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Technical Report:
Altoona Towers-New Multifamily Housing: Energy Efficiency Through Master Metering

WRU-2014-0013-0004

TECHNICAL REPORT

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ALTOONA TOWERS – NEW MULTIFAMILY HOUSING:

ENERGY EFFICIENCY THROUGH MASTER METERING

PREPARED FOR: PROFESSIONAL PROPERTY MANAGEMENT, INC.

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ENERGY SYSTEMS ENGINEERING

DATE: AUGUST, 2014

Executive Summary

This Technical Report sets forth evidence that a new multifamily housing development that proposes to reduce and control energy consumption through the building energy systems, equipment and appliances results in greater energy efficiency and is more effectively accomplished through a master metering arrangement where the property manager assumes the responsibility for comprehensive energy efficient planning, integrated design, implementation, operation and maintenance with the expenses offset by the energy cost savings available from a master metering arrangement.

Specifically, an Energy Design Assistance process identified and evaluated over 70 energy strategies for the Altoona Towers multifamily housing project consisting of two 4 story buildings with 103 residential apartments. Reduced energy consumption of 37% compared to a *new* energy code compliant baseline building was established using the DOE-2 building energy simulation program to analyze the strategies. The energy savings increases to 40% by including a package of supplemental energy strategies not evaluated by the energy simulation program. The Energy Design Assistance process and building simulation modeling was conducted by The Weidt Group under the Commercial New Construction Program sponsored by MidAmerican Energy.

When supplemental energy savings are factored in, the predicted Site Energy Use Index of 36.6 kBTU/SF per year is exemplary for multifamily housing, representing an energy reduction of over 45% compared to a typical Midwest Region multifamily apartment housing facility. Considering the split incentive barrier inherent in traditional multifamily housing design and construction projects, this level of reduced and controlled energy consumption is effectively accomplished and economically feasible only through a master metering arrangement.

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1. Introduction

This Technical Report documents the energy efficiency projects that Professional Property Management, Inc. proposes to incorporate as part of Altoona Towers; a major new multifamily housing/mixed use building project located in Altoona, Iowa. The property management team expects to continue an aggressive energy management policy for the design and construction of this new project. However, significant economic and practical barriers are encountered as the result of the electrical General Service requirement for individual metering of multi-occupancy premises where units are separately rented pursuant to 199 IAC 20.3(1)b.

The objective of this report is to identify the energy efficiency, practical, technical and economic considerations for an extremely energy efficient multifamily housing project as they apply to electrical metering options; and evaluate where the benefits of reduced and controlled energy consumption are more effectively accomplished through a master metering arrangement.

2. Background

Professional Property Management, Inc. (PPM) manages 53 multifamily housing buildings in the Des Moines metro area totaling almost 1,500 apartment units and also dozens of buildings and hundreds of units in Ames, IA. The Altoona Towers project would be the latest addition to this significant multifamily property holding. The management team at PPM is committed to energy efficiency as evidenced by a recent Energy Efficiency Demonstration project at the Sun Prairie Apartment complex which reduced electric, natural gas and water consumption by 10.1%, 8.5% and 54.2% respectively. PPM is also an Energy Star Partner, utilizing the resources of the Energy Star Multifamily program to support their commitment to energy efficiency.

PPM was founded over 35 years ago by Keith Denner, President. Mr. Denner has a long and distinguished track record of designing and managing energy efficient and cost effective residential rental properties. Throughout his career Mr. Denner's strategy has been to maximize long term investments by building highly efficient properties that result in low maintenance and low utility bills; and then securing financing for them at more attractive rates. Mr. Denner has been documenting energy use and savings on PPM projects for over 30 years. He is passionate about energy efficiency and has received state and national recognition for his innovation and commitment to energy efficiency.

Through the years, his projects have also garnered the support of many local trade allies, developers and bankers, including members of Des Moines Homebuilders' Association, real estate developers, bank presidents, and property appraisers. References and contact information would be made available as required for follow up confirmation of Professional Property Management, Inc and Mr. Denner's business practices.

3. Altoona Towers Project Overview

The Altoona Towers project would be located on Adventureland Drive in Altoona, Iowa and consists of two 4 story buildings with the majority of the building area assigned to multifamily housing. The A Building is proposed with 44 apartment units and would include administrative office space and a community room on the first floor. The total area of Building A would be 55,600 gross square feet. Building B is larger at 74,400 gross square feet and would include 59 apartments on floors one through four. In addition Building B is proposed with a Health Club/Fitness Center and 17 corporate extended stay (monthly lease) apartments on the first floor. The Altoona Towers project would offer 103 residential apartment units plus 17 corporate apartments for a total of 120 apartments and a nominal gross floor area of 130,000 square feet.

The two buildings would be essentially identical in construction, however the B Building would be about 30% larger than the A Building. The general building systems design criteria includes:

- Building Structure: Wood construction with stone veneer, insulated walls and attic floor and foundation systems, casement type insulated glass windows.
- Heating/Cooling System: Individual HVAC systems with local thermostat control, ventilation air and exhaust air for each apartment unit. Commercial space HVAC systems with zone thermostat control, ventilation and exhaust air with heat recovery for high exhaust situations such as the fitness center.
- Domestic Water Heating System: Between 30% and 40% of the total heating requirement for an energy efficient apartment building is committed to heating domestic water. Based on successful past performance a centralized system using a high efficiency gas fired hydronic boiler with integrated domestic water heater and storage tank was preferred.
- Lighting Systems: Combination of fluorescent and LED solid state lighting systems for apartments, corridors, common areas and commercial spaces. Daylighting and occupancy control for selected lighting applications. LED site lighting for parking lots, walkways and building entrance and sidewall security lighting.
- Plumbing Systems: Low flow water closets, showers and sink faucets.
- Major Appliances: Refrigerator, Dishwasher, Clothes Washer/Dryer, Oven/Range and Microwave for each residential apartment unit.

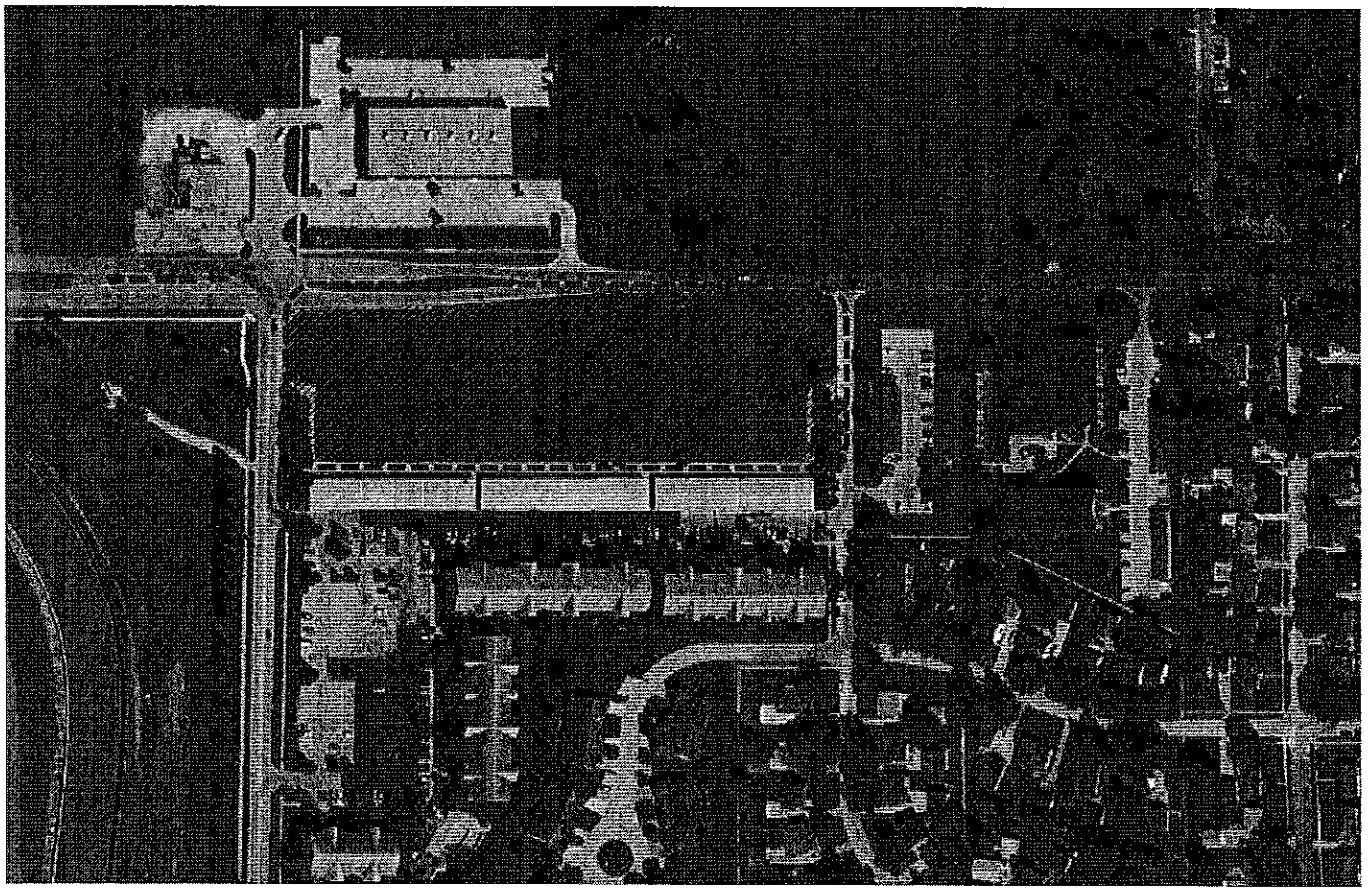
Natural Gas and Electric utility services would be provided by MidAmerican Energy. Under MidAmerican's Gas Metering Facilities requirements a master gas meter delivering gas for a centralized domestic hot water system would be provided. The Gas Metering Facilities requirements allow an exception to the individual meter measurement requirement for multi-occupancy premises for gas used in centralized heating, cooling, or water heating.

The MidAmerican Electric Metering of Service requirements stipulate that electricity delivered to multi-occupancy premises be measured on the basis of individual meter measurement for each

unit. An exception is allowed where individual metering is impractical. This Technical Report documents that reduced and controlled energy consumption benefits are more effectively accomplished through a master meter arrangement in support a waiver request for MidAmerican Energy to allow master metering for this project.

Water and sewer services for the project would be provided by the City of Altoona through a master water meter for each building.

Figure 3.1 Site Map



4. Energy Systems Design Approach

The goal of PPM management is to make the Altoona Towers project as energy efficient as possible, while remaining practical, cost effective and make business sense for the property owner. Successful energy efficiency measures from previous PPM multifamily housing projects would be incorporated on this project. Efficiency technologies showcased as part of the recent Energy and Water Efficiency Demonstration Project at the Sun Prairie Apartment Complex and determined to be cost effective would be considered favorably for this project. In addition, new technologies capable of further enhancing the energy efficiency of this project would be evaluated. The desired end result would be to provide an attractive, high performance housing package which provides energy efficiency as well as water efficiency; a healthy environment; security; and high level communications and internet support for all apartment residents.

To effectively organize and evaluate the various energy efficiency options, the project design team participated in the Commercial New Construction (CNC) Program available through MidAmerican Energy. Under this program the Property Management and Maintenance representatives; Project Design and Construction Team; MidAmerican Energy and The Weidt Group worked together on the energy efficiency aspects of the proposed buildings. The CNC Program provides energy design assistance through a customized whole building energy model that simulates the operation and energy use for the proposed project. The simulation model demonstrates which energy efficiency strategies have the most significant impact and are cost effective. The energy design assistance for the program was provided by The Weidt Group under contract to MidAmerican Energy. Their assistance in providing data for this report is gratefully acknowledged.

The building simulation program used for the energy analysis was the DOE-2 energy model. The DOE-2 building simulation program performs hour by hour thermal and luminous calculations on the subject building using Des Moines, IA DOE-2.2 Typical Meteorological Year (TMY) weather file. The energy model is used for comparative analysis of the building envelope, mechanical HVAC, lighting and control systems. The model is customized for the building layout, engineered systems, operational characteristics, usage patterns, average weather conditions and utility rate information. The DOE-2 program is considered the benchmark standard energy simulation program for the building industry. The results of the building simulation energy analysis were presented to the project team and documented in a series of reports and meeting memorandum. The energy data contained in this report was derived directly from the DOE-2 energy model results as presented to the project design and construction team in the CNC Program reports.

A baseline model establishes a benchmark for comparison of alternatives. The baseline model provides a reference point for compliance based on the prevailing energy code and recognized energy efficiency standards that apply to the project. These would include current versions of

ASHRAE 90.1 Energy Standards for Buildings, the State Energy Code/International Energy Conservation Code and the National Appliance Energy Conservation Act (NAECA).

As the basic building systems design evolved, the project team focused on energy strategies that were practical, cost effective and consistent with the design goals. As the various energy efficiency strategies were developed for the project, they were analyzed for energy savings and interaction effects through the building energy simulation model. Strategies were refined with updated energy performance and construction cost data as information on systems, equipment and installation became more precise. It should be noted that the information and data contained in the Energy Design Assistance Reports and in this Technical Report reflect the preliminary planning phases of the project and is subject to change as the final design and construction phases proceed.

The Commercial New Construction evaluation of energy efficiency strategies was limited to the strategies included in the CNC program analysis. This exclusion eliminated several strategies such as night setback thermostats and exterior/site lighting from the building simulation energy analysis. Several supplemental energy strategies were identified and evaluated independently from the building simulation energy model.

An overview of the Commercial New Construction/Energy Design Assistance Program is included in Appendix Section 1.1.A: CNC Energy Design Assistance Introductory Materials. A detailed description of the Energy Analysis Process including the DOE-2.2 building simulation program and Baseline Energy Model is presented in Appendix Section 1.1.B: CNC Strategy Report.

5. Energy Efficiency Strategies Description

The first group of energy efficiency strategies improve the building general service areas beyond the baseline level and are expected to be incorporated in the final design. These include:

- An exterior wall assembly with various materials, configurations and wall finishes add architectural interest to the building and increase the importance of wall thermal performance. Thermal and moisture integrity for the building envelope is maintained by a innovative wall sheathing system with integrated moisture and air barrier (trade name 'ZIP System Sheathing').
- An open cell spray foam insulation system fills the 2x6 wood framed wall cavity resulting in a wall assembly thermal resistance approaching R-20. The spray foam insulation system effectively seals any wall openings, essentially eliminating infiltration and air migration through the wall and increasing the effectiveness of the insulation R-Value.
- High performance vinyl casement windows with low-e insulating glass and exceeding Energy Star requirements with a U-Factor of 0.27; Solar Heat Gain Coefficient (SHGC) of 0.25 and 0.44 visible transmittance. Casement type windows with latch compression seals have the lowest operational leakage ratings of operable window types. The outward swing casement windows also increase natural ventilation and are easy to monitor externally for problems or inappropriate operation.
- Design sliding glass doors with low-e insulating glass exceeding Energy Star requirements with a U-Factor of 0.28; SHGC of 0.32 and 0.59 visible transmittance.
- The integrated wall sheathing system, spray foam insulation system, low air leakage windows and sliding glass doors and quilted window shades contribute to tightly sealed building envelope with extremely low air infiltration.
- Stepped daylighting control of lights in stairwell landings and occupancy control of lights in offices, public spaces, restrooms, laundry rooms, storage areas, fitness areas and other common use areas.
- High performance linear fluorescent and LED lighting to provide low lighting power densities for public spaces.
- High Efficiency air source heat pumps serving the community room, fitness center and other common areas with a 16 SEER and 9 HSPF rating.
- Total heat recovery ventilation system providing fresh air and exhaust air for the fitness center operating at 65% sensible and 65% latent effectiveness.
- Domestic water heating with a centralized, condensing high efficiency boiler coupled with an indirect heat exchanger/storage tank system. The system operates at 92 to 94% efficiency.
- Low water flow showerheads and low flow aerators on kitchen and bathroom sink faucets reduce water heating energy and save water.
- Building elevators with energy efficient regenerative drive systems reduce energy consumption.

Strategies to reduce energy consumption for the residential apartment units are considered as a second group and include the following additional strategies:

- Attic blown-in insulation system provides an R-50 insulation value over residential apartment unit ceiling areas in contrast to the R-37 energy code requirement.
- Apartment lighting using linear and compact fluorescent lamps as well as LED solid state lighting to achieve a low lighting power density of 0.43 watts per square foot; about 70% less than typical residential lighting power densities.
- High efficiency, inverter driven, variable capacity, ducted mini-split air source heat pump systems provide heating and cooling for the residential apartments at an HSPF of greater than 11 and SEER of 20 at part load conditions. Performance ratings are over 40% better for cooling and 26% for heating. Heat pumps also have a fan energy rating of 0.17 brake horsepower per 1000 CFM capacity – 45% less fan operating energy than standard fan systems.
- Energy Star qualified low energy bathroom exhaust fan with occupancy sensor control and integrated LED lighting. These fans would be six times more efficient than a standard fan.
- A full complement of Energy Star appliances for each residential apartment: Refrigerators rated 20% better than NAECA; Clothes washers with a 2.4 MEF; and Dishwashers rated at 275 kWH/yr or 22% over NAECA.
- Energy Star rated ceiling fan and light assemblies for the residential apartment units.

Two specialized energy strategies as applied to the residential apartment units were considered separately:

- An alternate insulation strategy evaluated a high density, closed cell, wall insulation system increasing the insulation value to R-25 or R-30.
- A sensor system interlocked with each apartment sliding glass door to deactivate the apartment heating and cooling system when the door was left open.

The proposed energy efficiency strategies were grouped or packaged into bundles for final energy modeling and evaluation. The final bundle energy modeling results included the baseline reference and three bundles of energy efficiency strategies:

- Baseline: Defines the building energy system criteria that conforms to current versions of the State of Iowa Energy Code; ASHRAE Energy Standard 90.1 and National Appliance Energy Conservation Act. Provides an energy consumption reference point that is compliant with building energy codes and meets federal standards for energy efficiency of appliances and manufactured products.

- Bundle 1: Describes the building energy system strategies that increase energy efficiency for the general service areas; including: administrative office space, community room, fitness center, corridors and common areas and other centralized services such as common laundry

equipment and domestic hot water circulation. In general, these energy loads would be on the general service or 'house' meter and not part of the energy metered to individual apartment units. The utility bill energy costs would be paid by the property manager, and any energy cost saving resulting from implementation of these strategies is recovered to offset the increased first cost of the energy efficiency strategies.

- Bundle 2: Describes the energy efficiency strategies that reduce and control energy consumption for the 103 individual residential apartment units that are rented separately. The energy model segregates the energy use for the residential apartments, applies individual tenant electric meters and excludes that energy from the general service house meter. Under this scenario, the increased first cost of the energy efficiency strategies would be paid by the property manager. With a master metering arrangement the property manager would be able to offset the increased first costs by energy cost savings. With individual tenant meters the tenant would benefit directly from related energy cost savings and the incentive for the property manager to invest in energy efficiency disappears.

- Bundle 3: Includes the two specialized building energy system strategies that provide increased opportunity for energy savings, but with questionable practical and economic feasibility. The alternate insulation strategy significantly increased construction first costs. and resulted in a simple payback of over 60 years. The second Bundle 3 strategy evaluated a sensor system interlocked with each apartment sliding glass door to deactivate the apartment heating and cooling system when the door was left open. This strategy also had a very high construction cost and a simple payback approaching 200 years. It was not further considered upon determining that a deactivated heating system with the sliding glass door open may result in below freezing conditions in the effected apartment.

In addition to the strategies described under Bundles 1, 2, and 3 above, several Supplemental energy and water efficiency strategies were identified for implementation on the project:

- Retractable insulating quilted window coverings for all residential apartment unit windows and sliding glass doors reduce infiltration and glass transmission energy losses. This strategy has demonstrated its effectiveness on other PPM managed residential rental properties. While the tenant has a choice on using the window coverings, they are the primary means of providing privacy and therefore are generally open during normal days and pulled down at night, thus significantly reducing nighttime heat loss/heat gain. They also effectively provide solar control, keeping apartments cooler during the summer. Field observations at other PPM properties note that the window covering quilts are down approximately 85% of the time. This strategy was not eligible for MidAmerican efficiency incentives and therefore not included Bundle analysis energy saving totals.

- Reduced building infiltration and air migration resulting from continuous spray foam insulation systems; air and moisture barriers placed in ceilings and walls; extensive caulking and sealing of building joints and wall/ceiling penetrations; and slightly positive building pressurization from outside ventilation air inlets. These measures all serve to tightly seal the individual apartments and substantially reduce outside air leakage. Field testing of each residential apartment with blower door infiltration measuring equipment was required for this strategy to qualify for efficiency incentives. Since the substantial expense of the field testing would render the strategy as not cost effective, it was resolved that the strategy would be implemented without the active field testing and without the incentive.
- Upgrading to an Energy Star Qualified Bathroom Exhaust Fan 4 watt nightlight with a 0.8 watt LED nightlight. Perhaps not significant for a single fan, but considering the load factor of 120 apartment units and nightlight operating hours, the small improvement still accumulates energy savings.
- Ventless clothes dryers for each residential apartment unit condense the moisture in the airstream exiting the dryer, discharging the moisture into the washer standpipe and recirculating the air to the space. For a traditional clothes dryer, between 3,000 to 9,000 cubic feet of room air may be used and exhausted to the outside for each load of clothes dried. The ventless dryer avoids exhausting the dryer vent to outside, eliminates the infiltration/makeup air requirement and the need for heating and cooling that makeup air. While clothes dryers are not yet Energy Star rated, Energy Star has developed a scoping report to assess energy use and savings potential in clothes drying technologies to prioritize future development work.
- Range with Convection Oven capability which evenly circulates heated air around the food, allowing lower oven temperatures and a 30% reduction in cooking time. This translates to about a 20 to 30% reduction in cooking energy for a convection oven. At this time Ranges and Ovens are not Energy Star rated.
- High efficiency LED Solid State exterior/site lighting is proposed for all facility walkways, parking lots, building security and canopy lighting. The proposed exterior lighting includes ambient light sensor photocells and motion detectors to further minimize lighting energy. In addition to improving lighting efficiency, the LED Solid State lighting system substantially improves lighting quality over traditional high pressure sodium and metal halide exterior lighting systems. A separate energy evaluation of exterior/site lighting was required due to the exclusion of exterior lighting from the CNC program.
- Water Efficiency strategies including Low Flow Toilets operating at 0.8 gallons per flush; Shower heads at 1.5 gallons per minute flow; and low flow aerators for kitchen and bathroom faucets.

These supplemental strategies further reduce energy consumption. The first five supplemental strategies impact the individual apartment units and have been evaluated independently from the building simulation program. The energy savings and costs for those five strategies have been

combined and shown as a separate line item in the energy results section as described later in this report. The energy savings associated with the exterior/site lighting is not considered building energy by industry definitions and not eligible under the CNC program. For those reasons it is not included as part of the building simulation program results.

A comprehensive description of the energy efficient strategies, related performance and operating characteristics, baseline references and energy savings potential is presented in Report Appendix Section 1.1.B: CNC Strategy Report. Preliminary Building Plan sets showing the Building, HVAC, Plumbing, Electrical and Lighting systems and details are included in Appendix Section 2.1: Altoona Towers Building Plan Sets. Detailed Technical Information on the building systems, equipment and appliances proposed for the project is compiled by building system category in Appendix Section 2.2: Energy Systems and Equipment Technical Information.

6. Building Energy Simulation Model Results

The DOE 2.2 building energy simulation model used through the CNC Energy Design Assistance Program provides sophisticated predictions of energy use and energy savings for buildings that have not been built. The baseline model establishes a reference point against a new energy code compliant building. The three Bundles of energy strategies are compared to the Baseline to determine energy reduction. The Supplemental energy strategies were evaluated independently and combined with Bundle 2 as a separate package. Results of the building energy simulation for total combined site energy are shown in Figure 6.1 as measured in MMBTU (million BTU).

Figure 6.1 Total Annual Site Energy – All Sources

Energy Strategy	Total Site Energy BTU x 10^6	Energy Savings to Baseline BTU x 10^6	% Energy Reduction to Baseline	Site Energy Use Index kBTU/SF
Baseline	7,914	---	---	60.5
Bundle 1	6,932	981	12%	53.0
Bundle 2	4,967	2,946	37%	38.0
Bundle 3	4,876	3,037	38%	37.3
Bundle 2 w/ Supplemental	4,788	3,126	40%	36.6

Implementing all of the Bundle 1 energy strategies that impact the general service or house meter result in a 12% energy reduction compared to the Baseline reference. When the Bundle 2 strategies which incorporate all of the energy strategies for the individual residential apartments are included, the energy use reduction becomes 37% against Baseline energy use. Combining Bundle 2 energy strategies with the Supplemental energy strategies results in a 40% reduction in energy use compared to the Baseline – a significant energy reduction for implementing the individual apartment rental units energy strategies.

The Site Energy Use Index measured in kBTU/SF (thousands BTUs per square foot gross building area) is a useful benchmark for evaluating energy use intensity when comparing the energy efficiency of similar buildings. The baseline building is modeled to be compliant with current building energy codes and operating with equipment, fixtures and appliances meeting federal energy standards for manufactured devices for a new building. Comparing the baseline Site Energy Use Index of 60.5 kBTU/SF to the 38.0 kBTU/SF for Bundle 2 combined general service/tenant energy strategies represents a substantial reduction of 37% or 22.5 kBTU/SF per year. When the Supplemental energy strategies are included the Site Energy Use Index drops to 36.6 kBTU/SF – or 40% less energy use.

