperature, and modulation percent should be available points for integration.
        - Stack temperature should be monitored by the BAS either through integration with the boiler controller or a dedicated high temperature sensor.
    - Boiler controllers should receive both an outside air temperature reading and heating calls from air handlers, VAV boxes, and radiators to manage load.
    - The hot water or steam loop temperature and pressure should be monitored by the BAS, not just the boiler controller.
        - Differential pressure setpoint reset logic should sequence variable speed pumps to match load while reducing energy consumption.

- AHUs (and packaged Roof Top Units)
    - Air handling units should utilize predictive start-up algorithms, using weather-service forecasting when possible.
    - Minimum outside air dampers should be replaced with demand-controlled ventilation, as noted in the building-wide DCV strategy.
    - Air handlers should utilize dual enthalpy-controlled economization, using temperature and humidity sensors in both the outside air and return air streams.
        - Where enthalpy control is possible but not employed due to lack of functional humidity sensors, new or replacement sensors should be installed.
    - The supply air temperature setpoint should be selected variably by logic using a combination of outdoor air temperature reset and zone feedback.
        - Each unit should use its own outside air temperature reading and the OAT min and max ranges should be 60° and 70°
        - The cooling minimum discharge temperature should always be lower than the air streams' dew point to increase passive dehumidification with the cooling maximum set to 65°.
        - The heating discharge air temperature should be limited to 20° above the highest zone temperature setpoint.
    - Supply fan speed should be set by air handler application and mode and utilize variable frequency drives whenever possible.
        - In variable air volume systems, the static pressure setpoint should be reset based on the worst-case VAV box requirement.
        - For constant volume applications, three speed settings should be established:
            - Minimum speed which provides design airflow with the economizer fully open.
            - Maximum cooling speed which provides design cooling air flow as prescribed on the mechanical schedule or latest balancing report.

        - Maximum heating speed which provides design heating air flow as prescribed on the mechanical schedule or latest balancing report, but no more than half the maximum cooling speed.
    - Return fan speed should be set to maintain a differential with the supply fan such that the building pressure is a positive 0.025” wc.
        - The building pressure should be measured by at least one sensor connected to the BAS.
    - Deep setback temperatures should be established for all equipment or zones when unoccupied, witch occupancy schedules being as precise as possible.
        - If predictive start-up algorithms are available heating and cooling temperatures may be set back as far as 60° and 85° respectively.
        - Where no predictive start-up algorithm is available heating and cooling temperatures may be set back to 64° and 80°.

- Exhaust fans
    - Building exhaust should never run continuously except when venting laboratories or hazardous materials storage.
    - Exhaust for odor or humidity control such as in gymnasiums and kitchens should be scheduled to match zone occupancy.
    - Bathroom exhaust should be controlled by occupancy sensor.
        - Where continuous bathroom exhaust is in place, fans should be re-wired for local occupancy sensor control.

Ventilation and Pollution Mitigation

This section contains guidance for meeting the requirements of the following LEED prerequisites and credits:

EQ Prerequisite: Minimum Indoor Air Quality Performance

EQ Credit: Enhanced Indoor Air Quality Strategies

Air quality optimization measures such as those outlined in the LEED EQ prerequisite and credit above should be applied to all projects. Air quality is important for employee and public health. Outside air control is one of the first things to evaluate in existing buildings as deferred maintenance can reduce air flow or increase energy use. Ventilation controls will also be a high priority in a post-COVID world.

Projects should double check ASHRAE 62.1-2016 to ensure that their outdoor air intake flow rates are compliant with the prerequisite and the 2018 International Mechanical Code (IMC).

The prerequisite requires measurement devices and alarms for VAV systems. These measures are above code. Outdoor air monitors are also required for mechanically vented systems. See the EQ Minimum Indoor Air Quality Performance section in LEED v4.1 manual for more details on compliance pathways.