The average Site Energy Consumption for a Midwest region multifamily apartment in 5 or more unit buildings is 66.0 kBTU per square foot (reference 2009 Residential Energy Consumption Survey, U.S. Energy Information Administration). Energy Bundle 1 at 53.0 kBTU/SF represents a

20% reduction from the Midwest region average; Bundle 2 represents a reduction of over 42%; and Bundle 2 with Supplemental energy strategies results in a 45% reduction in energy use from the Midwest region multifamily average. This metric represents a substantial energy reduction against the average energy performance of comparable multifamily housing facilities in the region.

Natural gas energy accounts for less than 20% of the total annual site energy, the remainder being electrical energy. Figure 6.2 shows the natural gas energy use predicted by the energy model as measured in Therms (100,000 BTUs).

Figure 6.2 Annual Natural Gas Energy

Energy Strategy	Natural Gas Use Therms	Natural Gas Savings Therms	% Nat Gas Reduction to Baseline	% Centralized Domestic Water Heating
Baseline	15,771	---	---	100%
Bundle 1	9,438	6,333	40%	100%
Bundle 2	7,812	7,959	50%	100%
Bundle 3	7,812	7,959	50%	100%

Natural gas energy is used only by the centralized service water heating system to provide domestic hot water for the individual residence apartments, common rest rooms, Community Room and fitness center. The natural gas energy reduction of 40% from Baseline to Bundle 1 represents the energy effect of centralized service water heating using a condensing hydronic boiler and indirect heat exchanger/storage tank system operating at 92 to 94% efficiency along with low flow shower heads and sink faucets. The energy reduction of 50% for Bundle 2 adds the impact of Energy Star clothes washers and dish washers in the individual residence apartment units. The Supplemental strategies do not involve the centralized water heating system or natural gas energy use.

Due to the application of electric heat pumps for space heating and cooling, electric energy use accounts for over 80% of the total annual site energy. Results of the building energy simulation model for electric energy and demand are shown in Figure 6.3.

Figure 6.3 Annual Electric Energy and Demand

Energy Strategy	Total Electric kWH	Electric Savings kWH	% Electric Reduction to Baseline	Electric Demand kW	Demand Savings kW	% Demand Reduction to Baseline
Baseline	1,857,162	---	---	398	---	---
Bundle 1	1,755,085	102,077	5%	375	23	6%
Bundle 2	1,226,960	630,202	34%	267	131	33%
Bundle 3	1,200,249	656,913	35%	265	133	33%
Bundle 2 w/ Supplemental	1,173,324	683,838	38%	264	132	34%

On the electric side, Bundle 1 energy strategies produce an electrical energy savings of over 5% and a demand savings of 6% compared to Baseline energy use. A 34% energy reduction and 33% demand reduction occurs when Bundle 2 is included. Adding the Supplemental strategies increases the total annual electrical savings to just under 684 MWH or a reduction of 38% from baseline. This energy savings demonstrates the major impact of energy strategies applied to the individual apartment units when compared to the general/house savings. The electrical demand reduction of 132 kW – of which 109 kW is attributed to the residential apartments – is credited to the very high efficiency mini-split heat pump air conditioning units serving the apartments. The demand reduction is would be expected to occur late afternoon through early evening, consistent with utility peaks and with field measured demand recording conducted on other PPM apartment buildings.

The individual residential apartment energy use is established separately from the general service or house electric use by the building simulation model. Figure 6.4 indicates the electric energy breakdown between the general service/house electric use and the combined total electric use for the individual residential apartments. The significant majority – approximately 80-85% – of the total electric energy in kWH goes to the individual tenant meters with the remaining 15% consumed through the general/house electric meter.

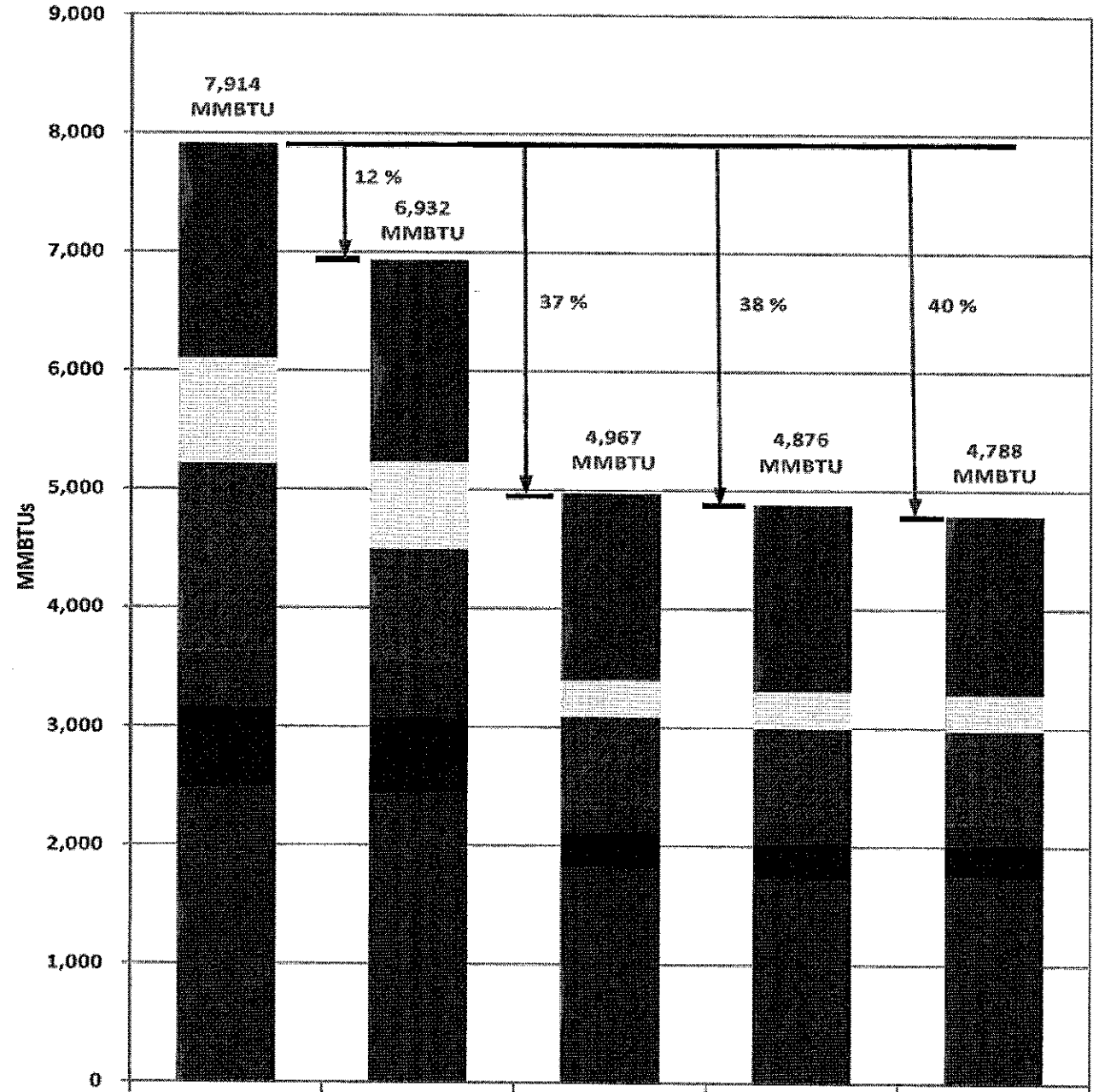
Figure 6.4 Electric Energy Breakdown – General/House to Residential/Apartment

Energy Strategy	Gen/House Electric kWH	Gen/House Electric Savings kWH	% Gen/House Reduction to Baseline	Residential Electric kWH	Residential Elec Savings kWH	% Residential Reduction to Baseline
Baseline	304,575	---	---	1,552,587	---	---
Bundle 1	238,692	65,883	22%	1,516,393	36,194	2%
Bundle 2	226,988	77,587	25%	999,972	552,615	36%
Bundle 3	220,846	83,729	27%	979,403	573,184	37%

Considering the residential/apartment only electric energy savings of over 552 MWH and 36% reduction to Baseline comparison for Bundle 2; Figure 6.4 clearly indicates the significant energy reduction potential of the energy strategies applied to the individual residential apartments. The extremely high efficiency heat pumps, fluorescent/LED lighting systems and Energy Star appliances assigned to the apartments are the primary contributors to the significant energy reduction.

The building simulation model determines the energy use of individual component energy loads to arrive at the total energy use described above. The individual end use components include: Heating, Cooling, Fan/Pump, Service/Domestic Water Heating, Lights and Equipment . The Equipment load category includes all major and minor appliances, consumer electronics, computers, building elevator, fire alarm and security systems along with all electrical outlet or plug loads down to cell phone chargers. Figure 6.5 shows the Annual Energy Consumption by End Use categories.

Figure 6.5 Annual Energy Consumption by End Use



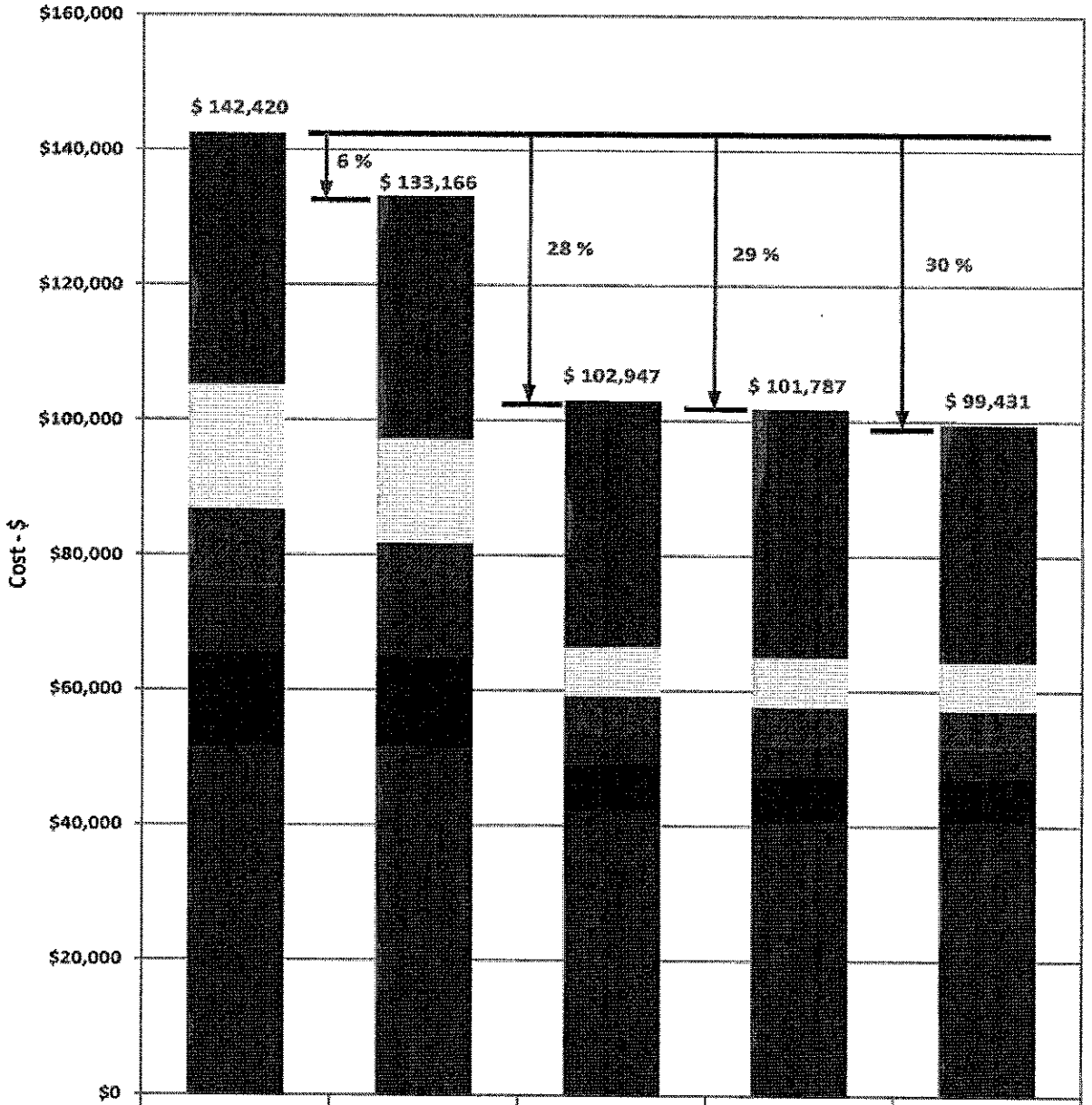
	Baseline	Bundle 1	Bundle 2	Bundle 3	Bundle 2 + Supplemental
Equip	1,804	1,700	1,569	1,569	1,503
Lights	889	732	314	314	308
SWH	1,582	941	785	785	785
Fan/Pump	471	484	196	196	187
Cool	680	628	288	288	262
Heat	2,484	2,445	1,817	1,726	1,744

The greatest energy savings by percent for Bundle 1 end use are Service Water Heating (SWH) and Lights/Lighting Control. For Bundle 2 (and Bundle 2 with Supplemental) all end use categories have significant reductions with the highest energy reduction by Lights, followed by Cooling, Fan/Pump, Service Water Heating, Heating and Equipment loads; in order of percent reduction to Baseline End Use.

7. Energy Economics

The building simulation model assigns the annual energy cost of individual component energy loads with the results shown in Figure 7.1. Savings are shown in almost all categories with the largest reduction in Lights, followed closely by Heating, Cooling, and Fan/Pump energy. The reduction in energy cost for implementing the Bundle 2 apartment strategies is almost $40,000 per year. Energy Cost Savings are influenced by electric rate schedules – for the individually metered Residential rate schedules, less electric energy is used but the unit cost of energy is higher.

Figure 7.1 Annual Energy Cost by End Use



	Baseline	Bundle 1	Bundle 2	Bundle 3	Bundle 2 + Supplemental
Equip	$37,252	$35,952	$36,424	$36,790	$35,053
Lights	$18,376	$15,401	$7,298	$7,371	$7,180
SWH	$11,355	$6,795	$5,625	$5,625	$5,625
Fan/Pump	$9,828	$10,089	$4,609	$4,637	$4,420
Cool	$14,124	$13,372	$6,801	$6,818	$6,481
Heat	$51,485	$51,557	$42,191	$40,545	$40,672

Implementing the various energy strategies increases project construction costs. To help offset additional construction costs MidAmerican Energy offers cash incentives for building owners to invest in energy efficiency under the Commercial New Construction program. The incremental construction cost is recovered by the potential reduction in annual energy costs. From a business perspective, the investment in energy efficiency is returned through reduced monthly energy expenses. A basic energy economics metric is simple payback, or the period of time required to recover the initial investment. Figure 7.2 provides a summary of additional construction costs, energy cost savings and simple payback for each of the Bundles compared to the Baseline.

Figure 7.2 Energy Economics Summary

Energy Strategy	Incremental Construction Cost	Estimated MidAmerican Incentive	Adjusted Incremental Cost	Annual Energy Cost Savings	Simple Payback Tenant Meter	Simple Payback Master Meter
Bundle 1	$64,851	$10,766	$54,085	$9,254	5.8 yrs	5.8 yrs
Bundle 2	$356,901	$103,815	$253,086	$39,473	No Payback	6.4 yrs
Bundle 3	$480,653	$110,892	$369,761	$40,633	No Payback	9.1 yrs
Bundle 2 w/ Supplemental	$407,901	$103,815	$304,086	$42,991	No Payback	7.1 yrs

Bundle 1 representing the energy efficiency strategies under the common building areas represents a modest increase in first costs with a reasonable payback. The Bundle 2 energy efficiency strategies as applied to the tenant residential areas have significant additional first cost and provide a larger utility incentive. The Bundle 2 with Supplemental energy strategies adds a small amount to the incremental cost and does not increase the incentive over Bundle 2. For Bundle 2; Bundle 3 and Bundle 2 with Supplemental there is no payback on the energy investment for the property owner under individual tenant metering and an attractive payback with master metering. The Bundle 3 strategies were rejected due to excessive first cost/payback and technical/operational feasibility as previously described.

It should be noted that the annual energy cost savings amount is calculated based on the summation of individual tenant meter energy savings applying MidAmerican Energy Rate Schedule RHS (Residential Apartment with Electric Space Heating). Under a master meter arrangement the Large General Service Rate Schedule would apply, resulting in about $31,000 annual cost savings with a 8 year payback on Bundle 2.

The annual energy cost savings of 6% for Bundle 1 is modest compared to the 30% cost savings for incorporating Bundle 1, Bundle 2 and the Supplemental strategies. With a 30% energy cost reduction for Bundle 2 with Supplemental, improving energy efficiency in residential apartments becomes an excellent energy investment opportunity under master metering.

While a lower unit cost for electricity would be available under a master metering arrangement, electrical demand charges would apply. The largest cost savings with master metering would be eliminating the $9.14 Fixed Monthly Charge for each tenant meter. Eliminating the fixed monthly charge for 103 apartments translates to a cost savings of over $11,000 per year. This fixed charge is constant and cannot be translated into energy cost savings.

8. Energy Star Program Participation

PPM has joined Energy Star as a Partner, making a commitment to protect the environment through the continuous improvement of their energy performance and utilizing the resources of the various Energy Star programs.

The Energy Star Portfolio Manager tool has been used by PPM to document electric, natural gas and water utility data to assist with evaluation of energy use and cost for other selected rental properties. PPM anticipates that the electric, natural gas and water utilities and related energy/facility management aspects for the Altoona Towers project would be tracked on the updated Energy Star Portfolio Manager tool for Multifamily Housing. These energy use records would also be made available to other interested parties for energy review and evaluation purposes.

The Altoona Towers project would be eligible for the EPA Energy Star Multifamily New Construction Program under the Multifamily High Rise category. To earn the Energy Star in that category the building must fulfill Energy Star Prerequisites in 9 building energy system categories, meet Performance Target requirements and be verified and field tested in accordance with Energy Star protocols. The proposed Altoona Towers building design meets or exceeds the prerequisites in all 9 building energy system categories as applicable. The Energy Star Performance Target is 15% energy cost savings over ASHRAE 90.1 Energy Standard baseline. That baseline is similar to the baseline model developed under the CNC Energy Design Assistance program. The implementation of the energy strategies under Bundle 1 and 2 result in an energy cost savings of 30%, or double the Energy Star Performance Target minimum level. The extensive administrative and documentation requirements are being evaluated by PPM before proceeding with Energy Star application paperwork.

The Energy Star Portfolio Manager Target Finder tool was considered to set energy targets and establish an Energy Star score for the Altoona Towers project. The Target Finder tool benchmarks predicted energy performance of the proposed building against a database of comparable buildings to determine a rating score indicating relative energy performance. Unfortunately, the Target Finder database does not allow for multifamily housing buildings to generate an Energy Star score at this time.

9. Management, Operation and Maintenance Aspects

The long term sustainability of energy efficient strategies is closely tied to effective management and ongoing operation and maintenance of the facility. Professional Property Management has a 25 year history in managing energy efficient multifamily housing projects and understands the operation and maintenance commitment necessary for energy efficiency to succeed. The Maintenance Manager for PPM properties provided valuable input on energy strategies and related maintenance as a member of the CNC Energy Design Project Team planning sessions.

Examples of Management, Operation and Maintenance procedures that would be adopted by PPM to ensure continuing energy efficiency under a master metering arrangement include:

- Provide replacement high efficiency fluorescent, CFL or LED lamps for tenants without charge for the duration of their rental agreement. This would apply to the tenants' personal light fixtures as well as the permanent apartment light fixtures. Compared to the cost and inconvenience of purchasing a standard lamp on their own, the tenant has a strong incentive to continue using the high efficiency light source. Since PPM would be responsible for electric costs under master metering and is able to bulk purchase quality lamps at a reduced cost, it is in their best interest to control energy consumption utilizing high efficiency lamps.
- Provide permanent building and apartment light fixtures designed with pin type lamp bases to prevent lamp replacement with standard lamps. This works with the above item to control energy consumption.
- Replace the standard incandescent lamps provided with refrigerators and microwave ovens with low wattage LED lamps.
- Inspect HVAC equipment and change the heating/cooling equipment air filters at routine intervals to maintain unit efficiency. Dirty, clogged air filters can result in an energy and performance penalty of up to 15%. Tenants are not likely to meticulously inspect and change air filters. Routine air filter replacement by facility maintenance serves to maintain the ultra-high efficiency of the heating/cooling units and extend the life of the equipment.
- Monitor the construction phase with a dedicated construction inspector whose particular emphasis would be window installation, building insulation systems, sheathing, air infiltration control, and other building envelope energy strategies. The on-site construction reviews would help ensure proper installation techniques further supporting the long term energy performance and sustainability of the project.
- Maintain records of energy use to track energy performance, monitor energy use patterns, identify variations and assist in diagnosing shortcomings in energy performance. Various tools including Energy Star Portfolio Manager could be used to benchmark energy performance.

An energy and environmental awareness program would be included with the management operational strategy for the apartment complex. The objective would be to inform and educate the tenant population on the importance of energy efficiency and the impact on global warming, reducing CO_2 emissions and related environmental issues. The exemplary energy efficiency and environmental design aspects of the apartment complex would call attention to the topic for prospective tenants. The CFL/LED replacement lamp program for tenants would serve as a focal point to educate tenants on their role in energy efficiency and the environment. The benefits of Energy Star televisions, audio/video systems, computers, printers and other personal electronic items would be promoted using Energy Star Partner materials and other publications to inform tenants considering the purchase of these items. Energy efficiency tips concerning proper operation of lighting, heating, air conditioning and ventilation systems, clothes washers and dryers, etc. would be publicized to make tenants aware of their personal contribution to control energy use and support the environment.

A detailed evaluation of another PPM property identified two major secondary considerations relating to the energy and water efficiency benefits. The high efficiency lighting, heating/cooling equipment and Energy Star appliances are generally more durable, higher quality and include more features than standard builder grade equipment and appliances. As a result the energy efficiency strategies provide for longer equipment life and reduced operation and maintenance costs.

PPM has extensive past experience in monitoring and managing the master metered natural gas and water service utility expenses for multifamily housing projects. The process includes closely monitoring master metered utilities, equitably assessing and pro-rating those expenses into the rental cost basis for individual apartment types. That process would also be applied to the master metered electric utility expenses for this project. PPM's commitment to energy efficiency coupled with diligence in monitoring and managing energy expenditures allows PPM to guarantee in writing tenant utility bills to not average over $30 for a one bedroom, $35 for a two bedroom; and $45 for a three bedroom apartment at Sun Prairie Apartment Complex, West Des Moines, IA.

The final step in the CNC Energy Design Assistance program is verification, which includes: a review of final construction documents, plans and specifications; and on-site physical verification of energy efficient strategies implemented. Specifics on this step are detailed in Appendix Section 1.1.D CNC Bundle Requirements Document. This step would be completed for the Altoona Towers project prior to occupancy.

10. Practicality of Master Metering for Altoona Towers Apartments

The MidAmerican Electric Metering of Service requirements stipulate that electricity delivered to multi-occupancy premises be measured on the basis of individual meter measurement for each unit. This requirement is derived from 199 IAC 20.3(1)b.(4). Exceptions are allowed where individual metering is impractical. As described by the electrical service requirements, a specific definition of impractical means: where the benefits of individual metering (reduced and controlled energy consumption) are more effectively accomplished through a master meter arrangement.

This report substantiates a case that reduced and controlled energy consumption by the building systems, equipment and occupants is more effectively accomplished through a master metering arrangement where the property manager assumes the responsibility for comprehensive energy efficiency planning, integrated systems design, implementation, operation, maintenance and management operations with the expenses offset by the energy cost savings available from a master metering arrangement.

Residential rental property managers are reluctant to invest in energy efficiency improvements when the tenant directly receives the energy savings benefit by paying the energy bill under tenant metering requirements. Tenants do not make energy efficiency investments in property they do not own. Serious reduction of energy use and cost requires a significant investment in energy efficiency measures on the tenant side of the electric utility meter. This dynamic is commonly referred to as the "split incentive" barrier to energy efficiency. Report Section 7 – Energy Economics; Figure 7.2 puts hard numbers to the attractive energy investment situation for the Altoona Towers project. Reduced and controlled energy consumption is effectively accomplished by implementation of the Bundle 2 and supplemental energy efficiency strategies with master metering. With an individual tenant metering arrangement the 'No Payback' designation eliminates the economic incentive for the property owner to invest in energy efficiency. The potential for reduced and controlled energy consumption at an effective level of 40% less than a new, current energy code compliant baseline building is diminished or lost.

It appears the intended benefit of individual tenant metering is reduced and controlled energy consumption – presumably implemented by a tenant with a desire to save energy. Opportunities for a tenant in a new residential apartment to seriously reduce and control energy consumption are limited on a practical basis. They may include: adjusting thermostat settings; turning off lights; replacing lamps with CFL or LED type lamps; sealing and draft stopping doors and windows; closing drapes at night; purchasing computers, TVs and other consumer electronics with an Energy Star label; reducing hot water usage for showers and clothes washing; and with other behavior modification strategies. The *Energy Efficiency Rating System for Rental Properties* prepared by Alliant Energy provides a numerical rating system for prospective tenants. The Altoona Towers project would score the maximum points in all applicable categories on that rating system. A review of the Energy Star *Top 10 Tips for Renters* and the *Energy Savings Tips for*

Renters produced by the Wisconsin Focus on Energy program provide an appropriate perspective on the energy reduction possibilities under the control of the tenants. While those lists have many good suggestions, many of the items are precluded by the energy efficiency strategies proposed for the PPM Altoona Towers project; and it is improbable that they would equate to a 40% reduction in energy. For details refer to Appendix Section 3.D – Energy Saving Tips for Apartments.