To achieve Enhanced Indoor Air Quality points, it is recommended project teams pursue at minimum 3 pollution mitigation and advanced ventilation strategies listed below and described in fuller detail in the LEED v4.1 manual:

1. Entryway Systems
2. Interior Cross-Contamination Prevention
3. Filtration of Outdoor Air
4. Filtration of Recirculated Air
5. Increased Ventilation 15%
6. Increased Ventilation 30%
7. Operable Windows
8. Engineered Natural Ventilation
9. Carbon Dioxide Monitoring
10. Additional Source Control and Monitoring

Sub-Metering

This section contains guidance for meeting the requirements of the following LEED prerequisites and credits:

- EA Prerequisite: Building-Level Energy Metering
- EA Credit: Advanced Energy Metering

To provide better understanding of energy use within the building, it is highly recommended that a submetering system be installed that provides data with greater granularity than monthly utility billing data.

- Electrical Sub-Metering
    - This submetering system should at a minimum capture electrical loads at the primary switchgear, or MDB (Master Distribution Panel) after the incoming transformer where PECO's high voltage power is transformed down to either 3 Phase 480 Volt or 3 phase 208 Volt.
    - If possible, the building loads relating to large energy users (10 KW and above) should be metered to provide data that can be used for system maintenance, energy tracking and energy performance benchmarking. Building systems such as Lighting, Chillers, Primary HVAC Systems should be captured within the metering system.
- Water Sub-Metering
    - The water meters are typically capable of pulsed outputs, or a magnetic rotation counter can be utilized to track meter rotations. This data can then be integrated into a pulse counter that converts the pulses into a volumetric value (gallons or cubic feet). The minimum data acquisition is at the incoming water level.

  - Cooling Towers - buildings equipped with large cooling towers that have a capacity greater than 200 Tons, should have a separate submeter installed. Many times, the fill valve control float on the cooling towers can become damaged since it is a mechanical component, failing open and causing water to run continuously down the drain until this issue is discovered.
- Swimming Pools
  - Swimming pools consume high amounts of water and energy for heating, backwashes and continuous filtration. It is recommended that the pool's power, water, and natural gas (if present) be sub-metered.
- Natural Gas Sub-Metering
  - The pulses from the gas meter or a magnetic rotation counter should be installed to monitor gas use at the main meter.

Sub-meter Data Integration and Monitoring

As the pace of innovation in data and data analysis outpaces the field installed hardware metering equipment, it is essential that the data from these sub-metering systems are properly integrated, warehoused and easily accessible to all City employees. This eases the burden of information transfer as the data from the metering system can empower the facilities management team and the Energy Office. For this reason, it is recommended that a cloud-based solution that utilizes cellular connectivity be utilized. This will mitigate the long-term burden on the City's OIT (Office of Information Technology) to manage the integration of this data into the city's network as well as managing the servers and associated software for this metering data.

Sub-meter device level integration

To facilitate the ease of data and data integration, the primary metering data integration devices should be capable of connectivity to the internet through the 3 primary routes that are commonly used, this includes ETHERNET / LAN, WIFI, and 4GLTE (Cellular). These diverse connectivity options provide a path for the City to integrate metering data through commonly internet protocol and eliminates the need for a multi-tiered integration path where a meter has to be integrated into a field controller, which then integrates to a physical server front end, which then has to be exported by someone on a regular basis. The goal is to streamline the data acquisition process and eliminate as many possible points of failure as possible while reducing the effort needed to derive value from the metering system.

Sub-meter data exports and GIS Impact

The graphical front end that visualizes the collected data should be capable of data exports through timed, .csv or JSON exports to allow the city to easily integrate this data into a GIS or greenhouse gas management application. This will reduce the burden of data management as the data is utilized by multiple systems during the value derivative process.

Sub-meter data Rules and Alerts

The submetering system should be capable of sending out notifications on system performance and alert the City of specific changes in the metering system. This might include:

- No Data Received

- Metering point exceeds upper threshold
- Metering point exceeds minimum threshold

This data can then be used by the city on long-term demand management, demand response, or smart grid opportunities in the future. These alerts can also notify the facility maintenance team on operation of the critical infrastructure (chillers, boilers, fans, pumps) within a building.

Domestic Hot Water

While the energy usage for the domestic hot water systems represents a small portion of the cumulative energy use for most buildings, there are still opportunities to reduce energy through conservation and efficiency improvement. Since domestic hot water contributes to the baseload energy use, any improvements to the energy use will result in year-round savings.