The current emphasis on building energy systems shifts the paradigm to energy efficiency, integrated design, occupant comfort and high performance "green" buildings. Almost all of the current energy using residential equipment such as heating and air conditioning units, refrigerators, clothes washers, lighting systems, water heating, etc., consume 25% to 75% less energy than their predecessors of several years ago. A high performance building envelope, systematic application of high efficiency equipment combined with effective control results in the 40% energy reduction predicted by the DOE-2 building energy simulation program. The impact of that reduction overwhelms the potential for tenants to reduce and control energy consumption on an individual basis. It is highly unlikely that the intense combined energy conserving efforts of all 200+ individual tenants in the apartment complex would be able to generate the equivalent 40% reduction in total energy consumption.

Consider major appliances as an example. Under a master meter arrangement the Energy Star rated refrigerator, dishwasher and clothes washer proposed for the Altoona Towers apartment units will produce a total energy savings of 312 million BTU per year (electric and gas for the central domestic water heater; not including water savings) or about $3,461 based on the data presented in the CNC Energy Analysis Bundle Report. With an individual tenant electrical metering arrangement and standard efficiency appliances, it would be impractical for the individual tenants to make up the 312 million BTU / $3,461 per year difference by controlling the appliance energy consumption. In this case the tenant has discretionary control only over the use of the appliance, not the efficiency of the appliance. Energy efficient appliances are passive – little if any tenant input is required to reduce or control energy consumption. The tenant's options to reduce and control energy consumption for a standard efficiency major appliance are limited. In general, the tenants use those appliances for their intended purpose with discretionary control dependent on the individual tenant's energy awareness and personal level of commitment – the tenant who is aware and committed most likely continues those habits independent of the specific efficiency of the appliance. The tenant has very little economic incentive to purchase a new energy efficient refrigerator or other appliance for a rental residence. In contrast, the property manager may have a purchasing advantage with a large quantity of premium appliances helping to reduce first cost; as is the case for PPM. As a practical matter, reduced and controlled energy consumption is more effectively accomplished with high efficiency appliances served through a master meter arrangement. The long term energy and environmental benefits over the life of the appliance favors master metering with energy efficient appliances.

The heating/cooling systems for the apartments are another example. The energy related cost of heating/cooling is slightly over 50% of the apartments annual energy cost based on the Altoona Towers project energy model. The heating/cooling energy is significantly reduced due to the high energy performance of the walls, windows, quilted shades and attic insulation building envelope components used on the project. The mini-split, air source heat pump system proposed is a relatively new energy efficient technology offering serious heating and cooling energy savings for residential type applications. A research project at the National Renewable Energy Lab (NREL) documents the efficiency of the mini-split heat pumps (NREL Research summary included in Appendix Section 2.2.C.2). For the Altoona Towers project a typical two bedroom apartment requires a single high efficiency, inverter drive, mini-split heat pump unit with a nominal capacity of one ton under a master metering arrangement. With an air conditioning SEER (Seasonal Energy Efficiency Ratio) of 20, a HSPF (Heating Season Performance Factor) of 11.5 and a low power, variable speed fan; the total heat/cool/fan energy consumption is estimated at 5,337 kWH per year for a typical apartment. The baseline system meeting current heating/cooling/fan energy standards is predicted to consume 8,647 kWH per year for a typical apartment unit with individual tenant metering. For the Altoona Towers project, this represents an estimated 340,000 kWH per year with a 63 kW peak electrical demand reduction and an annual energy cost reduction of almost $20,000 for this very effective energy efficiency strategy.

For the apartment heating/cooling systems the tenant only has control over the temperature setting, not the unit SEER/HSPF. Should the tenant be inclined to operate the standard efficiency baseline heat pump unit at an aggressive and consistent setback temperature of 5°F during unoccupied periods and during all seasons, the predicted energy reduction would be 5% (based on 1% per degree savings over an 8 hour setback), or approximately 432 kWH per year for *all* heating and cooling energy. Compared to the energy reduction of 3,310 kWH per year (nearly 8 times the savings) for installing high performance mini-split heat pumps with master metering it becomes evident that the reduced and controlled energy consumption of the high efficiency unit is more effectively accomplished as a benefit of a master meter arrangement.

Another significant energy category for the apartment units is the lighting systems. The lighting systems employ LED and CFL lighting; T-8 fluorescent tube lighting; along with extensive use of motion detectors and light level sensors for control. These high performance lighting systems consume less than one fourth the energy of their traditional incandescent counterparts. Efficient lighting strategies apply to all lighting systems at Altoona Towers, including table lamps owned by the tenant and exterior/site lighting. The property manager's incentive is to provide long life, high efficiency LED, CFL; fluorescent lighting sources and lighting control through master metering. To ensure the sustainability of the high efficiency lighting, pin type lamp bases are proposed for all possible LED and CFL lamps to prevent replacement with standard incandescent screw base lamps. Replacement lamps would be made available to the tenant at no cost as part of the high efficiency, master metering lighting strategy. The proposed long life, high efficiency lighting system effectively reduces and controls energy consumption through master metering.

As part of an energy efficiency pilot project at the PPM Sun Prairie Apartment Complex some apartment buildings were retrofitted with Energy Star appliance and air conditioning units. An alternative leasing arrangement provided for landlord paid electric utilities for these high efficiency apartments. Standard efficiency apartments remained as tenant paid electrical utilities. The electrical demand was recorded over a one week hot, summer period for both the high efficiency and standard efficiency near identical 36 unit apartment buildings. The high efficiency, landlord-paid building required a peak electrical demand of 36 kW compared to 46 kW for the standard efficiency building with tenant paid utilities. This represents a reduction of 10 kW or 20% in electrical demand. A preliminary evaluation pointed toward a 2 to 10% reduction in electrical use for the landlord paid utilities apartment building.

The above presents several examples where the benefits of reduced and controlled energy consumption are more effectively accomplished through a master meter arrangement. With energy efficiency as priority design consideration for the project, numerous similar situations and conditions exist throughout the project. The bottom line result is that the building energy simulation model predicts 40% less energy use than a baseline new building for inclusion of the permanent building and apartment energy strategies.

The benefits of master metering have been incorporated for the natural gas service to provide centralized domestic water heating for the apartments. The centralized system combines engineering design efficiency and energy efficiency with energy and operational benefits for the property owner, tenant and gas utility to provide a 50% reduction in natural gas consumption. It also serves as an example of how energy efficiency can be extended to the electrical service.

A practical management and administrative benefit of master metering is eliminating the need to issue and collect over 100 individual electric utility billings for the project. Only one billing would go to the property manager, who would then be responsible for the entire payment. The utility company would not be providing individual billing statements, payment processing and non-payment follow up with individual tenants. Also, the utility company would be relieved of making the numerous meter reads, service connects and disconnects required to maintain electric service for each individual apartment in a rental environment that typically has turnover.

Another issue of interest is that the conversion to master metering would result in payment of a 6% sales tax on electrical energy costs for commercial energy service that is not assessed against individual metering of a residential service. The sales taxes are of benefit to local and state governments at a cost to the property manager.

11. Summary and Conclusions

The Altoona Towers Apartment complex as proposed is extremely energy efficient. The project will set a precedent for privately developed, energy efficient multifamily housing in Iowa and the Midwest. The comprehensive energy planning process challenged the property manager, maintenance managers, project design team, contractors for the major trades, utility company and specialized energy consultants to create a new energy efficient, cost effective, and practical multifamily apartment facility. The result is a project approach and implementation of energy strategies that is exemplary and can serve as an example to other multifamily housing developers.

The overall energy efficiency achievements for the project include:

- Leadership from the property manager and comprehensive energy planning with the project design team
- Energy Design assistance through the MidAmerican Energy Commercial New Construction program using a DOE-2 building simulation program to predict energy savings
- Proposed implementation of over 40 energy strategies in the categories of building envelope, lighting, heating/cooling, equipment and appliances.
- Exclusive use of Energy Star certified appliances and equipment.
- Potential for an annual energy reduction of 7,959 therms natural gas, 683,838 kWH electricity and 132 kW electric demand
- Reduced energy consumption of 40% compared to a new energy code compliant baseline building
- Exemplary predicted Site Energy Use Index of 36.6 kBTU/SF – an energy reduction of over 45% compared to a typical Midwest Region multifamily apartment housing facility
- Meets or exceeds all criteria for an EPA Energy Star rating for Multifamily New Construction
- Reduction in global greenhouse gasses of 514 metric tons – or equivalent to 100 cars off the road for a year; reduction in CO_2 emissions equal to the energy use of 47 homes for a year.
- Carryover of energy efficiency to water efficiency strategies to reduce water usage – and the embedded energy in water and wastewater treatment

The energy savings from implementing the Bundle 2 with Supplemental energy strategies targeting tenant electric energy use result in an annual energy reduction of 581,761 kWH for tenant apartments, or 85% of the total building energy savings. This level of reduced and controlled energy consumption is effectively accomplished through a master metering arrangement and overwhelms the potential for individual apartment tenants to effectively reduce and control energy consumption by their actions through individual metering.

It is respectfully requested that a waiver be allowed of 199 IAC 20.3(1)(b) regarding the electrical General Service requirement for individual metering of multi-occupancy premises where units are separately rented. The requested waiver would be allow PPM to install energy efficiency strategies and recover the costs for such strategies through a master meter arrangement thereby more effectively accomplishing the purpose of 199 IAC 20.3(1)(b).

APPENDIX

NEW MULTIFAMILY HOUSING:

ENERGY EFFICIENCY THROUGH MASTER METERING

Section 1 – Commercial New Construction (CNC) Energy Design Assistance Program

1. **Energy Design Assistance Reports**
   A. CNC Energy Design Assistance Introductory Materials – Program Process (April 16, 2013)
   B. CNC Strategy Report – Detailed Description Energy Strategies (February 20, 2014)
   C. CNC Bundle Report – Results of Energy Simulation Modeling (March 27, 2014)
   D. CNC Bundle Requirements Document – Summary of Strategy Requirements (April 24, 2014)

2. **Energy Design Assistance Related Documentation**
   A. Memorandum – Meeting Notes from Introductory Meeting (April 24, 2013)
   B. Memorandum – Meeting Notes from Follow up Meeting (January 10, 2014)
   C. Memorandum – Meeting Notes from Strategy Meeting (February 24, 2014)
   D. Memorandum – Meeting Notes from Bundle Meeting (March 31, 2014)

Section 2 – Energy Efficiency Strategies Technical Documentation

1. **Altoona Towers Building Plan Sets**
   A. Architectural/Structural Plans
   B. HVAC/Plumbing Plans
   C. Electrical/Lighting Plans

2. **Energy Systems and Equipment Technical Information**
   A. Building Envelope Systems
   B. Domestic Water Systems
   C. HVAC Systems
   D. Lighting Systems
   E. Appliances and Equipment

Section 3 – Related Information

1. **Residential Energy Consumption Survey; Site Energy; Midwest Region; Multifamily Housing**
2. **Energy Star Multifamily High Rise National Performance Path Requirements**
3. **Energy Star Portfolio Manager / Target Finder**
4. **Energy Efficiency for Apartment Renters**

APPENDIX

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   C. Memorandum – Meeting Notes from Strategy Meeting (February 24, 2014)
   D. Memorandum – Meeting Notes from Bundle Meeting (March 31, 2014)
3. **Supplemental Energy Strategies Summary**

Section 2 – Energy Efficiency Strategies Technical Documentation

1. **Altoona Towers Building Plan Sets**
   A. Architectural/Structural Plans
   B. HVAC/Plumbing Plans
   C. Electrical/Lighting Plans
2. **Energy Systems and Equipment Technical Information**
   A. Building Envelope Systems
   B. Domestic Water Systems
   C. Heating, Ventilating and Air Conditioning (HVAC) Systems
   D. Electrical/Lighting Systems
   E. Appliances and Equipment

Section 3 – Related Information

1. **Residential Energy Consumption Survey; Site Energy; Midwest Region; Multifamily Housing**
2. **Energy Star Multifamily High Rise National Performance Path Requirements**
3. **Energy Star Portfolio Manager / Target Finder**
4. **Energy Efficiency for Apartment Renters**

ENERGY DESIGN ASSISTANCE

Introductory Meeting Materials

Altoona Towers

Altoona, IA

April 16, 2013
7590.0186

Commercial New Construction Program

Prepared for

MidAmerican ENERGY

106 East Second Street
Davenport, IA 52801
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By

THE WEIDT GROUP®

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Des Moines Minneapolis Denver Berkeley Tampa

Table of Contents

Program Process 4
Program Definitions 5
Energy Design Assistance Incentives 6
Project Summary 8
Draft Strategy List 9
Process Schedule 12
Building Characteristics Forms - Architect 13
Building Characteristics Forms – Owner or Owner's Rep 14
Building Characteristics Forms – Electrical Engineer 15
Building Characteristics Forms – Mechanical Engineer 16

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Meeting Agenda

Introductions	The Weidt Group	9:00
Energy Analysis Overview ▪ Process and goals	The Weidt Group	9:10
Building Design Review ▪ Design concept ▪ System characteristics ▪ Review building characteristic forms	Project Team	9:20
Predefined Strategy Review ▪ Review and edit list of potential strategies	The Weidt Group	9:40
Next Steps ▪ Schedule project meetings	ALL	10:20
Adjourn	ALL	10:30

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Energy Analysis and Design Workshop

by The Weidt Group ®

GBCI cannot guarantee that course sessions will be delivered to you as submitted to GBCI. However, any course found to be in violation of the standards of the program, or otherwise contrary to the mission of GBCI, shall be removed. Your course evaluations will help us uphold these standards. Please complete them as requested by GBCI or the education provider.

Approval date: 10/06/2010 Course ID: 0090004842

Approved for:

3.5

General CE hours

LEED-specific →

Recommended CMP Category:

Project Systems and Energy Impacts

LEED GREEN ASSOCIATE ☐

LEED AP BD+C ☐

LEED AP HOMES ☐

LEED AP ID+C ☐

LEED AP ND ☐

LEED AP O+M ☐

Program Process

1. **Introductory Meeting – TODAY**
   - **Program overview**
   - **Review building design**
   - **Review strategies for modeling**
2. Phase 1 Analysis
   - Energy modeling of baseline and strategies
   - Cost analysis
3. Strategy Results Meeting
   - Review of individual strategy results
   - Combine strategies into bundles
4. Phase 2 Analysis
   - Bundle energy analysis
   - Further cost analysis
5. Bundle Results Meeting
   - Review of bundle results
   - Review of program incentives
   - Bundle selection
   - Introduction to verification
6. Verification
   - Construction documents review
   - On-site verification of strategies

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Program Definitions

DOE-2 Energy Model

The DOE-2 energy model is the simulation tool used in this program. This energy model is used for comparative analysis of the building envelope, lighting, mechanical and control options. The model is customized for the building layout, expected operations, engineered systems, average weather conditions and utility rate information.

Baseline Model

The Baseline model provides a benchmark for comparison of alternatives. The sole purpose of the Baseline is to establish a starting point for utility program administration. The Baseline uses building characteristics provided by the Project Team, default operating characteristics representative of this building type, and minimum performance criteria for building components or systems based upon the prevailing energy code. A Protocol has been established for Baseline criteria.

Building Characteristics

Building characteristics are to be completed by the Owner and the Project Team for use by The Weidt Group. Forms are included in this packet. The Weidt Group uses default values unless substituted by the Project Team.

Incremental Costs

The Weidt Group provides a "Cost Guide" to assist the Project Team to develop the incremental costs beyond the Baseline building. The incremental costs are to be completed by the Project Team and forwarded to The Weidt Group one week prior to the next meeting.

Default cost values are provided for architectural and electrical strategies and can be used by the Project Team as part of this program to calculate simple paybacks. Default costs values are based on an assessment of values provided to us on past projects.

Energy Conservation Bundles

Alternatives developed by the Owner and Project Team to maximize project goals which may include energy performance, simple payback or long-term functionality.

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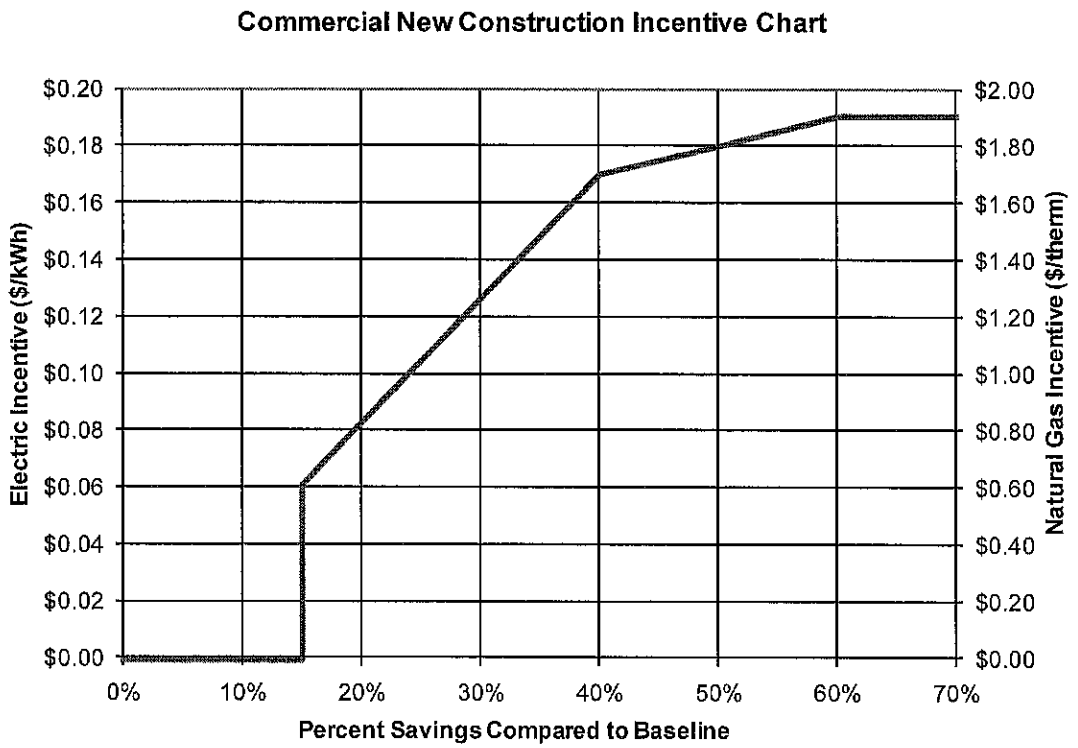
Energy Design Assistance Incentives

MidAmerican Energy Incentives to Owner

A one-time incentive payment occurs following project completion, occupancy and verification of strategies. The incentive is determined according to the chart below.

Chart 1. MidAmerican Energy Incentive Rates



- Incentives start at 15% better than Iowa State Energy Code. If a project does not achieve at least 15% better than Iowa State Energy Code at the time of verification, the project will not receive an incentive through Commercial New Construction and the project will not be eligible for prescriptive or custom incentives
- Incentives cannot reduce payback below one year
- Commercial New Construction gas conservation incentives are available to customers that purchase natural gas service (commodity) from the Sponsoring Gas Utility. Gas conservation incentives are not available for customers with "transport-only" arrangements with the Sponsoring Gas Utility.

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Commercial New Construction Incentives to Design Team

This program also provides for the Design Team to submit a participation invoice to the Sponsoring Utility for the following activities.

- Participation at formal meetings
- Transfer of building architectural/engineering design information to The Weidt Group
- Development of applicable energy conservation strategies' incremental costs (incremental as compared to a Baseline building)
- Completion and forward of Construction Documents to The Weidt Group

Please note that the participation amount is not intended to cover actual system(s) design or re-design associated with energy conservation strategies.

The Lead Design Firm will submit an invoice to MidAmerican Energy *after* The Weidt Group receipt of the completed Bundle Selection Form. MidAmerican Energy to document participation fee and terms via formal letter following Owner bundle selection. The invoice may be mailed to:

MidAmerican Energy
Accounts Payable
P.O. Box 3006
Sioux City, IA 51102-3006

Please also send a copy of the invoice to

MidAmerican Energy
Attn: Mindy Connors
106 E. Second Street
Davenport, IA 52801

Since this design participation is a fixed amount based on program track participation, documentation supporting hours worked by Design Team members or other miscellaneous or incidental expenses incurred are not necessary. Interim invoicing will be returned unpaid and an invoice for an amount in excess of the fixed amount will be returned and a revised invoice requested pursuant to MidAmerican Energy's accounts payable policy.

Program Track	Design Team Reimbursement
Quick Energy Design	$3,500
Custom Energy Design	$5,500
Custom Plus with 2 analysis modules	$7,500
Custom Plus with 3 analysis modules	$8,500

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Project Summary

Building Summary	
Building type	Housing
Location	Altoona, Iowa
Building area	120,000 sq ft
Garage area	
Number of stories	4
Building structure	
Building organization	
Glazing systems	
Lighting system(s)	
HVAC system(s)	
Areas heated	
Areas cooled	
Electric utility	MidAmerican Energy
Gas utility	MidAmerican Energy
Approx. construction document completion date	May, 2013
Approx. construction start	May, 2013
Approx. occupancy date	
Other notes	

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Draft Strategy List

Strategy ID	Envelope Insulation Strategies	Baseline	Strategy Level	Notes
EWC00	Baseline wall assembly	TBD	TBD	
EWC01	R-16 wall assembly, non-residential spaces	TBD	R-16	
EWC02	R-20 wall assembly, non-residential spaces	TBD	R-20	
ERC00	Baseline roof assembly	TBD	TBD	
ERC01	R-24 roof assembly, non-residential spaces	TBD	R-24	
ERC02	R-30 roof assembly, non-residential spaces	TBD	R-30	
ERC03	R-40 roof assembly, non-residential spaces	TBD	R-40	
EWR00	Baseline wall assembly, residential	TBD	TBD	
EWR01	R-16 wall assembly, residential spaces	TBD	R-16	
EWR02	R-20 wall assembly, residential spaces	TBD	R-20	
EWR03	R-30 wall assembly, residential spaces	TBD	R-30	
ERR00	Baseline roof assembly, residential	TBD	TBD	
ERR01	R-24 roof assembly, residential spaces	TBD	R-24	
ERR02	R-30 roof assembly, residential spaces	TBD	R-30	
ERR03	R-40 roof assembly, residential spaces	TBD	R-40	

Strategy ID	Glazing Strategies	Unit U-Factor	COG U-Factor	SHGC	Visible Trans.
W3901	Baseline: To be determined	TBD	TBD	TBD	TBD
W2101	Clear low-e, alum frame	0.42	0.29	0.38	0.70
W2201	Reduced SHGC low-e, alum frame	0.42	0.29	0.29	0.62
W2301	Tinted low-e, alum frame	0.42	0.29	0.24	0.35
W2401	Reflective low-e, alum frame	0.43	0.30	0.31	0.48
W2501	Clear low-e w/ argon, alum frame	0.38	0.25	0.37	0.70
W2601	Triple glazed clear low-e, alum frame	0.29	0.16	0.32	0.60
W2701	Triple glazed clear low-e w/ argon, alum frame	0.26	0.13	0.32	0.60
W2801	Clear low-e, warm edge, alum frame	0.39	0.29	0.38	0.70
W2901	Clear low-e, high performance alum frame	0.36	0.29	0.38	0.70

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Lighting Control Strategies					Daylighting Controls	
Space Type	**Occupancy Sensor Control**	**Occupancy sensor control to 1/3 level**	**Dual level occupancy sensor control**	**Dual level fixtures**	**Stepped Daylighting**	**Dimming Daylighting**
Apartment						
Circulation	•					
Storage	•					
Mech/elec	•					
Restroom	•					
Private office	•		•			
Lounge	•					
Laundry	•					
Common room	•					
Exercise	•					
9 hr/day retail						
Day care	•					
Garage	•					

Strategy ID	Lighting Design Strategies	Baseline	Strategy max W/sf	Notes
L01BW	Building wide 10% lower than 90.1-2007	90.1-LPD	10% Lower	Fluorescent
L02BW	Building wide 20% lower than 90.1-2007	90.1-LPD	20% Lower	Fluorescent
L03BW	Building wide 30% lower than 90.1-2007	90.1-LPD	30% Lower	LED

90.1-2010 slightly reduces the interior lighting power allowance for most spaces. Exterior lighting allowances are also reduced in the standard.

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Strategy ID	Cooling Efficiency Strategies	Baseline	Strategy Efficiency	Reference Size Tons	Notes
MAD01	DX cooling, 5% increased EER, Air cooled	TBD	TBD	TBD	
MAD02	DX cooling, 10% increased EER, Air cooled	TBD	TBD	TBD	
MAD03	DX cooling, 15% increased EER, Air cooled	TBD	TBD	TBD	
MPT01	Residential cooling 5% increased EER	TBD	TBD	TBD	
MPT02	Residential cooling 10% increased EER	TBD	TBD	TBD	
MPT03	Residential cooling 15% increased EER	TBD	TBD	TBD	

90.1-2010 slightly increases the efficiency requirement of PTAC, PTHP, water and evaporatively cooled DX units, and water cooled chillers.

Strategy ID	Heating Efficiency Strategies	Baseline	Strategy Efficiency	Notes
MPF01	Public heating at 85% efficiency	80%	at least 85%	
MPF02	Public heating at 90% efficiency	80%	at least 90%	
MPF03	Public heating at 95% efficiency	80%	at least 95%	
MAF01	Apartment furnace at 85% efficiency	80%	at least 85%	
MAF02	Apartment furnace at 90% efficiency	80%	at least 90%	
MAF03	Apartment furnace at 95% efficiency	80%	at least 95%	

Strategy ID	Heat Pump Efficiency Strategies	Baseline	Strategy EER/COP	Reference Size Tons
MHP01	Water loop heat pump, Alternate 1	TBD	TBD	TBD
MHP02	Water loop heat pump, Alternate 2	TBD	TBD	TBD

Strategy ID	Fan Strategies	Baseline	Strategy Level	Notes
MFD00	Baseline fan system power limitation	Appendix G	Maximum allowed	
MFD01	Fan system power 10% reduction	Appendix G	10% reduction	
MFD02	Fan system power 20% reduction	Appendix G	20% reduction	
MFD03	Fan system power 30% reduction	Appendix G	30% reduction	
MFD04	Proposed fan system design	Appendix G	proposed design	
MLR08	VFD on cooling twr fan	two speed	VFD	

90.1-2010 keeps requirement for VFD on VAV fan motors at 10 hp and larger.

Strategy ID	Pump Strategies	Baseline	Strategy Level	Notes
MMT04	Exceeds Premium efficiency pump motors	Premium	Exceeds Premium	

90.1-2010 requires VFD on pump motors for 5 hp and larger.

Strategy ID	Conditioning of Outside Air Strategies	Baseline	Strategy Level	Notes
MOA02	CO2 control of outside air	No control	CO2 control	
MOA22	Carbon monoxide sensor control of garage vent fans	Always on	CO control	
MHRS3	Garage heat recovery w/ CO control	No recovery	75% efficiency	
MHRS1	Sensible heat recovery	No recovery	Effic	
MHRT1	Total heat recovery	No recovery	Sensible	latent

90.1-2010 requires energy recovery on more AHUs based on outdoor air volumes.

Strategy ID	Service Water Heating Strategies	Baseline	Strategy Level	Notes
MHW00	Baseline service water heating system	0%	0%	
MHW01	85% service water heating efficiency	80%	at least 85%	
MHW02	90% service water heating efficiency	80%	at least 90%	
MHW03	95% service water heating efficiency	80%	at least 95%	

Strategy ID	Appliance Efficiency Strategies	Baseline	Strategy Level	Units	Notes
ACW01	Energy Star clothes washers, alt 1	1.26	2.00	MEF	
ACW02	Energy Star clothes washers, alt 2	1.26	2.50	MEF	
ADW01	Energy Star dishwashers, alt 1	355	295	kWh/yr	
ADW02	Energy Star dishwashers, alt 2	355	245	kWh/yr	
ARF01	Energy Star refrigerators, alt 1	NAECA	20% better	kWh/yr	
ARF02	Energy Star refrigerators, alt 2	NAECA	30% better	kWh/yr	
AHW01	Low flow showerheads	2.50	2.00	gpm @ 80 psi	

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Process Schedule

Process Step	Proposed Date	Revised Date	Responsible
Introductory Meeting	16-Apr-13		Project Team
Review building design			
Review building characteristics requirements			
Review pre-defined strategy list			
Strategy List Confirmation	**23-Apr-13**		
Send revised strategy list descriptions			The Weidt Group
Building Characteristics Confirmation	**23-Apr-13**		
Design drawings - CAD Files			Architect/Owner
Envelope/Operating Characteristics			Architect/Owner
Mechanical Characteristics			Mechanical Engineer
Heating/Cooling Plant Characteristics			Mechanical Engineer
Electrical Characteristics			Electrical Engineer
Incremental Cost Estimating Guide	**30-Apr-13**		
Informs Design Team			The Weidt Group
DOE 2 computer models			
Baseline model			The Weidt Group
Model alternatives within 8 to 10 strategy groups			The Weidt Group
Cost Analysis	**21-May-13**		
Cost analysis by Design Team			Design Team
Strategy Results Meeting	28-May-13		Project Team
Review strategy results & costs			Project Team
Assemble Bundles			
Bundle Meeting	11-Jun-13		Project Team
Review bundle results and incentives			Project Team
Introduce verification process			The Weidt Group
Receive/review bundle selection			MidAmerican Energy
Bundle Selection Conference Call	25-Jun-13		Project Team
Owner agrees to implement one bundle			Owner/ Design Team
Verification Process			
Send construction docs EDA team			Owner/ Design Team
Pay design team incentive			MidAmerican Energy
Construction document review for strategies			The Weidt Group
Field visit to verify strategies installed			The Weidt Group
Pay construction incentive			MidAmerican Energy

Note: All dates presented as "typical" for the purpose of discussion in context with the project's design schedule. Typically, these projects start at late-SD, early-DD stage.

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Building Characteristics Forms - Architect

Please forward completed form to Luke Hollenkamp by April 23, 2013.

Building Location

Address:	
City:	Altoona
State:	Iowa

Envelope Characteristics

Select all envelope construction characteristics that apply

Walls	
Wood frame	
Steel frame	
Frame w/ masonry exterior	
Masonry	
Metal	

Interior Floors	
Wood frame	
Steel frame	
Concrete	

Roof Construction	Select	Insulation Position
Wood Frame		
Steel Frame		
Concrete		

Roof Insulation Position Key	
A	Entirely above deck/ continuous
B	Entirely below metal deck
C	Other/ Combination

Window frame types	
Nonmetal	
Metal curtainwall/ storefront	
Metal punched opening	

Window characteristics	Value
Total U-Factor (winter)	
Center of glass U-Factor (winter)	
Solar heat gain coefficient	
Visible light transmittance	

Window treatment (list building areas w/ blinds or shades)

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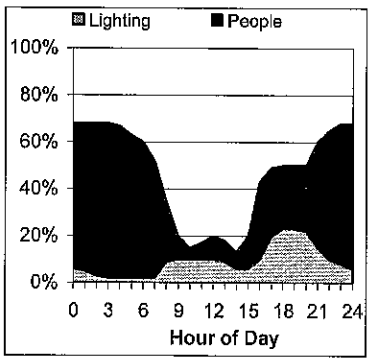
Building Characteristics Forms – Owner or Owner's Rep

Please forward completed form to Luke Hollenkamp by April 23, 2013.

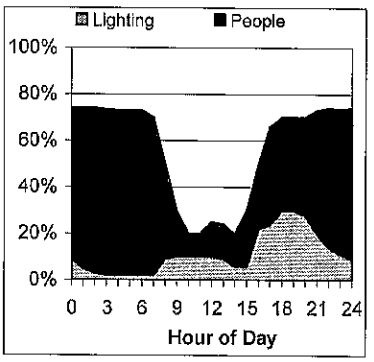
Building Operation Schedules

Select schedule that best describes operational use for lights and people use

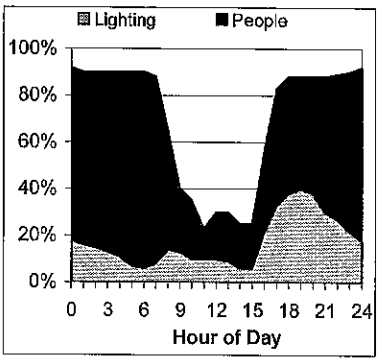
Light Use



Medium Use



Heavy Use



Building Type: Housing

Operation Notes

Building Characteristics Forms – Electrical Engineer

Please forward completed form to Luke Hollenkamp by April 23, 2013.

Utility Service

Select all that apply:

- ☐ 120/240 V or 120/208 V, single phase service
- ☐ 277/460 V, three phase service
- ☐ High voltage service with primary metering (>600 V)

Space Type Building Characteristics

Enter design values.
If ceiling height is unknown, enter a safety factor value to allow for over-design.
If design reflectances are unknown, enter the assumed reflectances.
Horizonal footcandle levels will be used in daylighting strategies. IESNA FC levels are from the Ninth Edition IESNA Lighting Handbook.
Equip W/sf defines the average internal loads from computers, appliances,and production process within each space type. It should include factors for diversity, meaning it should be the peak value for a typical day.

	Ceiling Height FT	Design Reflectances			IESNA FC Level		Design FC Level		Equip W/SF		Percent of Equipment on 120 / 240 V Transformers
		Ceiling	Wall	Floor	Horiz	Vert	Horiz	Vert	Default	Actual	
Apartment					5	N/A			N/A		
Circulation					3	3			0.10		
Storage					10	10			0.10		
Mech/elec					30	3			0.20		
Restroom					10	3			0.10		
Private office					30	5			1.20		
Lounge					3	3			0.10		
Laundry					30	3			N/A		
Common room					5	N/A			0.50		
Exercise					30	5			0.10		
9 hr/day retail					50	10			0.05		
Day care					30	5			0.20		
Garage					1	0.5			0.10		

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Building Characteristics Forms – Mechanical Engineer

Please forward completed form to Luke Hollenkamp by April 23, 2013.

Mechanical Zone Type Characteristics

- *Enter or select actual values for each parameter, default values are approximate based on standard space type conditions*
- *Enter an "X" to identify what type of equipment will be used.*

Space Type		Apartment	Circulation	Storage	Mech/elec	Restroom	Private office	Lounge	Laundry	Common room	Exercise	9 hr/day retail	Day care	Garage
Air Flow Type	CV													
	VAV													
Cooled Zone														
Heated Zone														

Perimeter Zones

Zones have fan powered boxes?														
Terminal fan power (W/cfm)														
Supply CFM/SF														
Min CFM ratio	Default	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
	Design													

Core zones

Zones have fan powered boxes?														
Terminal fan power (W/cfm)														
Supply CFM/SF														
Min CFM ratio	Default	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
	Design													

Ventilation

OA CFM/SF	Default	0.00	0.06	0.07	0.06	0.01	0.09	0.30	0.17	0.30	0.26	0.24	0.43	0.75
	Design													

Zone heat source

HW coil														
HW base board														
Electric coil														
Electric baseboard														
Heat Pump														
Gas furnace														

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Air handler and fan characteristics

Air Handler Number	1	2	3	4	5	6	7	8
Region of building served								
Air Handler Type	*Place an "X" for type*							
Central cooling/ terminal reheat								
Central cooling/ fan powered terminal reheat								
Four pipe fan coil								
Water loop heat pump								
Ground heat pump								
Packaged single zone units								
Packaged terminal A/C								
Dedicated outside air system (DOAS)								
Exhaust fan								
Fan Control	*Place an "X" for type*							
Constant volume								
Variable air volume								
Airflow Variables	*Enter data for each air handler*							
Supply cfm								
Minimum outside air cfm								
Design Min % outside air								
Is Outside air delivered by DOAS?								
Expected Exhaust cfm (1)								
(1) This is the expected exhaust from the air handler after accounting for building pressurization and toilet exhaust								
Economizer control	*Place an "X" for control type*							
None								
Air-side economizer (non-integrated)								
Air-side econo (integrated)								
Drycooler								
Water-side economizer								
Outside air control	*Place an "X" for control type; this applies to VAV systems only*							
Fixed cfm								
Proportional to supply cfm								
Fan Static estimate	*Note: Fan static values should include effects of ductwork, diffusers, coils, filters, etc*							
Supply (including filters), inches wc								
Filters only, inches wc								
Return, inches wc								
Exhaust, inches wc								
Fan horsepower								
Supply fan hp								
Return fan hp								
Exhaust fan hp								
Humidity Control	*Enter data for each air handler*							
Maximum setpoint								
Minimum setpoint								
Heating Plant / System	*Place an "X" for system type*							
Hot water coil								
Gas burner								
Electric resistance								
Heat pump								
Other:								
Cooling Plant / System	*Place an "X" for system type, for chiller systems make detailed entry in Plant form*							
No cooling								
Air cooled chiller								
Water cooled chiller								
Heat pump								
District cooling								
Direct expansion system data below								
Air cooled DX packaged or split								
Air cooled DX condensing units								
Evap. Cooled DX Rooftops								
Base design efficiency, EER								
- Include evaporator fan?								
Alternate design efficiency, EER								
- Include evaporator fan?								

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Fan power credits and deductions for ASHRAE 90.1-2007

		Air Handler Number	1	2	3	4	5	6	7	8
Air Stream	Description	Allowance	Enter appropriate fan static adjustment							
	Credits									
Supply	Particulate: MERV 9 through 12	0.5 in w.c.								
Supply	Particulate: MERV 13 through 15	0.9 in w.c.								
Supply	Particulate: MERV 16 and greater and electronically enhanced filters	2X clean filter DP								
Supply	Carbon and other gas-phase air cleaners	Clean filter DP								
Supply	Evaporative humidifier/ cooler in series with another cooling coil	Device DP								
Supply	Sound attenuation section	0.15 in w.c.								
Return	Fully ducted return air systems	0.5 in w.c.								
Return	Return airflow control devices	0.5 in w.c.								
Exhaust	Fully ducted exhaust air systems	0.5 in w.c.								
Exhaust	Exhaust airflow control devices	0.5 in w.c.								
Exhaust	Filters, scrubbers, or other exhaust treatment	Device DP								
Outdoor	Heat recovery device	Device DP								
Outdoor	Evaporative humidifier/ cooler in series with another cooling coil	Device DP								
	Deductions									
Exhaust	Fume hood exhaust exception (required if 6.5.3.1.1 Exception [c] is taken)	-1.0 in w.c.								

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Heat Recovery Characteristics

Sensible heat wheel		
Recovery effectiveness (winter)		
Recovery effectiveness (summer)		
Supply Static		
Exhaust Static		
Bypass when heat recovery not needed?		
Wheel motor hp		
Capacity/Frost control	**Capacity**	**Frost**
Wheel speed		
Outside air bypass		
Exhaust air bypass		
Trim economizer		
No control		
Frost control calculation		
Keep exhaust air above 33 F		

Total enthalpy wheel		
Sensible effectiveness (winter)		
Sensible effectiveness (summer)		
Latent effectiveness		
Supply Static		
Exhaust Static		
Bypass when heat recovery not needed?		
Wheel motor hp		
Capacity/Frost control	**Capacity**	**Frost**
Preheat outside air		
Preheat exhaust air		
Wheel speed		
Outside air bypass		
Exhaust air bypass		
Trim economizer		
No control		
Frost control calculation		
Keep exhaust air above 33 F		
Based on winter design OA condition		
Done by real time calculations		

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Boiler Plant Characteristics

Strategy Description	Standard Boiler	Condensing Boiler
Names systems served (or ALL)		
Type (water, steam, etc)		
Number of units		
Output per unit (KBTU/HR)		
Total output (KBTU/HR)		
Fuel Source (Gas, electric, etc)		
Rated supply water temperature		
< or > Rated return water temperature		
Thermal efficiency at rated supply T		
< or > Combustion efficiency at rated supply T		
Boiler AFUE		
Condensing boiler? (Y or N)	N	Y
Delta T at capacity		
Temperature reset strategy		
Reset boiler supply temp based on outside air temp?		
Lower limit outside temp		
Boiler supply temp at low outside temp		
High limit outside temp		
Boiler supply temp at high outside temp		
Primary circulation loop (connects to boilers)		
Indicate the primary pump configuration by marking with "X"		
Each boiler has its own pump		
A single pump in the primary loop serves all boilers		
A bank of pumps in the primary loop serves all boilers		
Number of primary pumps		
Primary pump head (ft water)		
Primary pump GPM (total of all pumps)		
Primary pumps have VFDs? (Y or N)		
Primary loop min flow ratio		
Primary pumps use head pressure reset control? (Y or N)		
Secondary circulation loop (where applicable - connects to building load)		
Number of secondary pumps		
Secondary pump head (ft water)		
Secondary pump GPM (total of all pumps)		
Secondary pumps have VFDs?		
Secondary loop min flow ratio		
Secondary pumps use head pressure reset control? (Y or N)		

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Chiller Plant Strategies

Chiller Plant	MAC01	MAC02	MAC03
Chiller Type Name			
Open or Hermetic			
Air or Water Cooled	air	air	air
Standard, VFD or Frictionless			
Number of units			
Itemized cooling tons			
Total cooling tons	0	0	0
KW/ton at AHRI rated conditions *			
Items below refer to chiller system at design operating conditions			
KW/ton at design conditions *			
Design evaporator leaving water temperature			
Design entering condenser temp (Entering water for cooling tower, outdoor air for air-cooled)			
Chilled water supply temperature reset strategy			
Reset based on load (via return T or valve positions)?			
Reset based on outside air temp?			
Lower limit outside air temp			
Chilled water supply temp at low OA temp			
High limit outside air temp			
Chilled water supply temp at high OA temp			
Primary chilled water loop (connected directly to chiller)			
Indicate the primary pump configuration by marking with "X"			
Each chiller has its own pump			
A single primary pump serves all chillers			
A bank of pumps in the primary loop serves all chillers			
Number of primary pumps			
Primary pump head (ft water)			
Primary chiller gpm/ton			
Primary pumps have VFDs? (Y or N)			
Primary loop minimum flow ratio			
Primary pumps use head pressure reset control?			
Secondary chilled water loop (where applicable, connects to building load)			
Number of secondary pumps			
Secondary pump head (ft water)			
Secndary pump gpm/ton			
Secondary pumps have VFDs?			
Secondary loop minimum flow ratio			
Secondary pumps use head pressure reset control?			

** KW/ton is compressor only for water cooled units, compressor + condenser fan for air cooled*

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Cooling Tower Characteristics

Cooling tower type	*Choose one by marking with "X"*		
Axial fan or propeller fan			
Centrifugal fan			
General information			
Tower capacity, Tons			
Number of cooling towers			
Number of cells per tower			
Tower fan hp per cell			
Design condenser water setpoint			
Design air wetbulb			
Design approach to wetbulb			
System has water-side economizer mode? (Y or N)			
Is tower fluid separated from condenser loop by a heat exchanger? (Y or N)			
Tower capacity control	*Choose one by marking with "X"*		
Fan cycling			
Fluid bypass			
Discharge damper			
Two speed fan			
Variable speed fan			
Tower temperature reset control			
Use reset control? (Y or N)			
Minimum tower setpoint			
Tower recirc loop - recirculates fluid from the tower to the condenser water loop			
Does each tower have a recirc pump? (Y or N)			
Tower recirc gpm/ton			
Tower recirc pump head			
Tower recirc pumps have VFDs? (Y or N)			
Condenser water loop (leave blank for water loop heat pump)			
Indicate the condenser water pump configuration by marking with "X"			
Each condenser has its own pump			
A single pump in the loop serves all condensers			
A bank of pumps in the loop serves all condensers			
Number of pumps			
Pump gpm/ton			
Pump head			
Pumps have VFDs?			
Condenser loop min flow ratio			
Primary pumps use head pressure reset control? (Y or N)			

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Water loop heat pump system characteristics			
Heat pump unit data	Alternate 1	Alternate 2	Notes
Unit size, Tons			enter avg. or attach a list
Approx. no. of units			
Cooling EER, Btu/Watt			
entering water temp			for EER listed above
ent air temp (db)			for EER listed above
ent air temp (wb)			for EER listed above
Heating efficiency, COP			
entering water temp			for COP listed above
ent air temp (db)			for COP listed above
Supply fan static, in			total static
Outside air fan data			
Supply fan static, in			
Return fan static, in			if applicable
Preheat Type			Ht pump, gas, electric, etc
Economizer			None or max % outside air
Building loop pump data			
Pump flow, gpm/ton			
Number of pumps			
Pump head, ft			
Total gpm of all pumps			
Building loop pumps have VFDs (Y or N)			VFD, 2-speed, staging, or None
Primary loop min flow ratio			
Pumps use head pressure reset control? (Y or N)			
Pump hours of operation			24 hrs/day or w/ fans; prim/2nd

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Residential Housing Characteristics	
General Apartment Information	Data
Total number of apartments	
Average number of bedrooms per apartment	
Average number of bathrooms per apartment	
Average number of people per apartment	
Number of apartments with laundry in unit	
Is there a public laundry area?	
Does the kitchen have an exhaust fan that vents to outside?	
Are clothes dryers Gas or Electric?	
Are cooking stoves Gas or Electric?	
Does each apartment have its own electric meter?	
Does each apartment have its own gas meter?	
Apartments have baseboard heat for central boiler strategies?	
Parking Garage Information	Data
With CO control, do fans cycle on at night to vent oil/gas fumes?	

Service Water Heating System Characteristics	
Number of hot water heater units	
Hot water tank size, gal per unit	
Hot water heat source (Gas, Electric, or Steam)	
Hot water heater input rate (per unit, kBTU/hr)	
Hot water system combustion efficiency (baseline)	80%
Hot water system combustion efficiency (design level)	
Hot water system supply temperature, deg F	
Hot water circulation pump flow, gpm	
Hot water circulation pump head, feet	
For kitchens: # breakfasts per day	
For kitchens: # lunches per day	
For kitchens: # dinners per day	

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COMMERCIAL NEW CONSTRUCTION PROGRAM

Strategy Report

Altoona Towers

Altoona, IA

February 20, 2014
7590.0186

Prepared for

MidAmerican ENERGY

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midamericanenergy.com

by

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Project Participants

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Architect.....Imprint Architects
Karl Chambers
Ron Barkey

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Chuck Gassman
Larry Dewey

General Contractor .....Erickson Balmer Construction LLC
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Table of Contents

Introduction 3
Building Summary 4
Energy Analysis Process 8
Base Building Results 10
Strategy Summary List 12
Integrated Utility Savings 14
Strategy Descriptions and Results 17
Appendix A. Building Characteristics 48
Appendix B. Detailed Results 59
Appendix C. Lighting Control Sequences and Schematics 64
Appendix D. LED Lighting 69
Appendix E. Daylighting Guidelines 75

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Introduction

This Report is designed to assist the Owner and Project Team in making energy-related decisions about building design. In the Introductory Meeting, the group identified a series of energy conservation strategies appropriate to this building—affecting gas, electricity, district energy, or other energy sources—and this Report documents the results of computer simulations for each strategy compared to the baseline. With "hard" numbers attached to each strategy, potential energy savings are clear and cost-effectiveness can be easily determined.

While the virtual building model estimates overall energy consumption, it is primarily designed to forecast savings, much like forecasting the savings from buying a fuel-efficient car. Energy consumption and savings forecasts are based on assumptions about occupancy, operations, weather, and other factors. As with a car, however, changes in use or operation affect the absolute value of savings, but the relative value—percentage saved, for example—compared to the less fuel efficient option, will still be valid. In the end, it is up to the Owner/operator to use and operate the building effectively in order to realize savings.

This program should not be construed as correcting or overriding previous decisions or recommendations of the Project Team. The program is analytical in nature, using tools and methods not normally part of the customary design contract. The Project Team remains responsible for the implementation of strategies and final engineering of systems, as well as for determining costs of various strategies.

The process follows a clear methodology of information gathering, collaboration, and analysis in an integrated setting of three formal meetings. The Owner, Project Team, and The Weidt Group work together to understand how the building will use energy and where cost-effective savings can be realized, through design. These are the steps, with the current stage shown in bold.

1. Introductory Meeting
   - Program overview
   - Review building design
   - Review strategies for modeling
2. Phase 1 Analysis
   - Energy modeling of baseline and strategies
   - Cost analysis
3. **Strategy Results Meeting - TODAY**
   - **Review individual strategy results**
   - **Combine strategies into bundles**
4. Phase 2 Analysis
   - Bundle energy analysis
   - Further cost analysis
5. Bundle Results Meeting
   - Review bundle results
   - Review program incentives
   - Bundle selection
   - Introduction to verification
6. Verification
   - Construction Documents review
   - On-site verification of strategies

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Project Summary

The following table is a project summary. This information is based on a review of the design documents and conversations with the Project Team. Additional building characteristics are listed in the Appendices.