Design Standards for Energy Efficiency and Performance

As mentioned in the “HVAC” section, the ASHRAE standards and guidelines available to support energy efficiency in service water systems for both new and existing building projects. Read-only versions of many ASHRAE resources can be found at the following link:

https://www.ashrae.org/technical-resources/standards-and-guidelines/read-only-versions-of-ashrae-standards

Early in the conceptual and schematic phases of design, consult the most current City-adopted editions of the following ASHRAE resources:

- ASHRAE Standard 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings
    - This Standard includes a Service Water Heating section to establish requirements for efficiency ratings, placement of insulation, and control sequences to minimize energy usage.
- ASHRAE Standard 100: Energy Efficiency in Existing Buildings
    - This Standard includes general operating practices and energy efficiency measures to minimize energy use for domestic hot water systems.

Equipment Selection Guidelines

The following list provides options for energy-efficient equipment to provide domestic hot water, including options to transition from fossil fuels. Where possible, consider selecting an ENERGY STAR Certified unit, which uses 70% less energy than a standard model, and specify adequate insulation for domestic hot water piping to minimize heat loss.

1) Conventional Storage Water Heaters
    a) This type of water heater maintains water at a specified temperature setpoint in a storage tank and provides a large volume of hot water before needing to recover. When selecting a storage water heater, consider tanks with a high insulation level (R-12.5 or

above) which will reduce standby heat losses. The recovery rate is the amount of hot water the heater can provide in a period, which is an important consideration for selecting a water heater. The higher the recovery rate, the faster the unit can generate hot water. Note, that gas-fired and oil-fired units will require proper venting to prevent toxic emissions from combustion entering the building.

2) Instantaneous Water Heaters
    a) This type of water heater generates hot water continuously as needed without a storage tank. Also known as a tankless water heater, the instantaneous water heater is comprised of a heat exchanger either with a natural gas burner or an electric heating coil to provide heat to cold water. This type of unit is more energy efficient than storage water heaters, as there are no standby energy losses. The flow rate of the instantaneous water heaters is limited based on the heating output of the unit. Spaces with minimal domestic hot water needs, like lavatory and kitchen faucets, are a good application for this type of domestic hot water unit.
3) Heat Pump Water Heater
    a) A type of electric storage water heater is a heat pump, which transfers heat from the ambient air to a storage tank to heat water. This process is like an air conditioner working in reverse. These heat pump water heaters are two to three times more energy efficient than conventional electric resistant water heaters. These units are appropriate for spaces in with warmer ambient air, like mechanical rooms with excess heat to recover.
4) Indirect Fired Water Heater
    a) Indirect water heaters utilize the main furnace or boiler to heat hot water, which is circulated through a heat exchanger in a water storage tank. These configurations are best with boilers with high efficiency rates and high turndown ratio to generate hot water in the summer months, when the space heating demands are lower, and the domestic hot water is still needed. Like the conventional storage water heater, the storage tank should be equipped with a high level of insulation.

Controls Best Practices

Advanced controls for domestic hot water systems are not common, as the setpoints do not change daily or based on the weather. However, there are control sequences available to minimize the hot water generated based on the occupancy of the building and should be considered for new construction and large renovation, regardless of the size of the building. The following parameters are listed to provide typical control points for domestic hot water systems, based on guidance from ASHRAE 90.1-2016.

- Temperature
    - The hot water temperature should be maintained to 120°F or lower to a maximum temperature based on the application. Note, this temperature can vary based on the property space type and the manufacturer's installation guidelines for the storage tank.
- System Timers
    - Automatic time switches or other system controls can be used to turn off hot water circulation through the building during extended periods when hot water is not needed.

- Outlet Temperature Controls
  - The maximum temperature of the outlet from lavatory faucets should be 110°F. This point within the system can be measured to ensure the system is not overheating water.
- Circulating Pump Controls
  - These systems are equipped with circulating pumps to direct hot water throughout the building. To maintain the storage water tank temperature, circulating pumps should be equipped with timer controls to limit operation from the start of the heating cycle to five minutes after the heating cycle has ended.

Irrigation Systems

This section contains guidance for meeting the requirements of the following LEED prerequisites and credits:

- WE Prerequisite: Outdoor Water Use Reduction
- WE Credit: Outdoor Water Use Reduction

Many City projects do not typically require landscape irrigation, so the LEED prerequisite and credit for Outdoor Water Use Reduction are both fully achievable under this condition.