Building Summary	
Building type	Multi-family Housing
Location	Altoona, Iowa
Building area	130,800 sf
Number of stories	2 - 4 story buildings
Building structure	Wood construction with sloped roof. Using spray foam insulation with a target R-25 total wall assembly. Insulation in the attic will be installed at the bottom chord. Target R-value R-50. Considering an inch of spray foam in the roof with blown-in insulation on top to reach the R-50 target and reduce infiltration.
Building organization	2 apartment buildings. First floor of Building B will house a fitness center and extended stay efficiency units available for lease on a monthly basis. First floor of Building A will have office space and a community room.
Glazing systems	Punched vinyl windows throughout Window to floor area ratio: 7.4%; Window to wall area ratio: 16.1%
Lighting system(s)	Fluorescent lighting planned throughout with an interest in LED lighting where it makes sense.
HVAC system(s)	Ducted mini-split systems in the apartment units, efficiency units will have electric base board heat and through wall air conditioners. An air to air heat pump will be utilized in the community space and offices. An air to air heat pump with an ERV will be used in the fitness room. Central gas fired service hot water.
Areas heated	All, except circulation spaces (stairs tempered to 60 degrees)
Areas cooled	All, except circulation and stairs
Electric utility	MidAmerican Energy
Gas utility	MidAmerican Energy
Approx. construction document completion date	
Approx. construction start	
Approx. occupancy date	November, 2014
Other notes	

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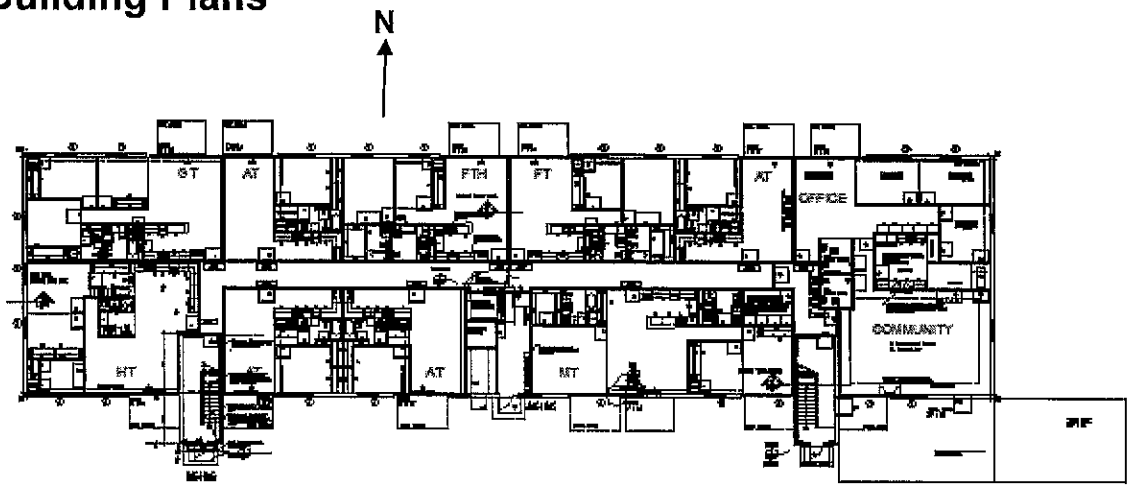
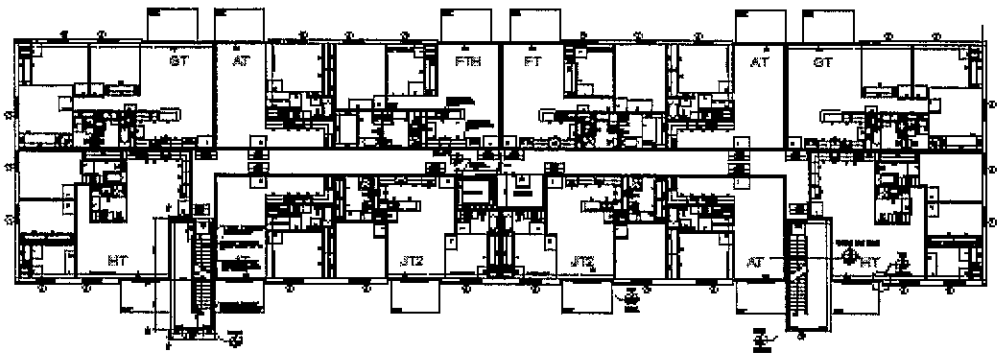
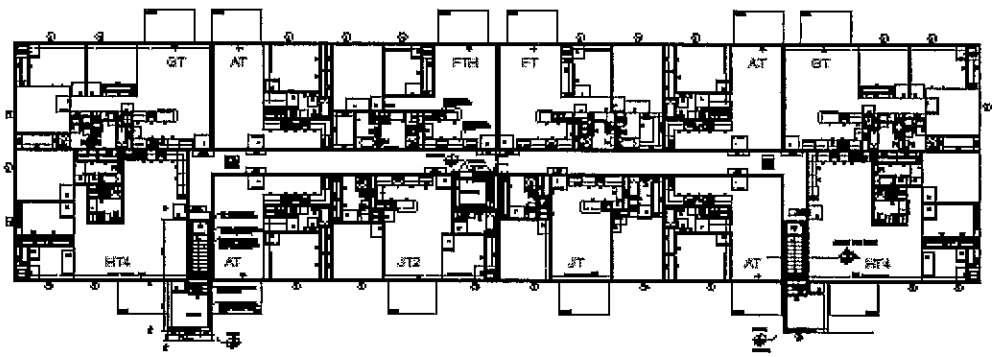
Building Plans



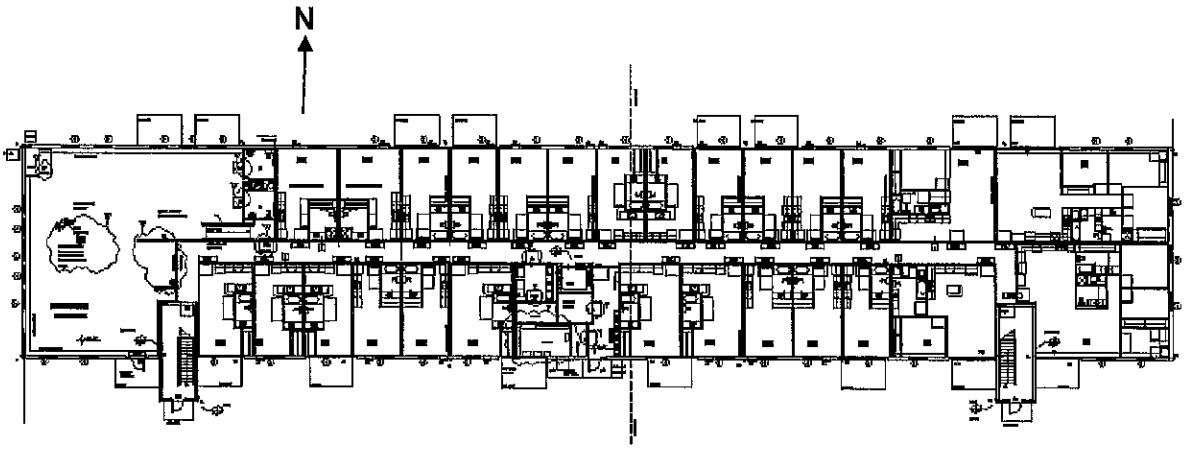
Building A – Level One Floor Plan



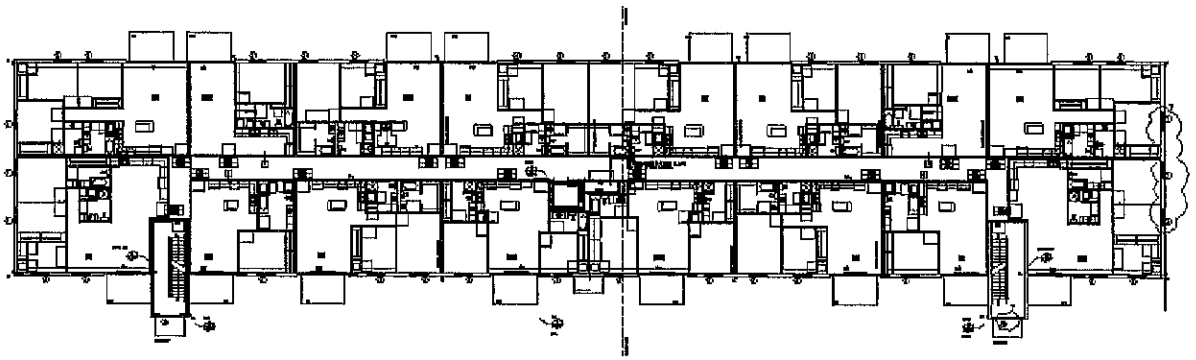
Building A – Level Two and Level Three Floor Plan



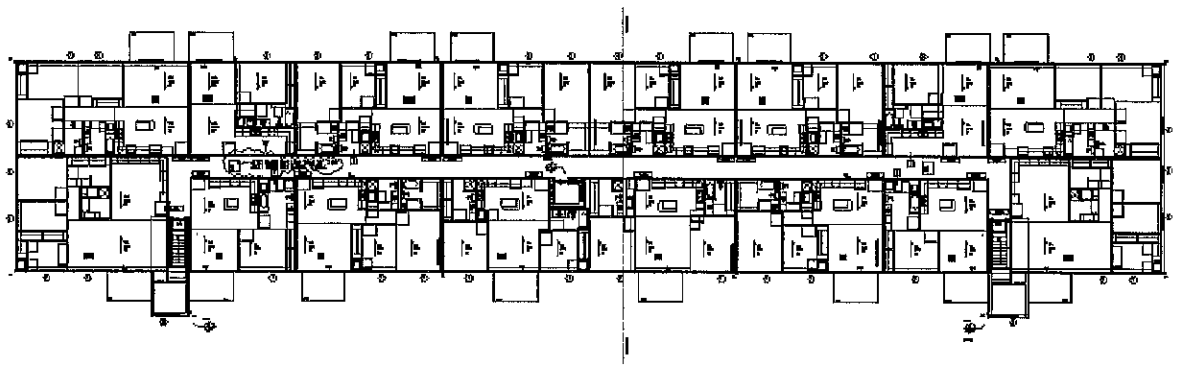
Building A – Level Four Floor Plan



Building B – Level One Floor Plan



Building B – Level Two and Level Three Floor plan



Building B – Level Four Floor Plan

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Energy Analysis Process

DOE-2 Energy Model

The Weidt Group analyzes energy solutions using DOE-2.2, a building simulation program. The program performs thermal and luminous calculations on an hour-by-hour basis, using typical yearly climatic data, to determine the building's energy loads and system requirements.

The Weidt Group gathers building description data and assumptions from the Owner and Project Team to construct the model. Some of the customized operating assumptions include the following.

- Building geometry
- Building base envelope construction
- Building programming and operation
- Base mechanical system design
- Base lighting system design

The energy models are simulated using the Des Moines, IA DOE-2.2 Typical Meteorological Year (TMY) weather file.

This energy model is intended for comparison of relative differences in net energy use for various design alternatives, compared to a baseline condition; it is not intended for system design and/or equipment selection. In addition, the actual energy use of this building will be different from the DOE-2.2 simulations because there will be differences in the weather, operating parameters, occupancy, and other circumstances not anticipated in the model. Given those qualifications, however, this model offers energy savings estimations as good as any other means available for a building that has not yet been built.

Baseline Model

The Baseline model provides a benchmark for comparison of alternatives. The sole purpose of the Baseline is to establish a starting point for utility program administration. The Baseline uses building characteristics provided by the Project Team, default operating characteristics representative of this building type, and minimum performance criteria for building components or systems based upon the prevailing energy code. A Protocol has been established for Baseline criteria.

Building Characteristics

For this modeling program, a number of building design characteristics, owner operating schedules and representative utility energy cost tariffs are assumed. This document includes the modeling assumptions provided by the Owner, Project Team, and The Weidt Group. A summary of this information can be found in the Appendices.

Incremental Costs and Payback Analysis

The Weidt Group provides default values. Default costs values are based on an assessment of values provided to us on past projects. The Weidt Group requests that the design team review these values and provide project specific costs whenever more specification is necessary. The Weidt Group also requests the design team's cost development assistance for strategies where default values are not available.

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Modeling of Specific Strategies

At the Introductory Meeting, representatives of the Owner, Project Team, and The Weidt Group reviewed and edited a list of energy savings strategies, so as to bracket a range of acceptable design solutions. The strategy list can be found beginning on page 12 of this Report. By running a range of solutions, the model allows comparative analysis between envelope, mechanical and lighting system energy conservation alternatives.

Isolated Strategy Review

The Weidt Group simulates each strategy individually and compares results to the Baseline model to illustrate the impact of each strategy alone. It is common for individual strategies to impact the base models by less than 10%. However, selecting 15 strategies, each with an average value of 2% to 3%, might result in an annual building energy cost performance on the order of 30% to 40% better than the baseline. It is important to understand that the results are not always 100% additive; two strategies that save 2% alone, may not save 4% together. More likely, they will save 3.2% to 3.8% when combined.

Bundle Identification

Once the Isolated Strategy Analysis is complete, the Owner and Project Team will identify bundles of strategies via a spreadsheet tool. The bundles may be roughly organized as follows.

Bundle 1: Include all strategies that are fairly certain to be included in the final design

Bundle 2: Include all of the Bundle 1 strategies, but add those with promising paybacks

Bundle 3: Include all of the Bundle 2 strategies, while adding feasible strategies that optimize energy savings

The Owner and Project Team may then use the bundles' economic value to determine an appropriate construction solution.

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Baseline Building Results

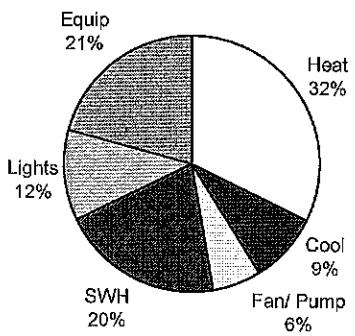
This page identifies the projected baseline energy consumption of this building. The baseline model assumes all energy design parameters are set to meet the prevailing energy code and provides for comparison for all modeled energy conservation strategies.

The baseline mechanical system consists of a code level single packaged vertical air conditioner and electric baseboard heating serving the efficiency units. Code level single package vertical heat pumps serve the 1-bedroom, 2-bedroom, 3-bedroom, and 4-bedroom apartment units, with electric resistance baseboard backup heat. The fitness and community room spaces are served by code level air to air heat pumps. The stair areas have electric resistance heating and the interior circulation spaces are not conditioned or ventilated. The charts below show the Baseline model breakdown of annual energy consumption and energy cost. Note that these results do not include exterior lighting or elevator operation.

The annual energy use prediction for the baseline model is 59 kBtu/sq ft and the energy cost is $1.12/sq ft. Total energy cost is approximately $146,000 per year at baseline.

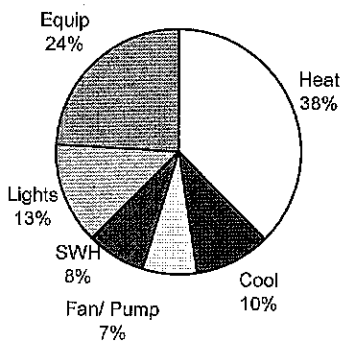
Comparative Energy Streams –Baseline Model

Energy Breakdown (BTU)



Baseline Model - Detailed Energy Parameters	
Annual Electrical Consumption	1,800,000 kWh
Peak Electrical Demand	381 kW
Annual Natural Gas Consumption	1,577 MMBTU

Energy Cost Breakdown ($)



Energy Cost By End Use	
Heating	$54,600
Cooling	$15,000
Fans / Pumps	$10,400
SWH	$11,400
Lighting	$19,400
Equipment	$35,200

Key Observations

- The Btu Energy use is the energy delivered to the building, not including the energy for generation and transmission of electricity or gas
- Heating is the dominant end use in this building, followed by service water heating, and equipment

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Baseline Operation Assumptions

The baseline model assumes the following design parameters as well as accompanying operational assumptions, based upon transmittal information from the Owner and Project Team.

Space Type	Floor area	% area	Baseline lighting power (W/sf)	Base equipment/ plug load (W/sf)	System air flow (CFM/sf)	Annual lighting full load hours	Annual scheduled fan hours
Apartment	100,900	77%	1.54	1.05	0.48	1,000	8,760
Efficiency Apartment	8,800	7%	1.54	1.05	0.54	1,000	8,760
Circulation	10,600	8%	0.50	0.10	0.50	8,760	8,760
Storage	200	0%	0.80	0.10	0.50	3,000	3,800
Mech/elec	800	1%	1.50	0.20	0.50	3,500	3,800
Restroom	100	0%	0.90	0.10	0.50	4,300	4,800
Exercise	2,900	2%	0.90	0.10	0.81	4,500	5,400
Locker Room & Shower	200	0%	0.60	0.50	0.50	4,200	5,400
Community Room	1,000	1%	1.30	0.50	0.58	2,400	5,500
Private office	700	1%	1.10	1.20	0.84	3,800	5,000
Open office	500	0%	1.10	1.20	0.68	4,900	5,000
Laundry	100	0%	0.60	7.31	0.50	6,000	8,760
Serving	200	0%	1.20	5.00	0.74	3,700	5,500
Stairs	3,800	3%	0.50	0.10	0.50	8,760	8,760
Total	**130,800**	**100%**					
Average			**1.40**	**0.92**	**0.49**	**2,000**	**8,600**

Additional mechanical design assumptions may be found in the Appendices of this Strategy Report. The Baseline model also assumes the following mechanical design/ operating parameters.

- Non 24/7 spaces operate in a setback mode during unoccupied hours in which thermostats in conditioned spaces are reset downward in winter and upward in summer
- Outside air dampers for non 24/7 spaces are assumed to be closed at night, and fans cycle on to maintain nighttime temperature settings

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Strategy Summary List

The following tables provide a complete list of the modeled energy conservation strategies described in this Report.

Strategy ID	Envelope Insulation Strategies	Baseline	Strategy Level	Notes
EWN00	Baseline wall assembly: non-residential/ residential	R-15.6/ R-19.6	R-15.6/ R-19.6	
EWN01	R-20 wall for non-residential, R-20 wall for residential	R-15.6/ R-19.6	R-20	
EWN02	R-25 wall for non-residential, R-25 wall for residential	R-15.6/ R-19.6	R-25	
EWN03	R-30 wall for non-residential, R-30 wall for residential	R-15.6/ R-19.6	R-30	
ERN00	Baseline roof assembly: non-residential/ residential	R-37/ R-37	R-37	
ERN01	R-50 roof for non-residential, R-50 roof for residential	R-37/ R-37	R-50	
ERN02	R-60 roof for non-residential, R-60 roof for residential	R-37/ R-37	R-60	

Strategy ID	Other Envelope Strategies	Baseline	Strategy Level	Notes
EWRF2	Reduced infiltration	standard	reduced	
EWWQ2	Window Quilts	no quilt	quilt	

Strategy ID	Glazing Strategies	Unit U-Factor	COG U-Factor	SHGC	Visible Trans.
WGA01	Baseline: Nonmetal framing	0.35	N/A	0.40	0.44
WGB01	Design Glass: M1 Casement	0.27	0.24	0.25	0.44
WGC01	Design Glass: Sliding Doors	0.31	0.28	0.32	0.59

Strategy ID	Daylighting Control Strategies	Region of building	Daylight Control	Notes
DGA02	Exercise Stepped Daylighting		Fluorescent Stepped	1,408 sf of area controlled
DGA03	Exercise Dimming Daylighting		Fluorescent Dimming	1,877 sf of area controlled
DGA04	Common Room Stepped Daylighting		Fluorescent Stepped	543 sf of area controlled
DGA05	Common Room Dimming Daylighting		Fluorescent Dimming	724 sf of area controlled
DGA06	Stairs Stepped Daylighting		Fluorescent Stepped	1,728 sf of area controlled
DGA07	Stairs Dimming Daylighting		Fluorescent Dimming	1,728 sf of area controlled

Automated multistep daylighting controls for primary sidelighted areas ≥ 250 sf is required by 90.1-2010
Automated multistep daylighting controls for toplighting when area under skylights or rooftop monitors > 900 sf is required by 90.1-2010

Strategy ID	Lighting Control Strategies	Peak reduction	Annual hrs reduction	Notes
LCCI1	Circulation occupancy sensor control	20%	30%	
LCCI2	Circulation occupancy sensor control to 1/2 level	10%	15%	
LCST1	Storage occupancy sensor control	50%	70%	
LCME1	Mech/elec occupancy sensor control	50%	70%	
LCRR1	Restroom occupancy sensor control	35%	55%	
LCFT1	Exercise occupancy sensor control	25%	40%	
LCLR1	Locker Room & Shower occupancy sensor control	30%	50%	
LCCM1	Community Room occupancy sensor control	25%	40%	
LCPO1	Private office occupancy sensor control	15%	40%	
LCPO3	Private office dual level occupancy sensor control	20%	45%	
LCPO4	Private office dual level fixture	15%	15%	
LCOO1	Open office occupancy sensor control	0%	40%	
LCLA1	Laundry occupancy sensor control	25%	40%	
LCSV1	Serving occupancy sensor control	5%	25%	
LCSW1	Stairs occupancy sensor control	20%	30%	
LCSW2	Stairs occupancy sensor control to 1/2 level	10%	15%	

90.1-2010 requires space control with dual level fixtures as well as occupancy sensors in most spaces

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Strategy Summary List (continued)

Strategy ID	Lighting Design Strategies	Baseline	Strategy max W/sf	Notes
L01BW	Corridor and stairs at As-designed LPD, Other public spaces at 10% lower than 90.1-2007 LPD (excludes apartments)	0.68	0.53	Fluorescent
L02BW	Corridor and stairs at As-designed LPD, Other public spaces at 20% lower than 90.1-2007 LPD (excludes apartments)	0.68	0.50	Fluorescent
L03BW	Corridor and stairs at As-designed LPD, Other public spaces at 30% lower than 90.1-2007 LPD (excludes apartments)	0.68	0.47	LED
L01AP	Apartment lighting alt 1, 30% lower than baseline (includes efficiency units)	1.54	1.08	
L02AP	Apartment lighting alt 2, As-designed (includes efficiency units)	1.54	0.43 (Apts) 0.57 (Eff. Units)	

90.1-2010 slightly reduces the interior lighting power allowance for most spaces. Exterior lighting allowances are also reduced in the standard.

Strategy ID	Cooling Efficiency Strategies	Baseline	Strategy Efficiency	Reference Size Tons	Notes
MPT02	As-designed through the wall units (Efficiency Apartments)	9.0 EER	9.8 EER	0.0 to 5.4 Tons	

90.1-2010 slightly increases the efficiency requirement of PTAC, PTHP, water and evaporatively cooled DX units, and water cooled chillers.

Strategy ID	Heat Pump Efficiency Strategies	Baseline	Strategy EER/COP	Reference Size Tons	Notes
MPT01	As-designed mini-split heat pumps (Apartments)	9.0 EER/ 3.0 COP	20.2 SEER/ 11.6 HSPF 12.8 EER/ 3.8 COP	0.0 to 5.4 Tons	ton weighted average efficiencies
MPT03	As-designed heat pump (Community and Fitness)	13.0 SEER/ 7.7 HSPF	16 SEER/ 9.0 HSPF	0.0 to 5.4 Tons	

Strategy ID	Fan Strategies	Baseline	Strategy Level	Notes
MFD00	Baseline fan system power limitation	Section 6.5.3	Maximum allowed	0.31 bhp/1000cfm
MFD04	Proposed fan system design at 0.17 bhp/1000 cfm	Section 6.5.3	proposed design	0.17 bhp/1000 cfm

90.1-2010 keeps requirement for VFD on VAV fan motors at 10 hp and larger.

Strategy ID	Conditioning of Outside Air Strategies	Baseline	Strategy Level	Notes
MOA02	OS control of bathroom exhaust fan	No control	OS control	
MHRS1	Sensible heat recovery (Fitness)	No recovery	65% Effic	
MHRT1	Total heat recovery (Fitness)	No recovery	65% Sensible	65% latent

90.1-2010 requires energy recovery on more AHUs based on outdoor air volumes.

Strategy ID	Service Water Heating Strategies	Baseline	Strategy Level	Notes
MHW01	91.7% service water heating efficiency	80%	at least 91.7%	
MHW02	92.5% service water heating efficiency	80%	at least 92.5%	
MHW03	94.1% service water heating efficiency	80%	at least 94.1%	

Strategy ID	Appliance Efficiency Strategies	Baseline	Strategy Level	Units	Notes
ACW01	Energy Star clothes washers, alt 1	1.26	2.00	MEF	
ACW02	Energy Star clothes washers, alt 2	1.26	2.40	MEF	
ADW01	Energy Star dishwashers, alt 1	355	295	kWh/yr	
ADW02	Energy Star dishwashers, alt 2	355	245	kWh/yr	
ARF01	Energy Star refrigerators, alt 1	NAECA	20% better	kWh/yr	
ARF02	Energy Star refrigerators, alt 2	NAECA	30% better	kWh/yr	
AHW01	Low flow showerheads	2.5	1.6	gpm @ 80 psi	
AHW02	Low flow kitchen and bathroom sink aerators	2.2	1.0	gpm @ 80 psi	

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Integrated Utility Savings

The table below shows Whole Building results for various individual strategies or groups of strategies in order to show where the best opportunities are. Note that dollar savings affect payback, and savings accrue every year for the life of the building.

Strategy Description	How does this strategy save energy?	Annual Energy Savings	For detailed strategy descriptions go to section entitled...
As-designed mini-split heat pumps (Apartments)	Cooling and heating energy is reduced by an increased system efficiency	$13,906	HVAC Efficiency Strategies
Lowest wattage lighting design	Lighting wattage is saved by reducing light level or increasing lighting system efficiency	$7,533	Lighting Design Strategies
Appliance efficiencies	Gas and electric consumption of appliances is reduced by selection of efficient equipment	$6,811	Appliance Efficiency Strategies
OS control of bathroom exhaust fan	Heating and cooling energy are reduced by lowering ventilation rates when bathrooms are unoccupied	$3,985	Conditioning of Outside Air Strategies
Fan system power reduction	Building fans energy is reduced relative to maximum allowed by Section 6.5.3	$3,255	Fan Strategies
Best SWH system	Gas consumption is reduced by using high efficiency service water heaters	$1,942	Service Water Heating Strategies
Max envelope	Heating and cooling load is reduced by increasing insulation levels	$1,790	Envelope Insulation Strategies
Occupancy sensor control of lighting	Lighting energy is saved by turning lights off when applicable spaces are empty	$998	Lighting Control Strategies
Total heat recovery	Heating and cooling energy are reduced by recovering heat from building exhaust air	$641	Conditioning of Outside Air Strategies
Reduced infiltration	Heating and cooling load is reduced by reducing infiltration levels	$593	Other Envelope Strategies

The strategies are defined in detail beginning on page 18 of the Report, as well as selected Appendix sections, which may be found beginning on page 48. The chart on the following page provides further visual comparison of the savings potential of these key strategies.

Hourly Whole Building analysis allows us to present integrated results. Individual conservation and efficiency strategies can affect more than one fuel source. For example, a more efficient lighting design will produce less heat in a building. This reduction in interior heat gain also reduces cooling energy needs. If cooling energy is produced by electricity, those savings are integrated into the *Annual Dollar Savings* above. However, that more efficient lighting may cause a need for more heating energy in the winter. If the heating energy came from consuming gas, the additional heating cost would also be reflected in the values above.

We use the same methodology throughout this Report. A positive *Annual Dollar Savings* means that the offsetting changes between electric consumption, gas consumption and central or district energy consumption result in a savings.

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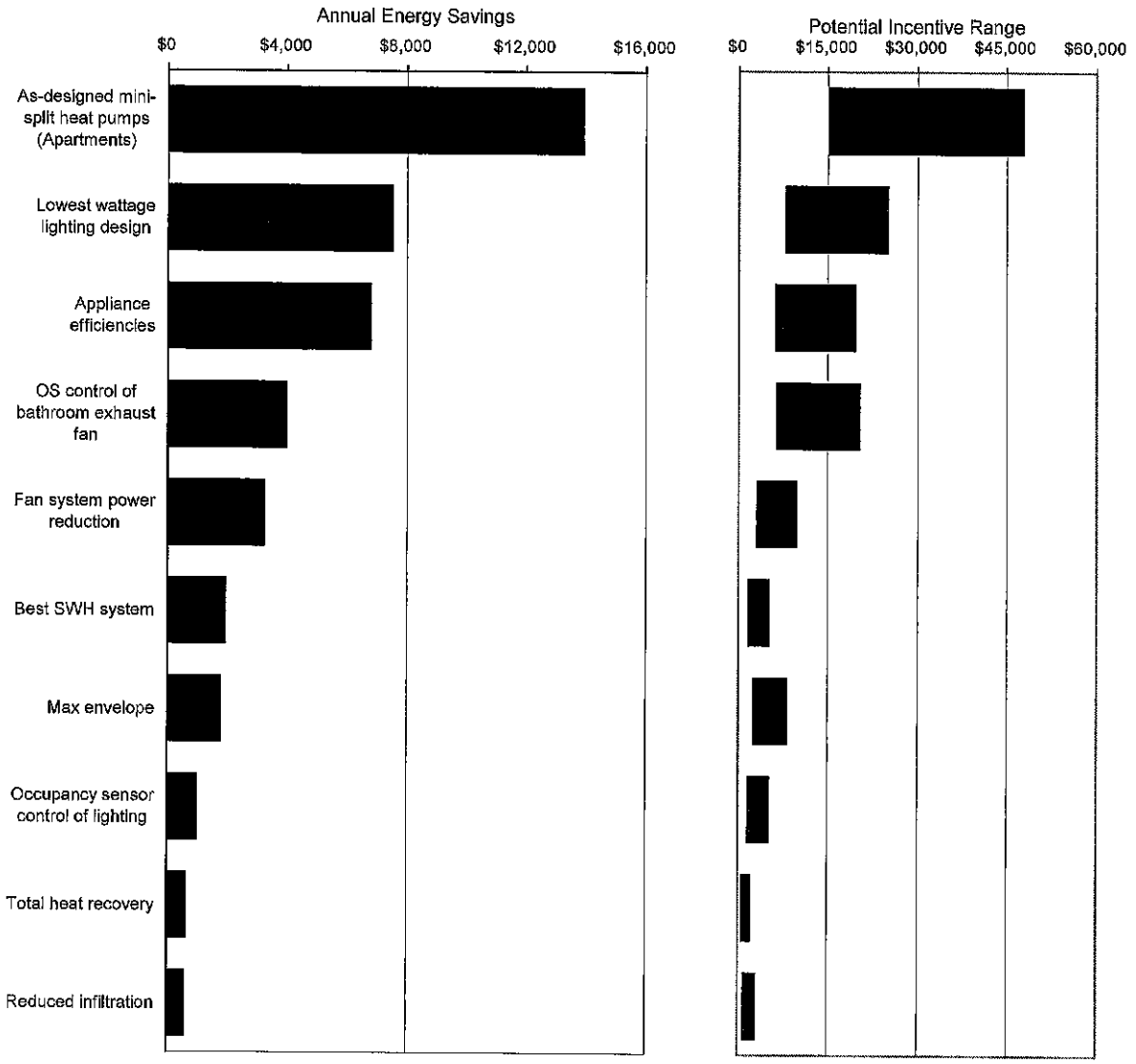

Key Observations

- The as-designed mini split heat pump system shows the highest savings and incentive potential. The mini-split heat pump units show heating, cooling, and fan energy savings compared to the baseline system
- Reduced lighting power densities in the apartment spaces and common areas also show significant savings potential. The lighting design savings above account for as-designed lighting power densities in the apartments, efficiency units, corridors, and stairs; and a 30% lighting power reduction is applied to all remaining spaces
- EnergyStar appliances and low flow showerheads and faucets show significant equipment energy savings

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Strategy Descriptions and Results

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Envelope Insulation Strategies

Strategy Objectives

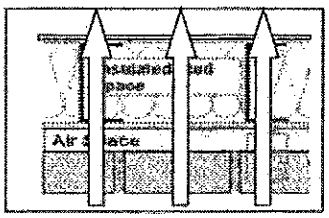
Minimize heat loss through cost-effective insulation choices.

Strategy Descriptions

The envelope insulation strategies incorporate additional insulation to the roof and walls of the building. The insulation R factors listed in the table below are overall average thermal resistance values of the entire wall or roof assembly, accounting for:

- Effects of thermal bridging of structural elements such as studs, joists, columns, etc.
- Average thickness of tapered roofs
- Average for multiple wall or roof assemblies
- Exterior and interior finishes and air films

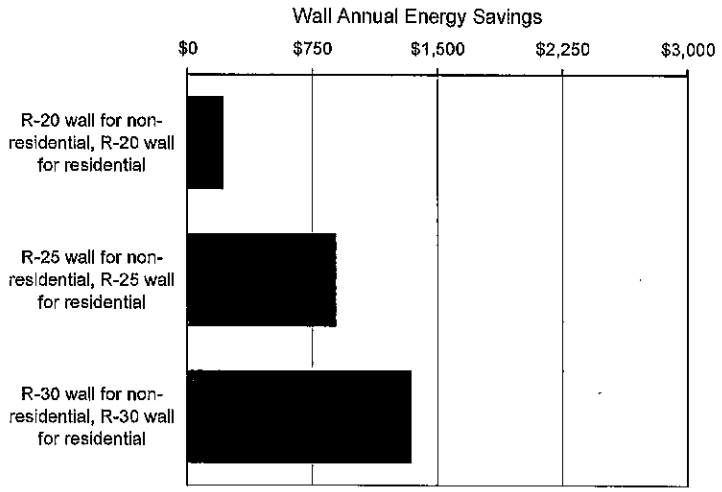
The following table identifies a few wall construction types to illustrate the effect of thermal bridging.

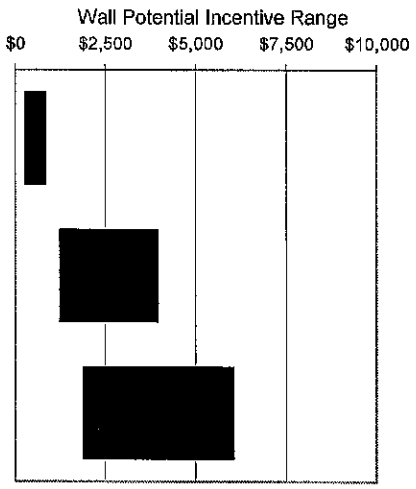
Thermal Bridging in a Stud Wall	Typical Construction	Assembly
 R-3 R-22 R-3	6" metal studs with R-19 batt insulation	R-10 (U-0.10)
	6" wood studs with R-19 batt insulation	R-16 (U-0.06)
	6" metal studs with R-19 batt insulation and R-6 (1" polyiso) continuous insulation	R-16 (U-0.06)
	8" CMU with R-12 (2" polyisocyanurate) continuous insulation	R-16 (U-0.06)

Strategy ID	Envelope Insulation Strategies	Baseline	Strategy Level	Notes
EWN00	Baseline wall assembly: non-residential/ residential	R-15.6/ R-19.6	R-15.6/ R-19.6	
EWN01	R-20 wall for non-residential, R-20 wall for residential	R-15.6/ R-19.6	R-20	
EWN02	R-25 wall for non-residential, R-25 wall for residential	R-15.6/ R-19.6	R-25	
EWN03	R-30 wall for non-residential, R-30 wall for residential	R-15.6/ R-19.6	R-30	
ERN00	Baseline roof assembly: non-residential/ residential	R-37/ R-37	R-37	
ERN01	R-50 roof for non-residential, R-50 roof for residential	R-37/ R-37	R-50	
ERN02	R-60 roof for non-residential, R-60 roof for residential	R-37/ R-37	R-60	

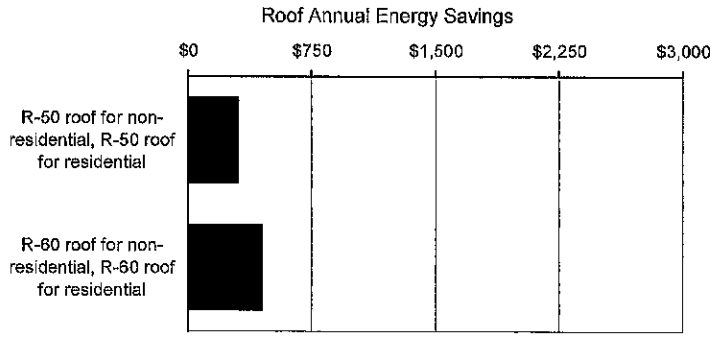
Envelope Insulation Results

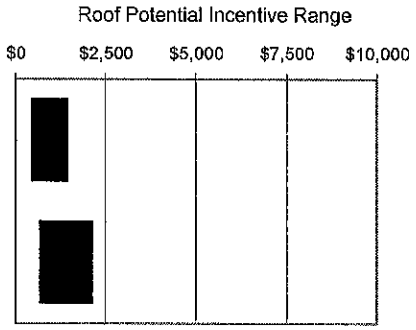
Wall Insulation Variations





Roof Insulation Variations





Key Points

- Increased insulation values for roof and walls generally save heating energy
- In general, increasing roof and wall insulation values will not be as cost-effective as the other strategies that have been investigated

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Other Envelope Strategies

Strategy Objectives

Reduce undesired heat loss or gain through cost-effective envelope upgrades beyond increased thermal resistance.

Strategy Descriptions

Reduced Infiltration: Represents reduced infiltration via improved construction practice. More information on construction practice strategies may be found in ASHRAE 90.1-2010 Section 5.4.3 Air Leakage. Reduced infiltration strategy credit will require air barrier construction photos of key wall locations prior to enclosure and blower door test results. Blower door testing fees are the responsibility of the Owner or Design Team.

The calculation methodology for reduced infiltration strategies is still under development for many energy efficiency standards, including ASHRAE 90.1 and the Performance Rating Method described in Appendix G. In addition, the test protocols to determine a building's air infiltration are not representative of a building's operational condition. Air infiltration testing is conducted using a blower door test with a fixed test pressure drop of 75 Pa placed on the building which is approximately equivalent to a constant 25 mph wind. Under these conditions a "baseline" infiltration value is around 0.4 cfm/sf, where the denominator square footage is the entire exposed envelope area of the building. The "improved" infiltration value reported here is assumed to be 0.25 cfm/sf, again when the building is subject to a 75 Pa test pressure drop.

In reality, infiltration is subject to the exterior wind velocity and direction, as well as the building's pressurization developed by the air handling system. In addition, tall buildings exhibit a "stack effect" which draws in exterior air near the ground and relieves it near the top of the building naturally, similar to the draw through a chimney. The program modeling methodology does not have the capability to model all of these factors.

For this energy model, the baseline is simulated with a 0.6 (apartments) and 0.1 (common spaces) air change per hour infiltration rate, and the program adjusts this rate according to the operating schedule of the ventilation system and the wind speed/direction from the weather file. Reduced infiltration envelope measures are calculated using a ratio of "improved-to-baseline" assumptions.

Window Quilts: Represents reduced infiltration and improved window characteristics through the installation of window quilts on all windows and sliding doors throughout the apartments and common areas.

Strategy ID	Other Envelope Strategies	Baseline	Strategy Level	Notes
EWRF2	Reduced infiltration	standard	reduced	
EWWQ2	Window Quilts	no quilt	quilt	

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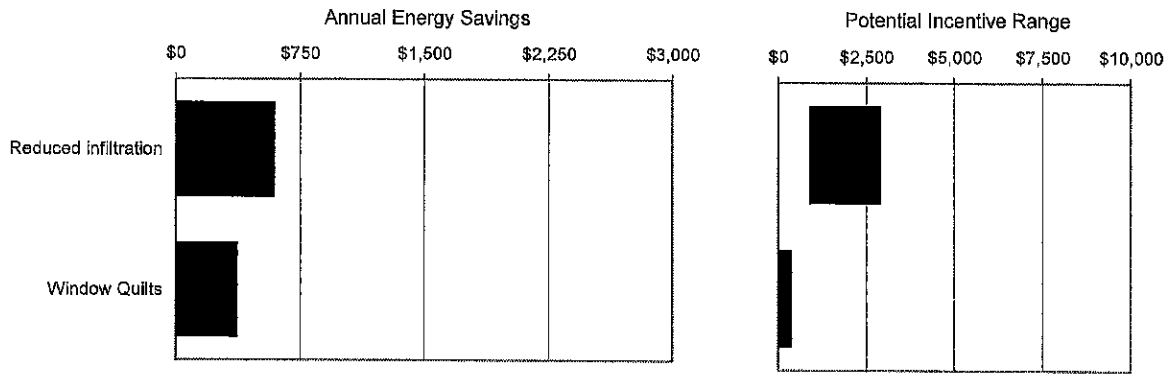
Other Envelope Results



Key Points

- The reduced infiltration show some savings potential over the baseline
- Use of window quilts shows some energy savings potential when compared to baseline manually controlled blinds

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Glazing Strategies

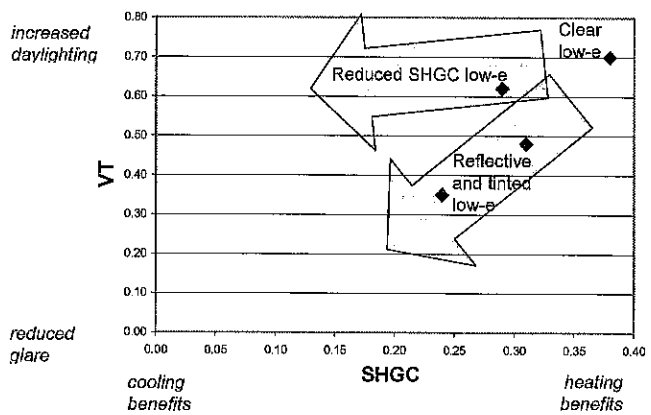
Strategy Objectives

Manage heat gain, and daylighting through appropriate glass selection.

Strategy Descriptions

A variety of glass types are evaluated compared to the Baseline level glass assembly.

The strategies listed below bracket a range of glazing characteristics which are available from a number of manufacturers, along with a much larger range of variations based on extent and color of coatings and tints, number of panes and suspended films, etc. Other characteristics specific to one manufacturer or product can be simulated.



Solar heat gain coefficient (SHGC) is the fraction of total incident solar radiation that is transferred through the glazing system.

Visible light transmittance is a ratio of the amount of light radiation transmitted through the glass compared to the amount of light striking the exterior surface. Higher values provide more daylight.

Strategy ID	Glazing Strategies	Unit U-Factor	COG U-Factor	SHGC	Visible Trans.
WGA01	Baseline: Nonmetal framing	0.35	N/A	0.40	0.44
WGB01	Design Glass: M1 Casement	0.27	0.24	0.25	0.44
WGC01	Design Glass: Sliding Doors	0.31	0.28	0.32	0.59

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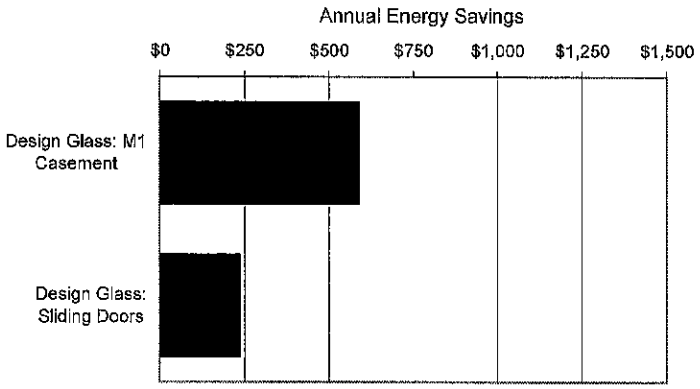
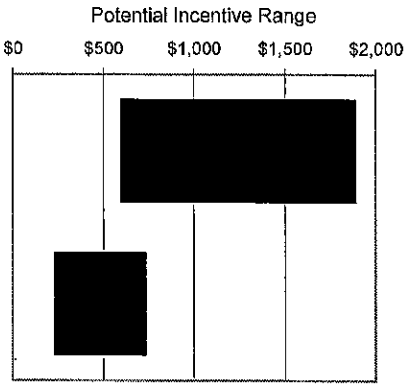
Glazing Results





Key Points

- The as-designed glazing systems for the windows and sliding doors show some heating and cooling energy savings compared to code glass
- Note that these results do not include daylighting controls, and thus the effects of Visible Transmittance are not accounted for. See the Daylighting Controls section that follows for the impact of Visible Transmittance

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Daylighting Control Strategies

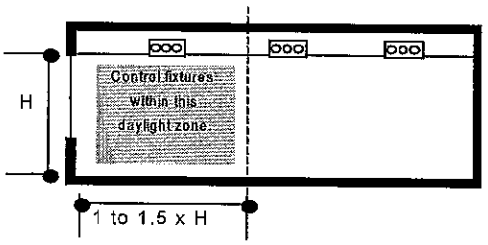
Strategy Objectives

Reduce electric lighting in spaces with daylight, utilizing automated or manual controls.

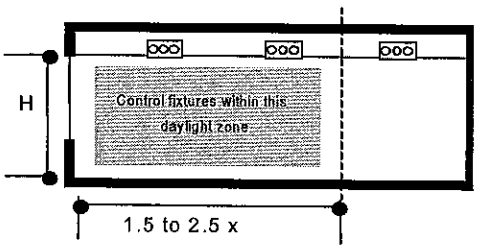
Strategy Descriptions

Two types of daylight controls are considered for various spaces in the building.

Stepped Daylighting Control Systems turn off selected lamps/fixtures within the daylight control zone. This works best where the daylight level is above the design light level most of the day. Control device options include *exterior* or *interior photo-sensors* measuring the daylight source connected to a lighting relay able to switch lights on or off based on daylight availability or an *astronomical time clock*, programmed to automatically switch lights off after sunrise and on before sunset, varying daily.



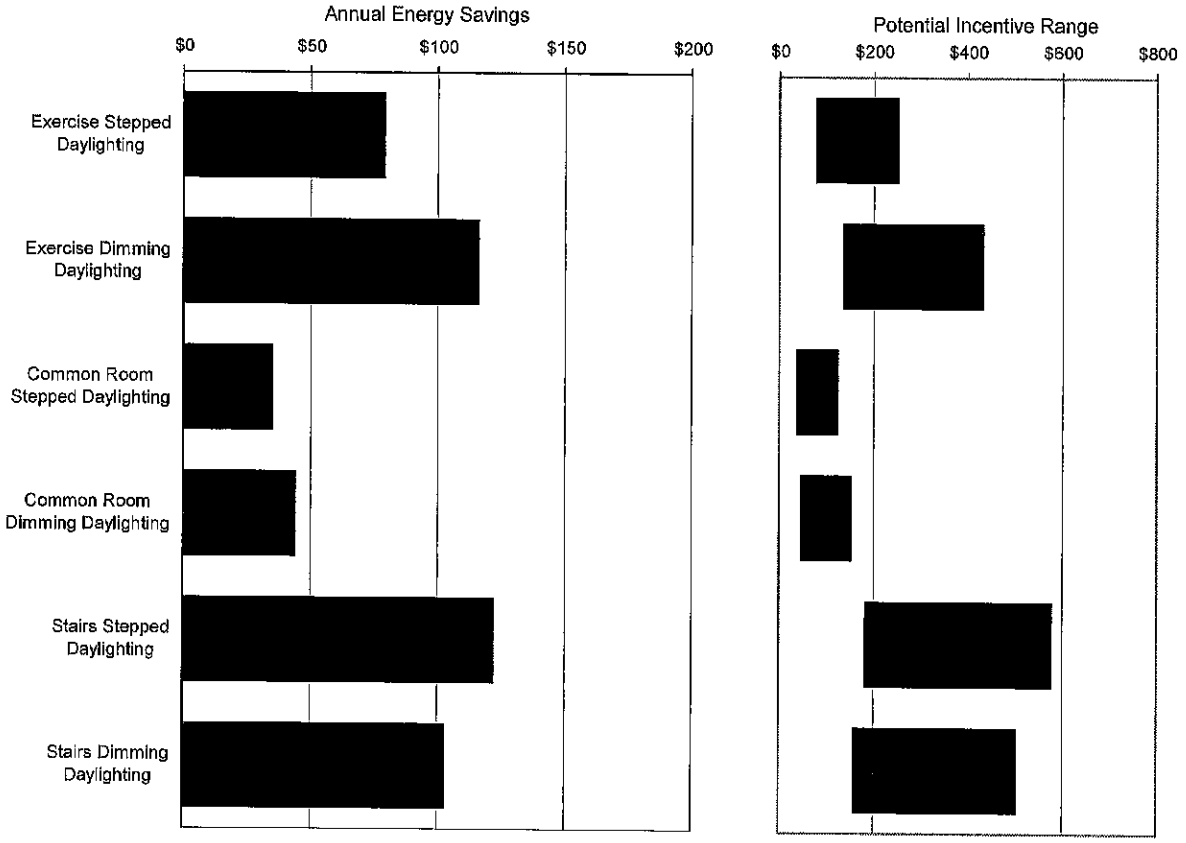
Dimming Daylighting Control Systems use interior photo-sensors to control electronic dimming ballasts that gradually dim or brighten lamps within the daylight zone. This system can be transparent to the building occupant since the dimming system continuously maintains the designed light levels without switching lamps on or off.



Strategy ID	Daylighting Control Strategies	Region of building	Daylight Control	Notes
DGA02	Exercise Stepped Daylighting		Fluorescent Stepped	1,408 sf of area controlled
DGA03	Exercise Dimming Daylighting		Fluorescent Dimming	1,877 sf of area controlled
DGA04	Common Room Stepped Daylighting		Fluorescent Stepped	543 sf of area controlled
DGA05	Common Room Dimming Daylighting		Fluorescent Dimming	724 sf of area controlled
DGA06	Stairs Stepped Daylighting		Fluorescent Stepped	1,728 sf of area controlled
DGA07	Stairs Dimming Daylighting		Fluorescent Dimming	1,728 sf of area controlled

Automated multistep daylighting controls for primary sidelighted areas ≥ 250 sf is required by 90.1-2010
Automated multistep daylighting controls for toplighting when area under skylights or rooftop monitors > 900 sf is required by 90.1-2010

Daylighting Control Results



Key Points

- Daylight control strategies provide some lighting energy savings
- Daylighting control in the stairs area has been applied to 50% of the lights on each landing. The stepped strategy is showing higher savings potential than the dimming strategy, as the stepped strategy is assumed to turn completely off while the dimming control is assumed to dim to a minimum level (30%)

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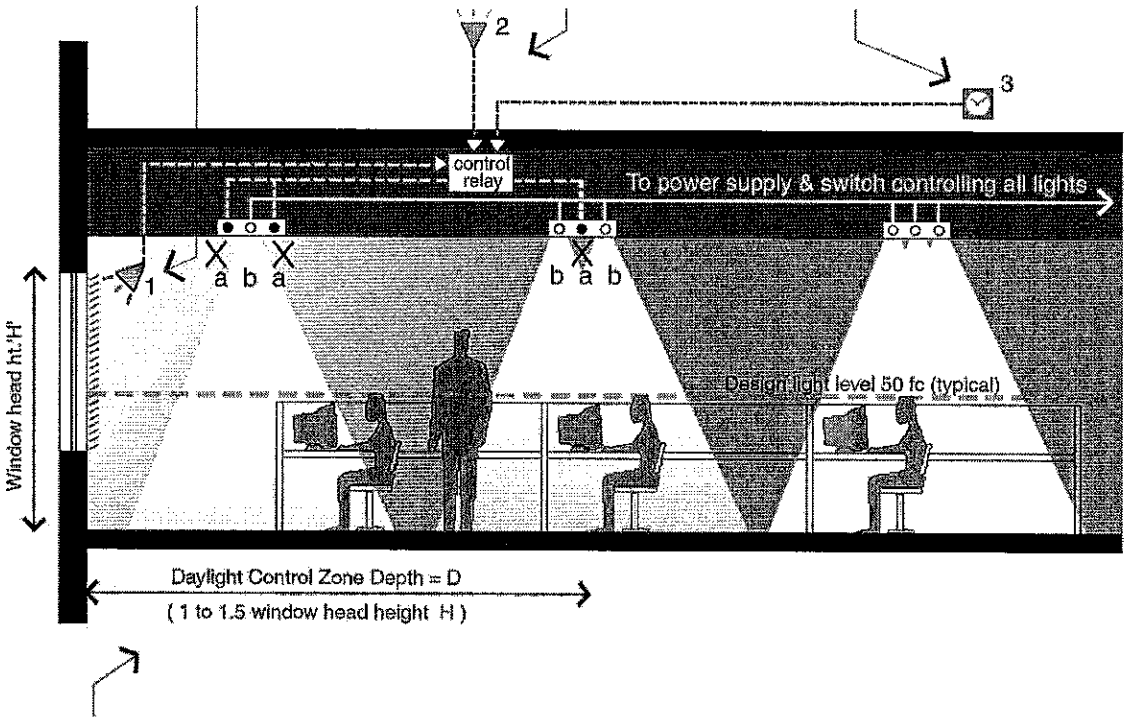
Stepped Daylighting Controls

type	1. Interior Photosensor Viewing Out to Window	2. Exterior Photosensor Viewing out to Sky	3. Astronomical TimeClock
	Can have one sensor and relay for each orientation and by floor if desired. IMPORTANT to shield sensor from light from indirect fixtures hanging below it.	Provides one control for all perimeter lighting control relays in building.	Part of BAS or stand-alone component. Provides one control for all perimeter lighting control relays in building.
advantage	Greater control of light for space	Fewer sensors to calibrate	Simple system to setup and operate
disadvantage	More controls to calibrate	Less energy saving due to wider deadband setting	May need overide during periods of very dark cloud cover
sensor range	10-200 FC	100-1000 FC	N/A
calibration	OFF at 50-100 FC & ON at 25-50 FC	OFF at 600-1000 FC and ON at 300-500 FC	Set latitude of building location OFF: 1 to 1.5 hours after sunrise ON: 1 to 1.5 hours before sunset



Control lamps in fixtures where daylight level is normally above design light level and DO NOT control ALL lamps in each fixture.