If outdoor irrigation is required, project teams should reduce the project's landscape water requirement (LWR) by at least 50% from the calculated baseline for the site's peak watering month to be able to achieve the minimum one point in the WE credit. The bulk of water use reduction should first be achieved through strategic plant selection and irrigation efficiency. Integrating alternative water sources and smart scheduling technologies will help to achieve additional reductions.

Refer to the Environmental Protection Agency (EPA) WaterSense Water Budget Tool linked below to measure water use efficiency:
https://www.epa.gov/watersense/water-budget-tool

Water Fixtures and Appliances

This section contains guidance for meeting the requirements of the following LEED prerequisites and credits:

- WE Prerequisite: Indoor Water Use Reduction
- WE Credit: Indoor Water Use Reduction

To reduce the building's potable water use, it is recommended that only U.S. EPA WaterSense labeled product be used for replacements and new installations. Similarly, appliances that use water such as clothes washers and commercial kitchen appliances should be ENERGY STAR certified. Some equipment that uses potable or process water fall outside of product categories for WaterSense and ENERGY STAR, such as medical laboratory equipment and district steam systems; refer to the requirements for the Indoor Water Use Reduction credit in the LEED BD+C v4.1 manual for further efficiency guidelines for various equipment.

Overall, project teams should aim to achieve a minimum 30% reduction with reference to baseline indoor water use. Use the LEED Indoor Water Use Reduction Calculator linked below to measure reduction:

https://www.usgbc.org/resources/leed-v4-indoor-water-use-reduction-calculator

For LEED projects, an additional benefit of achieving the Indoor Water Use Reduction credit is the project will also earn a Regional Priority credit.

Electric Vehicle (EV) Charging Stations

This section contains guidance for meeting the requirements of the following LEED prerequisites and credits:

- LT Credit: Electric Vehicles

Types of Chargers

Two types of electric vehicle chargers are currently recommended for municipal parking sites:

1. AC Level 2, 208-volt to 240-volt single-phase circuit with an 80-amp maximum, but often using 40-amp rated circuits. These come in various designs and often can be mounted on the ground, wall, pole, or ceilings.
2. DC fast charger or Level 3, converts AC power levels rated at 208 volts to 480 volts (3-phase) to DC power to deliver up to 50 kilowatts at the EV's battery voltage. These are often ground-mounted on pedestals or as part of larger charging station equipment. Often, one DC fast charger has two charging cables/plugs to serve two parking spaces.

Fully depleted, Level 2 EV supply equipment can fully recharge a 24-kilowatt-hour battery in less than 4 hours. Using DC fast chargers, most vehicles will recharge up to 80 percent of capacity in 30 minutes or less. As a faster charging option, DC chargers should be prioritized if space efficiency is needed since multiple vehicles can use the charger throughout the day. However, a scheduling system may be needed to coordinate when the charger and parking space is available. If reserved parking spaces for individual EV vehicles are available, Level 2 chargers may be sufficient for charging needs.

Charging Infrastructure

LEED BD+C v.4.1 Electric Vehicles credit requires chargers for 5% of all parking spaces used by the project or at least two spaces, whichever is greater. These chargers must provide a Level 2 charging capacity or greater, be networked, and capable of participating in a demand response program or time-of-use pricing to encourage off-peak charging.

If this is not possible to achieve at the time of construction, it is recommended that projects follow the option 2 for compliance in the credit which specifies 10% of all parking spaces or at least 6 spaces EV Ready, whichever is greater.

EV Ready spaces have electrical infrastructure nearby prepared to accommodate the addition of charger equipment in the future. To be EV Ready, include a dedicated electrical circuit with sufficient capacity for each required space. Each circuit shall have conduit and wire sufficient to provide Level 2 charging or greater and shall end at an electrical box or enclosure located near each required space. Ethernet cable should also be considered for inclusion in conduits if Wi-Fi or cellular service for a future charging unit is not readily available or transmissible through the parking structure. See “Connectivity” below for more details.

Locating the Charger

Sheltered spaces are recommended for EV charging spots to protect chargers from wear due to wind, rain, or ultraviolet light. Charging stations can also be located near an electrical room, an existing electrical panel, or elevators where existing power and available conduits may be located to minimize installation costs. Installation of new conduit is most efficiently done by surface mounting onto walls, beams, or ceilings. Wall-mounted charging stations with surface-mounted conduit tend to be the most cost-effective.