Tandem wire ballasts in each lamp to provide inboard/outboard switching for occupant control.

● ○ ● 3-lamp fixture with lamps denoted by '●' are on the daylight relay and lamps denoted by 'O' are not.

Diagram above is for a typical open office space. For classroom spaces provide"aba" switching for all light fixtures in room and place the inboard lamp on the daylight control relay.

Dimming Daylighting Controls

type

Continuous Dimming Closed Loop Photosensor & Controller
Controller and Photosensor can be separate or single device.
For open plan office use at least one sensor per space per floor per orientation.
For class room spaces use one sensor controlling all lamps in room.

Electronic Dimming Ballast
Use electronic dimming ballasts for all lamps in the daylight control zone. Connect control wires (typically low voltage) from photosensor controller to all dimming ballast in the control zone.

advantage

Continuous & gradual dimming of the light source improves the occupant comfort & reduces the potential complaints compared to the stepped daylighting control.
Additional savings with lumen maintenance: Brand new lighting systems provide 20 to 35% more light than desired to account for the degradation in light output over time. A well-calibrated control system provides additional savings by dimming lamps to the desired light level, with or without daylight.

disadvantage

Higher first cost compared to stepped daylighting control.

sensor range

5-100 FC

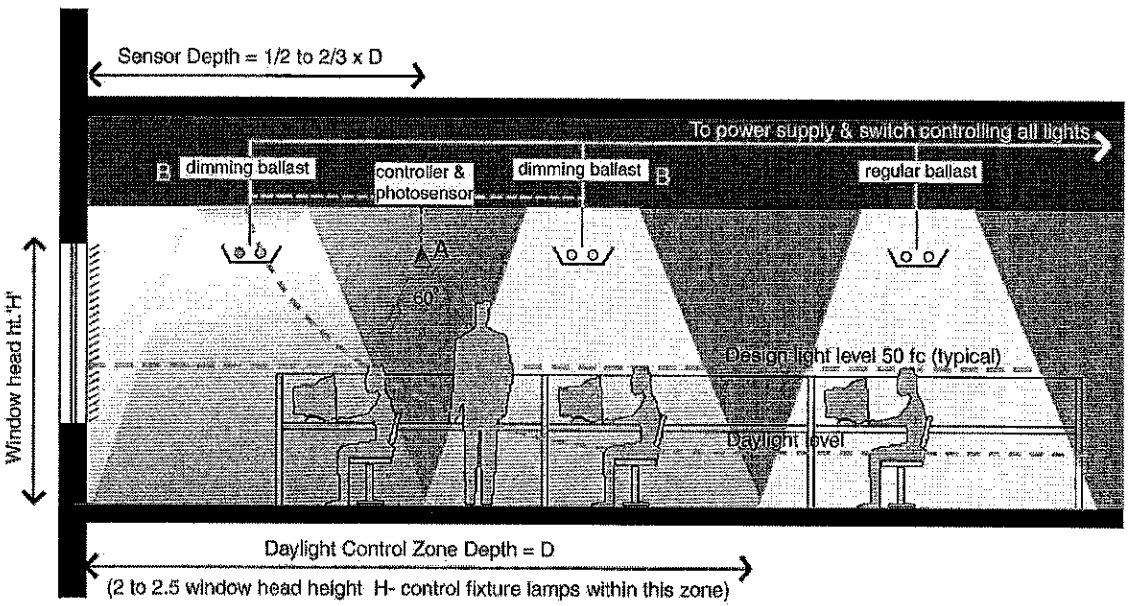
calibration

Photosensor & Controller

Max. dimming setpoint:	Set to begin dimming at design light level- typ. 50 FC
Min. dimming setpoint:	Set to dim no less than 20% of full light output
Time delay:	Set from 3 to 8 minutes
Fade rate:	Specify at least a 20 second time fade from min. to max. dimming
Control output signal:	Specify compatibility with ballast input signal, typically 1-10 vdc

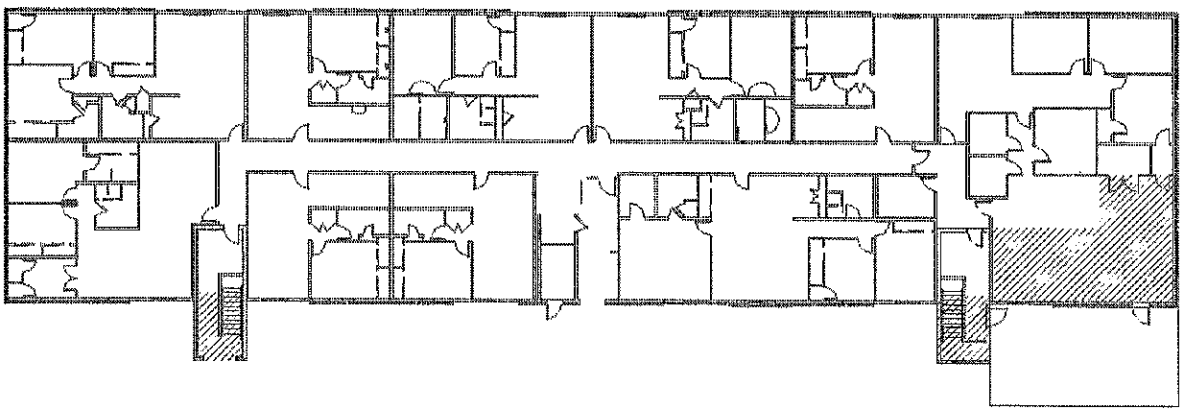
Dimming Ballast

Min. dimming range:	10 to 20%
No. of ballasts on control:	Check the manufacturer's min & max number of ballasts per control

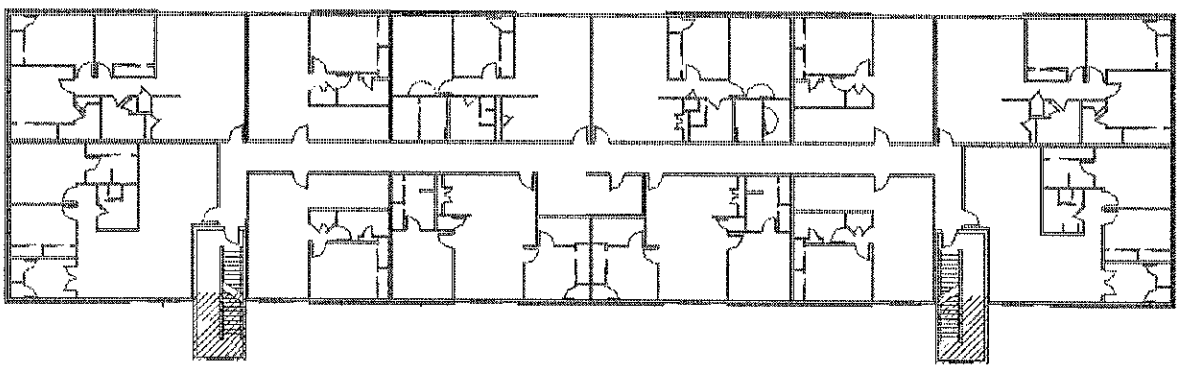


A Continuous Dimming Photosensor typically views a 60°cone of view of the workplane luminance. For indirect fixture designs it is IMPORTANT to shield or locate sensor below fixture to prevent unwanted light from fixture directly controlling system.

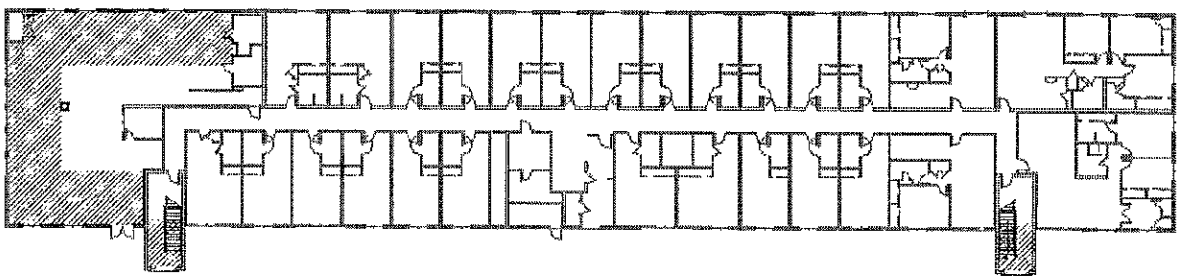
Daylighting Control Zones



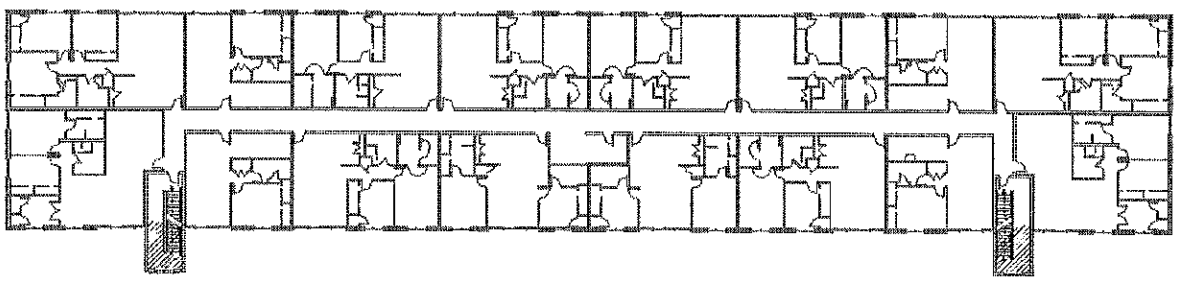
Building A – Level One Floor Plan



Building A – Level Two and Level Three Floor Plan



Building B – Level One Floor Plan



Building B – Level Two and Level Three Floor Plan

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Lighting Control Strategies

Strategy Objectives

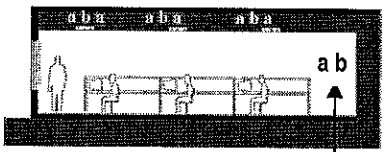
Reduce electric lighting energy by turning lights off (or down) when they are not needed.

Strategy Descriptions

Occupancy sensor control is appropriate for most space types where it is common for lights to be on when no one is present for periods throughout the day. To reduce "False-Ons" the sensor should not view out a door or into adjacent spaces. A wall switch is still required to allow occupants to turn lights off when space is occupied.

Dual level occupancy sensor control of lights is applicable for smaller enclosed spaces. The control comprises an occupancy sensor with two switches that control two separate lighting circuits in the room. The circuits connect separate fixtures in the space or separate lamps in each fixture. As the wall-mounted sensor detects occupancy, it switches 'on' one of the lighting circuits. The other circuit has to be manually turned 'on'. If no occupancy is detected for an extended period, the occupancy sensor switches 'off' both circuits. If the space has access to daylighting, the savings can increase further. Presently, this type of integrated sensor is manufactured by Lutron, Sensor Switch and Wattstopper.

Dual level fixture is applicable for rooms with variable light level requirements. Manual switches provide for two or more levels of light output. These strategies provide greatest savings opportunities when switch design follows an inboard–outboard ("b" lamp "a" lamp) scheme per fixture.



Dual Level a & b switches at Entry to room

Strategy ID	Lighting Control Strategies	Peak reduction	Annual hrs reduction	Notes
LCCI1	Circulation occupancy sensor control	20%	30%	
LCCI2	Circulation occupancy sensor control to 1/2 level	10%	15%	
LCST1	Storage occupancy sensor control	50%	70%	
LCME1	Mech/elec occupancy sensor control	50%	70%	
LCRR1	Restroom occupancy sensor control	35%	55%	
LCFT1	Exercise occupancy sensor control	25%	40%	
LCLR1	Locker Room & Shower occupancy sensor control	30%	50%	
LCCM1	Community Room occupancy sensor control	25%	40%	
LCPO1	Private office occupancy sensor control	15%	40%	
LCPO3	Private office dual level occupancy sensor control	20%	45%	
LCPO4	Private office dual level fixture	15%	15%	
LCOO1	Open office occupancy sensor control	0%	40%	
LCLA1	Laundry occupancy sensor control	25%	40%	
LCSV1	Serving occupancy sensor control	5%	25%	
LCSW1	Stairs occupancy sensor control	20%	30%	
LCSW2	Stairs occupancy sensor control to 1/2 level	10%	15%	

90.1-2010 requires space control with dual level fixtures as well as occupancy sensors in most spaces

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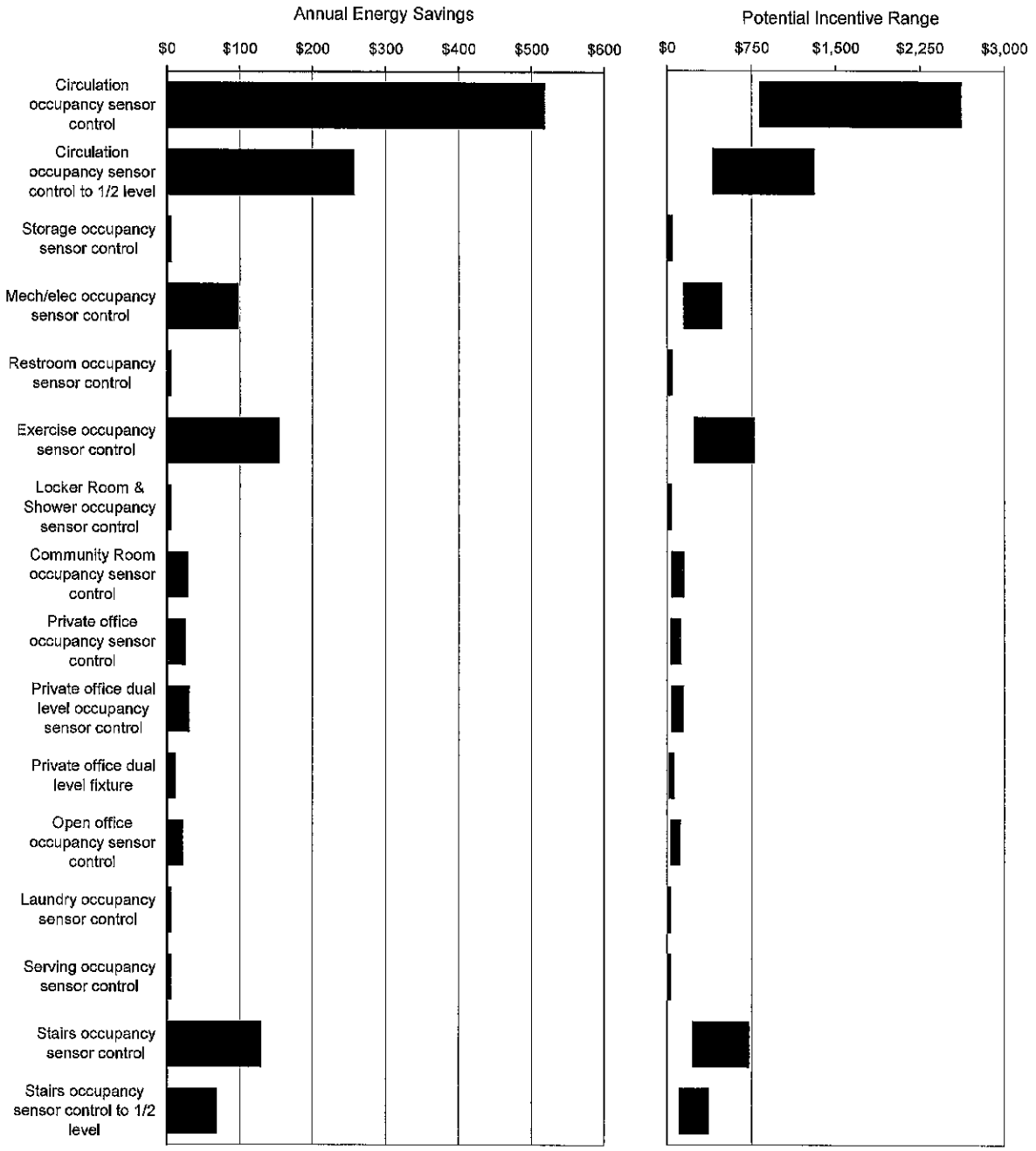
Lighting Control Results



Key Points

- Savings due to occupancy sensors can be significant for a building with diverse functions and rooms with intermittent use
- Depending on the base lighting level and occupancy assumptions, some space types save more than others
- If your occupancy patterns are different from those assumed for this model, savings could vary from results presented

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Lighting Design Strategies

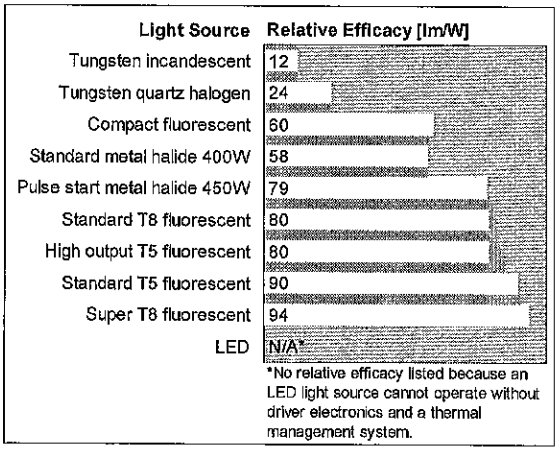
Strategy Objectives

Reduce electric lighting energy through appropriate lighting equipment selection and layout.

Strategy Descriptions

The design strategies listed below may combine various light sources, luminaire types, layouts, and surface reflectances (wall, ceiling, etc) to achieve a desired light level in footcandles (fc).

Light Source Type has the largest impact on reducing the overall lighting power density. Light sources with high efficacies (high lumens per Watt) will require less power for the same light output, all other factors being equal. The graph to the right shows the average efficacies of various light sources. These values are known as *relative efficacies* because they are for the light source only, before taking into account losses from the fixture, optics and other components.



Luminaire Type also influences lighting power density because some luminaires are more effective at providing general ambient lighting, while others are intended to provide directional and/or supplemental lighting. *Absolute efficacy* accounts for the combined efficiency of both the light source and the luminaire. The table below shows typical ranges for absolute efficacies of various types of complete luminaires (lamp plus fixture and other components).

Luminaire Type	Light Source	Absolute (Luminaire) Efficacy [lm/W]
Recessed Downlight	Compact Fluorescent	27 – 53
	LED	33 – 75
Track/Spotlight	LED	25 – 48
2X2 Troffer	17W T8 Linear Fluorescent	49
	32W T8 U-bent Fluorescent	44 – 56
	28W T5 Single Tube CFL	60 – 64
	LED	36 – 80
High Bay	Metal Halide	53
	Standard T8 Fluorescent	79
	LED	51 – 80
Under Cabinet	Compact Fluorescent	20 – 36
	LED	16 – 54
Task/Portable	Halogen	9 – 11
	Compact Fluorescent	24 – 43
	LED	16 – 42

Source: DOE Commercially Available LED Product Evaluation and Reporting (CALiPER) program, Detailed Test Reports, Jul 2006 – Oct 2011.

Total Lumen Output of the luminaire is also important to consider. Although a particular luminaire may have a high efficacy (lumen output per Watt), the total lumen output may be lower than a comparable luminaire. This is particularly true of LED luminaires. More luminaires arranged in a tighter spacing would then be required in order to achieve the desired light level.

Strategy ID	Lighting Design Strategies	Baseline	Strategy max W/sf	Notes
L01BW	Corridor and stairs at As-designed LPD, Other public spaces at 10% lower than 90.1-2007 LPD (excludes apartments)	0.68	0.53	Fluorescent
L02BW	Corridor and stairs at As-designed LPD, Other public spaces at 20% lower than 90.1-2007 LPD (excludes apartments)	0.68	0.50	Fluorescent
L03BW	Corridor and stairs at As-designed LPD, Other public spaces at 30% lower than 90.1-2007 LPD (excludes apartments)	0.68	0.47	LED
L01AP	Apartment lighting alt 1, 30% lower than baseline (includes efficiency units)	1.54	1.08	
L02AP	Apartment lighting alt 2, As-designed (includes efficiency units)	1.54	0.43 (Apts) 0.57 (Eff. Units)	

90.1-2010 slightly reduces the interior lighting power allowance for most spaces. Exterior lighting allowances are also reduced in the standard.

Important: These are example design strategies that bracket a range of installed watts per sq. ft., based on generic lighting design alternatives. Watts/sq. ft. is the critical metric defining each strategy – not footcandle or system type.

Space by Space Lighting Power Density (W/sf)

Lighting Design				
Space Type	**Baseline LPD (W/sf)**	**L01BW**	**L02BW**	**L03BW**
Circulation	0.50	0.31	0.31	0.31
Storage	0.80	0.72	0.64	0.56
Mech/elec	1.50	1.35	1.20	1.05
Restroom	0.90	0.81	0.72	0.63
Exercise	0.90	0.81	0.72	0.63
Locker Room & Shower	0.60	0.54	0.48	0.42
Community Room	1.30	1.17	1.04	0.91
Computer	1.20	1.08	0.96	0.84
Private office	1.10	0.99	0.88	0.77
Open office	1.10	0.99	0.88	0.77
Laundry	0.60	0.54	0.48	0.42
Serving	1.20	1.08	0.96	0.84
Stairs	0.50	0.42	0.42	0.42

Note: Apartment and Efficiency Units are excluded from L01BW, L02BW, and L03BW. Lighting improvements for these space are modeled in separate strategies listed above (L01AP and L02AP)

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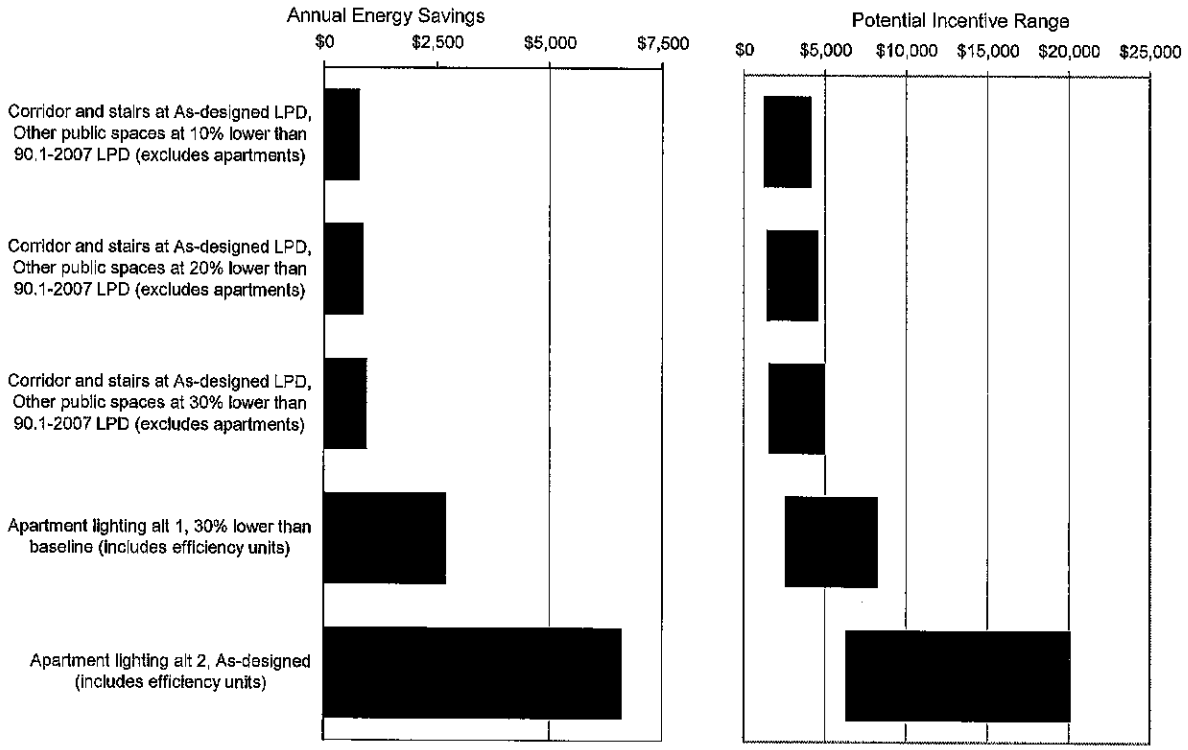
Lighting Design Results



Key Points

- Successful implementation of these strategies requires the power density ranges in the table to the left be met for each lighting design strategy selected
- As-designed lighting power densities were provided for the corridor and stair spaces, thus the common area lighting power strategies include the as-designed values for the corridor and stairs and then apply a 10%, 20%, and 30% reduction to the remaining spaces.
- As-designed lighting power densities for the apartments and efficiency units are significantly lower than the baseline value of 1.54 W/sf, thus show significant energy savings and incentive potential

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Base HVAC Efficiency Strategies

Strategy Objectives

Reduce energy use by selecting higher efficiency systems

Cooling Strategy Descriptions

Through the wall units: Change from the base system to a high efficiency through the wall AC system. These units will serve the efficiency apartment units, which have electric baseboard heating. The baseline SPVAC equipment base efficiency is 9.0 EER (cooling).