Posts and poles can provide good opportunities for mounting a charging station. Posts and poles often have buffer space or barriers that would also protect EV supply equipment attached to, or adjacent to them. The EV supply equipment should be oriented so that the post protects the equipment from adjacent parking.

Space Considerations

The wider and/or longer parking spaces in a parking facility are usually best for installing EV charging stations. Extra space is needed to accommodate the new equipment and its operation. Finding adequate space plus factors such as power availability, ADA accessibility, and convenience helps identify potential EV charging sites.

Spaces should allow for room for the vehicle operator to stand while charging and persons with disabilities need additional room to maneuver while charging a vehicle. A person in a wheelchair needs maneuvering room including space at or near the EV supply equipment to turn around. Space is also needed to the sides of the vehicle to maneuver the charging cable. Unfortunately, cables placed on the ground do not always lie flat. Level 2 cables are about ¾ inches in diameter with a typical length of 18 feet to 20 feet (allowable up to 25 feet).

To protect the charging equipment, also consider reserving space for space for barriers such as curbs, wheel stops, railing, wall-mounted barriers, and bollards. These barriers also help define the separation between parking and other uses such as landscaping and pedestrian spaces.

Connectivity

The three methods for communication relevant to EV charging stations are Wi-Fi, cellular, and Ethernet.

Most EV supply equipment is designed with several potential communication pathways since the equipment is be used in a variety of settings. Most commercial charging stations use cellular technology to become networked. A cellular wireless modem can establish connections with many charging stations using either Wi-Fi or a personal area network technology and then route the data to a network service.

Groups of EV supply equipment installed at the site can use mesh communication technologies to better ensure correct data transmission to the modem. With mesh, EV supply equipment located in the same area receive and re-transmit data among the group. Units farthest from the main cellular modem need only to transmit their data to other nodes that can communicate with the modem.

Adequacy of signal strength can be readily checked in parking structures and in underground garages where effective transmission can be difficult. If impenetrable surfaces interfere with the wireless signals, signal repeaters or amplifiers can be installed to extend the radio frequency signal. Ethernet cable might be necessary to extend the signal to a location with strong, reliable signal quality.

Steps can be taken to minimize the need for signal repeaters, including:

3. Test signal strength at several alternative charging station sites.
4. Locate equipment where physical barriers such as concrete walls will not block wireless service.
5. Avoid locations near other electrical equipment known to interfere with signals, such as electric motors and fluorescent lights, and
6. Install away from other wireless devices emitting the same signal frequency.

Lighting

Locations where charging stations will be installed should be checked for night-time illumination levels between parked cars especially if the style of EV supply equipment being used has cables that extend along the ground between the EV supply equipment and the charging port on the vehicle. Dim lights and cables along the ground could create a tripping hazard. Note that some EV supply equipment includes lighting. See Lighting under ***Energy Project and Building*** Guidelines section for additional guidance.

Signage

Way finding signs that direct drivers to EV charging stations are best placed where they are easily seen but will not cause safety issues by blocking an important view or creating a hazardous barrier.

Signage at a charging station helps identify parking stalls associated with EV charging and inform persons about the rules associated with parking there. Signs inform drivers on topics such as identification of EV charging stations, parking restrictions, and enforcement, such as towing. To avoid confusion, each parking stall should have signage. Signage can be emphasized by painting the entire charging station space a distinct color matching the signage to distinguish it from standard parking.

Pre-Occupancy

Air Quality Testing

This section contains guidance for meeting the requirements of the following LEED prerequisites and credits:

- EQ Credit: Indoor Air Quality Assessment

To optimize indoor air quality pre-occupancy and achieve the LEED v4.1 Indoor Air Quality credit, the Option 2 (Air Testing) pathway for the credit is recommended. Option 1 (Flush Out) often requires supplemental ventilation and the building to be kept empty for a period that can be difficult to justify. Recent DPP projects have passed air testing by a large margin, and test results can provide reassurance to employees. Air testing should include at least testing of particulate matter and inorganic gases before occupancy. Including testing for volatile organic compounds (VOCs) to achieve more complete test results, and a second point in the credit, is preferred.

Appendix

LEED Credit Strategy Guidance

The following table shows all prerequisites (in green) and credits available in LEED BD+C v4.1 along with general guidance on which credits and points to target in pursuit of LEED Gold certification for large municipal projects. Prioritized credits (in gold) are needed to comply with the LEED Ordinance while Recommended credits are other credits that are likely feasible for most municipal projects.

Credits considered Regional Priority for Philadelphia are also marked with Stars (★). A project can earn one additional point for Regional Priority if the project achieves a point threshold under the original credit (varies by credit). A project may earn up to four Regional Priority credits. These credits have been identified by the USGBC regional councils and chapters as having additional regional importance for the project's region.

See the LEED BD+C v4.1 Manual for details on credit requirements.

Prioritized	Recommended	Regional Priority	Type	Credit Name	Points Available	See Section
21	**44**				**110**	
1			Credit	Integrative Process	**1**	Integrative Process
1	**11**			**Location and Transportation**	**16**	
			Credit	LEED for Neighborhood Development Location	16	
	1		Credit	Sensitive Land Protection	1	
	2	★	Credit	High Priority Site and Equitable Development	2	
	5		Credit	Surrounding Density and Diverse Uses	5	
	3	★	Credit	Access to Quality Transit	5	
			Credit	Bicycle Facilities	1	
			Credit	Reduced Parking Footprint	1	
1			Credit	Electric Vehicles	1	Electric Vehicle (EV) Charging Stations
1	**3**			**Sustainable Sites**	**10**	
			Prereq	Construction Activity Pollution Prevention	Required	
1			Credit	Site Assessment	1	Project Site Assessment
			Credit	Protect or Restore Habitat	2	
	1		Credit	Open Space	1	
		★	Credit	Rainwater Management	3	
	1		Credit	Heat Island Reduction	2	
	1		Credit	Light Pollution Reduction	1	

3	**4**		**Water Efficiency**		**11**	
			Prereq	Outdoor Water Use Reduction	Required	Irrigation Systems
			Prereq	Indoor Water Use Reduction	Required	Water Fixtures and Appliances
			Prereq	Building-Level Water Metering	Required	
1	1		Credit	Outdoor Water Use Reduction	2	Irrigation Systems
2	2	★	Credit	Indoor Water Use Reduction	6	Water Fixtures and Appliances
		★	Credit	Optimize Process Water Use	2	
	1		Credit	Water Metering	1	
13	**7**		**Energy and Atmosphere**		**33**	
			Prereq	Fundamental Commissioning and Verification	Required	Commissioning
			Prereq	Minimum Energy Performance	Required	Energy Modeling
			Prereq	Building-Level Energy Metering	Required	Sub-Metering
			Prereq	Fundamental Refrigerant Management	Required	
2	1		Credit	Enhanced Commissioning	6	Commissioning
10	5		Credit	Optimize Energy Performance	18	Energy Modeling
1			Credit	Advanced Energy Metering	1	Sub-Metering
			Credit	Renewable Energy	5	
			Credit	Enhanced Refrigerant Management	1	
	1		Credit	Grid Harmonization	2	
0	**5**		**Materials and Resources**		**13**	
			Prereq	Storage and Collection of Recyclables	Required	
	3	★	Credit	Building Life-Cycle Impact Reduction	5	
	1		Credit	Environmental Product Declarations	2	
			Credit	Sourcing of Raw Materials	2	
			Credit	Material Ingredients	2	
	1		Credit	Construction and Demolition Waste Management	2	
2	**8**		**Indoor Environmental Quality**		**16**	
			Prereq	Minimum Indoor Air Quality Performance	Required	Ventilation and Pollution Mitigation
			Prereq	Environmental Tobacco Smoke Control	Required	
1	1		Credit	Enhanced Indoor Air Quality Strategies	2	Ventilation and Pollution Mitigation
	3		Credit	Low-Emitting Materials	3	
	1		Credit	Construction Indoor Air Quality Management Plan	1	

1	1		Credit	Indoor Air Quality Assessment	2	Air Quality Testing
			Credit	Thermal Comfort	1	
	2		Credit	Interior Lighting	2	
			Credit	Daylight	3	
			Credit	Quality Views	1	
			Credit	Acoustic Performance	1	
0	**6**		**Innovation**		**6**	
	5		Credit	Innovation	5	
	1		Credit	LEED Accredited Professional	1	