Strategy ID	Cooling Efficiency Strategies	Baseline	Strategy Efficiency	Reference Size Tons	Notes
MPT02	As-designed through the wall units (Efficiency Apartments)	9.0 EER	9.8 EER	0.0 to 5.4 Tons	

90.1-2010 slightly increases the efficiency requirement of PTAC, PTHP, water and evaporatively cooled DX units, and water cooled chillers.

Heating & Cooling Strategy Descriptions

Mini-split heat pumps: Change from the base system to mini-split heat pumps with improved efficiency. Mini-split heat pump units will serve each apartment space (with additional electric baseboard heating in some larger apartments). The baseline SPVHP equipment efficiency is 9.0 EER (cooling) and 3.0 COP (heating).

Air-cooled heat pumps: Change from the base system to heat pumps with improved efficiency. These heat pump units will serve the fitness and community room/office areas. The baseline efficiency is 13.0 SEER (cooling) and 7.7 HSPF (heating).

Strategy ID	Heat Pump Efficiency Strategies	Baseline	Strategy EER/COP	Reference Size Tons	Notes
MPT01	As-designed mini-split heat pumps (Apartments)	9.0 EER/ 3.0 COP	20.2 SEER/ 11.6 HSPF 12.8 EER/ 3.8 COP	0.0 to 5.4 Tons	ton weighted average efficiencies
MPT03	As-designed heat pump (Community and Fitness)	13.0 SEER/ 7.7 HSPF	16 SEER/ 9.0 HSPF	0.0 to 5.4 Tons	

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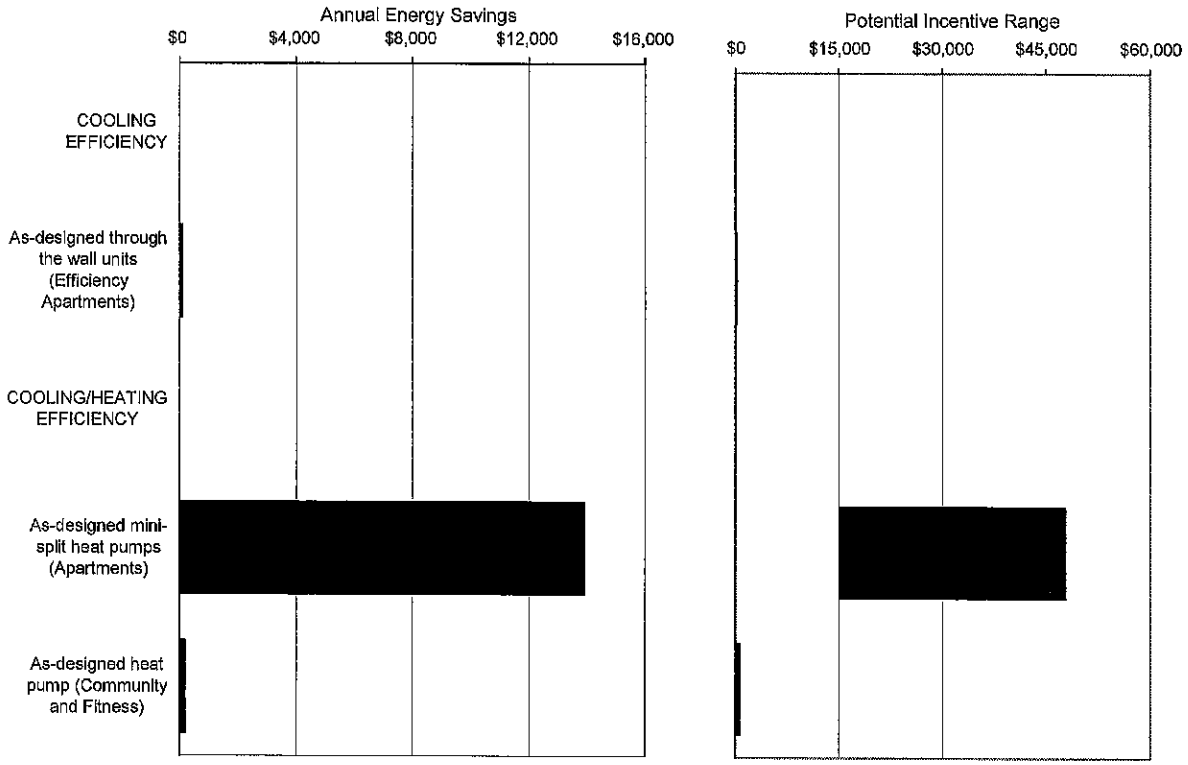
Base HVAC Efficiency Results



Key Points

- The as-designed mini-split heat pump system shows the highest savings and incentive potential of all the strategies that were model
- The through the wall units and air to air heat pump units also show some energy savings, but they are significantly smaller in scale compared to the mini-split heat pumps which serve a much larger portion of the buildings

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Fan System Strategies

Strategy Objectives

Reduce the fan energy necessary to move design supply and return airflow to and from the conditioned spaces. As these selections are integrated with other building systems, study needs to be accomplished early in the design process.

Strategy Descriptions

Reduced fan system power: Fan power reduction strategies are design-specific, thus the potential savings associated with the proposed design are based on the fan power included in the current design. The following paragraph provides an example of one approach to reducing the fan system power.

- **Fan efficiency:** Select fan components with improved operating efficiency. These may be accomplished through the design of the fan housing or the blade pitch. Careful selection nearest maximum efficiency can help reduce static losses inherent within the fan.

Strategy ID	Fan Strategies	Baseline	Strategy Level	Notes
MFD00	Baseline fan system power limitation	Section 6.5.3	Maximum allowed	0.31 bhp/1000cfm
MFD04	Proposed fan system design at 0.17 bhp/1000 cfm	Section 6.5.3	proposed design	0.17 bhp/1000 cfm

90.1-2010 keeps requirement for VFD on VAV fan motors at 10 hp and larger.

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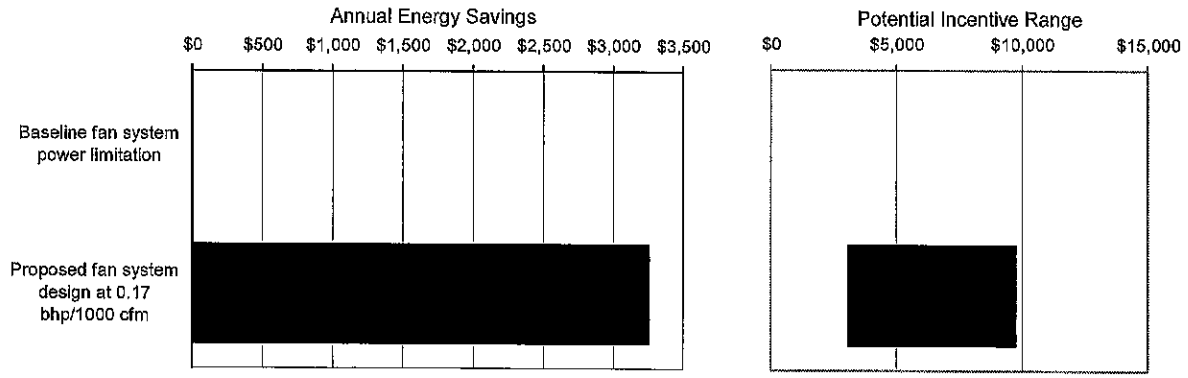
Fan System Results



Key Points

- A reduction in fan power associated with the mini-split heat pump systems serving the apartment spaces shows significant fan energy savings and incentive potential

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Conditioning of Outside Air

Strategy Objectives

Reduce energy use by adjusting the volume of outside air that needs conditioning according to the actual building load or by recovering heat/cool from return air or equipment.

Strategy Descriptions

Sensible Energy Recovery: This strategy represents recovery of sensible heat from the exhaust air streams to the unconditioned ventilation air. This strategy may be accomplished with a run-around loop, flat plate heat exchanger, heat wheel, or heat pipe heat exchanger. This strategy is assumed to have an effectiveness of 65% at design airflow and temperature, and applies to fitness area of the building. The strategy also assumes that 90% of the building exhaust volume is gathered for energy recovery use.

Total Energy Recovery: This strategy represents recovery of both sensible and latent heat from the exhaust air streams to the unconditioned ventilation air. This is typically accomplished using an enthalpy wheel or permeable membrane cross-flow heat exchanger. This strategy is assumed to have both sensible and latent effectiveness of 65% at design airflow and temperature, and applies to fitness area of the building. The strategy also assumes that 90% of the building exhaust volume is gathered for energy recovery use.

Strategy ID	Conditioning of Outside Air Strategies	Baseline	Strategy Level	Notes
MOA02	OS control of bathroom exhaust fan	No control	OS control	
MHRS1	Sensible heat recovery (Fitness)	No recovery	65% Effic	
MHRT1	Total heat recovery (Fitness)	No recovery	65% Sensible	65% latent

90.1-2010 requires energy recovery on more AHUs based on outdoor air volumes.

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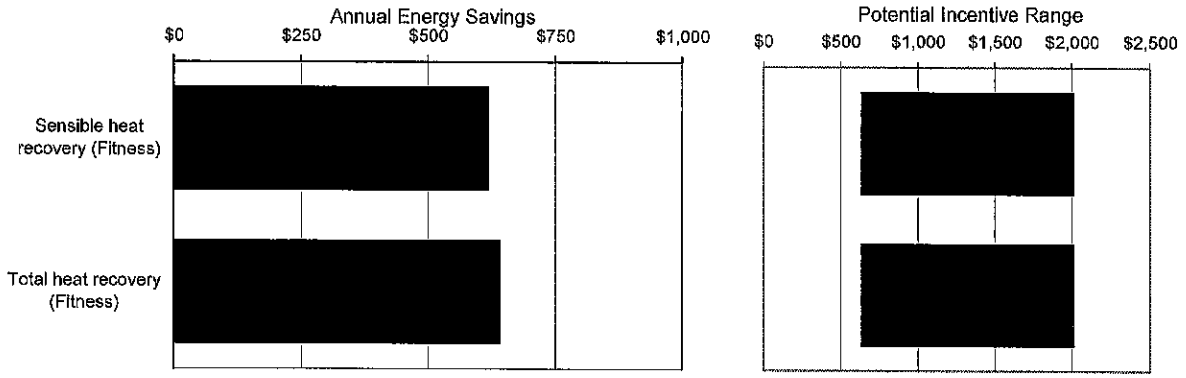
Conditioning of Outside Air Results



Key Points

- Heat recovery for the dedicated outside air system serving the fitness room shows some energy savings potential, with minimal additional savings when adding the latent effectiveness of the total heat recovery option

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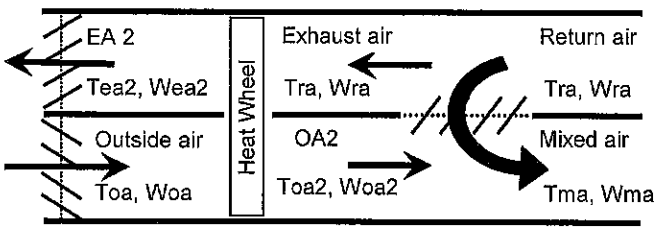
Heat Recovery Control Issues

All heat recovery systems must be able to control the capacity of the heat recovery both to prevent overheating of ventilation air during milder weather and to prevent frost buildup during colder weather. One method of capacity control that applies to all heat recovery system types is the use of an air bypass around the heat recovery media. For run-around loop heat recovery, capacity can be reduced by varying the liquid flow rate, either by throttling or by a variable frequency drive on the pump motor. For heat wheel systems, capacity can be reduced by a variable speed drive on the wheel motor. These issues are best described by examples.

Overheating

To illustrate the issue of overheating, a simple heat wheel can be considered, with a heat recovery effectiveness of 75% and a ventilation rate of 20%. A schematic of the heat wheel as it is situated in an air handler is shown below.

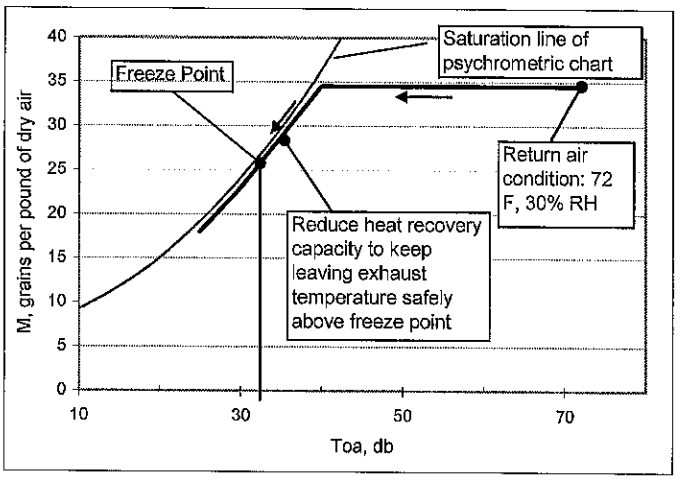


The following table shows the performance of the heat wheel at different outside air temperatures. For each outside air temperature, the table lists the mixed air temperature with no heat recovery, the mixed air temperature with full heat recovery, and the desired mixed air temperature that would just meet the requirements of the air handler. At an outside air temperature of -10 F, the full output of the heat wheel would raise the mixed air temperature to 68 F, or 1 F above the desired temperature of 67 F. In order to prevent this overheating, the capacity of the heat wheel must be reduced to 93%. As outside air temperature increases, the "full recovery" mixed air temperature increases and the desired mixed air temperature decreases due to reduced envelope heat loss. Further reductions in heat recovery capacity are needed to prevent overheating of the mixed air and subsequent re-cooling. For outside temperatures ranging from 20 F to 60 F, the heat wheel must be completely disabled, and the system operates in economizer mode.

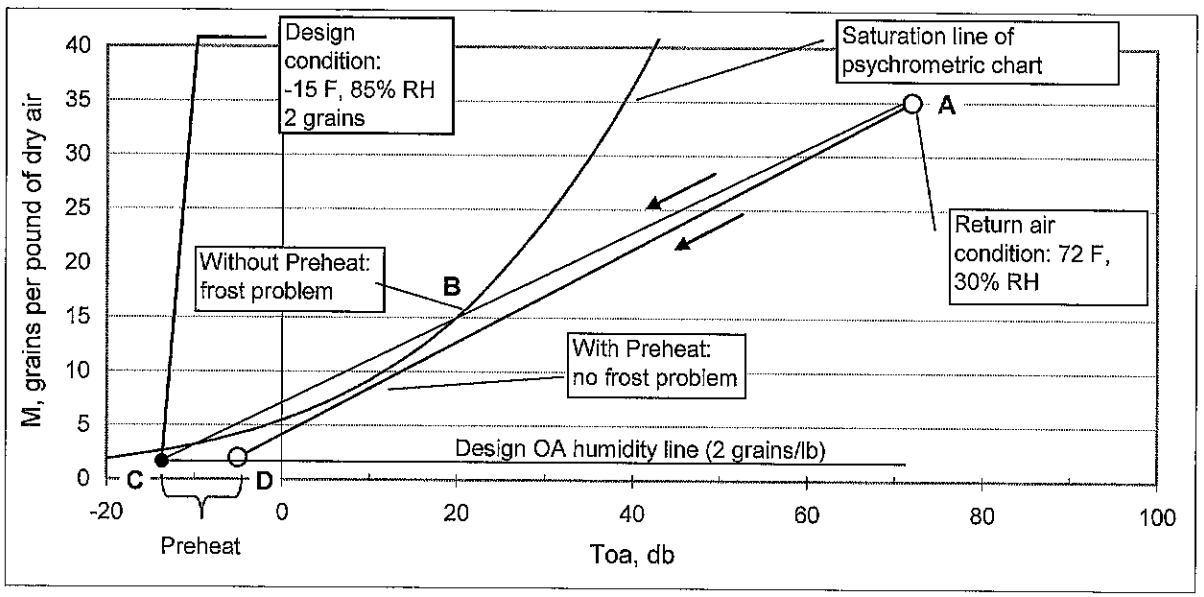
Efficiency	Percent OA	Tra	Toa	Toa2, full recovery	Tma, no recovery	Tma, full recovery	Tma, desired	Heat recovery part load
75%	20%	72	-10	52	56	68	67	93%
75%	20%	72	0	54	58	68	65	69%
75%	20%	72	10	57	60	69	63	37%
75%	20%	72	20	59	62	69	61	0%
75%	20%	72	30	62	64	70	59	0%
75%	20%	72	40	64	66	70	57	0%
75%	20%	72	60	69	70	71	55	0%
75%	20%	72	80	74	74	72	55	100%
75%	20%	72	100	79	78	73	55	100%

Frost Control

When moist return air passes through the exhaust side of a heat recovery system, the temperature of the air drops, and the relative humidity increases. If the temperature reaches the dew point, then water will condense out of the air. If the temperature is below 32° F, then ice can form, potentially damaging the heat exchanger. For a sensible-only heat exchanger, the process starts off following a horizontal line on the psychrometric chart from the return air condition to the dew point, and it then follows the saturation line as shown in the figure to the right.



For a total enthalpy heat exchanger, the process follows a diagonal line on the psychrometric chart that extends from the return air condition to the outside air condition. If the diagonal line crosses the saturation curve (line ABC in the figure below), then condensation will occur, and possibly frost. One method to prevent frost is to reduce the capacity of the heat exchanger (via bypass or wheel speed) to keep the exhaust air from reaching the saturation line (point B). A more effective method to prevent condensation is to preheat the entering ventilation air such that the line drawn from the return air condition no longer crosses the saturation line, as shown by line AD in the following figure.



Service Water Heating (SWH) Strategies

Strategy Objectives

Reduce overall energy use of service water heating plant and distribution systems.

Strategy Description

Improved SWH efficiency: Install improved efficiency SWH systems as listed in the table below. Details of the base SWH system are provided with other building characteristics in the Appendices.

Strategy ID	Service Water Heating Strategies	Baseline	Strategy Level	Notes
MHW01	91.7% service water heating efficiency	80%	at least 91.7%	
MHW02	92.5% service water heating efficiency	80%	at least 92.5%	
MHW03	94.1% service water heating efficiency	80%	at least 94.1%	

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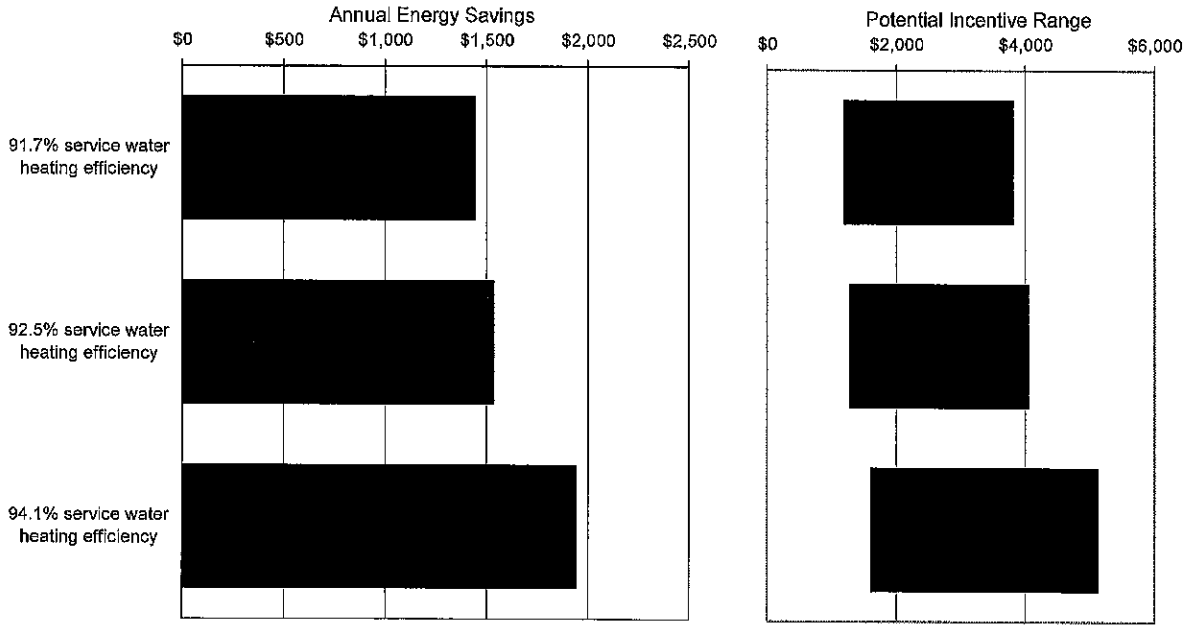
Service Water Heating Strategy Results



Key Points

- Service water heating was a significant end use in the building, thus improvements to the service water heating efficiency show good energy savings and incentive potential

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Appliance Efficiency Strategies

Strategy Objectives

Reduce energy consumption by selecting higher efficiency appliances.

Strategy Descriptions

The strategies described below are improvements over the requirements of the National Appliance Energy Conservation Act (NAECA).

Clothes Washer Alt 1: Change from unit that just meets Appliance Energy Act to one that just meets ENERGY STAR® requirements. This would be a top-loading unit with low water use and improved spin effectiveness. The performance is rated using the Modified Energy Factor (MEF), which is the load capacity in cubic feet divided by the energy consumption per cycle (cu ft/kWh/cycle). Since the washer spin cycle affects dryer energy, the energy consumption in the MEF includes dryer use. An MEF of 2.00 or higher will qualify for this strategy.

Clothes Washer Alt 2: Change from unit that just meets Appliance Energy Act to a unit with MEF rating of 2.40 or higher. This would be a front-loading unit with low water use and improved spin effectiveness. Electric use by the washer itself may increase under the clothes washer strategies, but domestic hot water use will likely decrease, as will dryer energy use.

Dishwasher Alt 1: Change from unit that just meets Appliance Energy Act to one that just meets ENERGY STAR requirements. Dishwashers are rated using kWh/yr of electricity and a unit that uses 295 kWh/year or less will qualify for this strategy.

Dishwasher Alt 2: Change from unit that just meets NAECA to one that exceeds ENERGY STAR requirements by at least 22%. A unit that uses 245 kWh/year or less will qualify for this strategy.

Refrigerator Alt 1: Change from unit that just meets NAECA to one that just meets ENERGY STAR requirements. This will exceed the basic Baseline requirement by 20%.

Refrigerator Alt 2: Change from unit that just meets NAECA to one that exceeds ENERGY STAR requirements by at least 15%. This will exceed the basic Baseline requirement by 30%.

Low flow showerheads: Change from showerheads that use 2.5 gallons per minute at a line pressure of 80 PSI to showerheads that use only 1.6 gallons per minute. Energy savings for this strategy take the form of domestic hot water consumption.

Low flow faucets: Change from faucets that use 2.2 gallons per minute at a line pressure of 60 PSI to showerheads that use only 1.0 gallons per minute. Energy savings for this strategy take the form of domestic hot water consumption.

For a complete list of ENERGY STAR appliances see the website: http://www.energystar.gov

Strategy ID	Appliance Efficiency Strategies	Baseline	Strategy Level	Units	Notes
ACW01	Energy Star clothes washers, alt 1	1.26	2.00	MEF	
ACW02	Energy Star clothes washers, alt 2	1.26	2.40	MEF	
ADW01	Energy Star dishwashers, alt 1	355	295	kWh/yr	
ADW02	Energy Star dishwashers, alt 2	355	245	kWh/yr	
ARF01	Energy Star refrigerators, alt 1	NAECA	20% better	kWh/yr	
ARF02	Energy Star refrigerators, alt 2	NAECA	30% better	kWh/yr	
AHW01	Low flow showerheads	2.5	1.6	gpm @ 80 psi	
AHW02	Low flow kitchen and bathroom sink aerators	2.2	1.0	gpm @ 60 psi	

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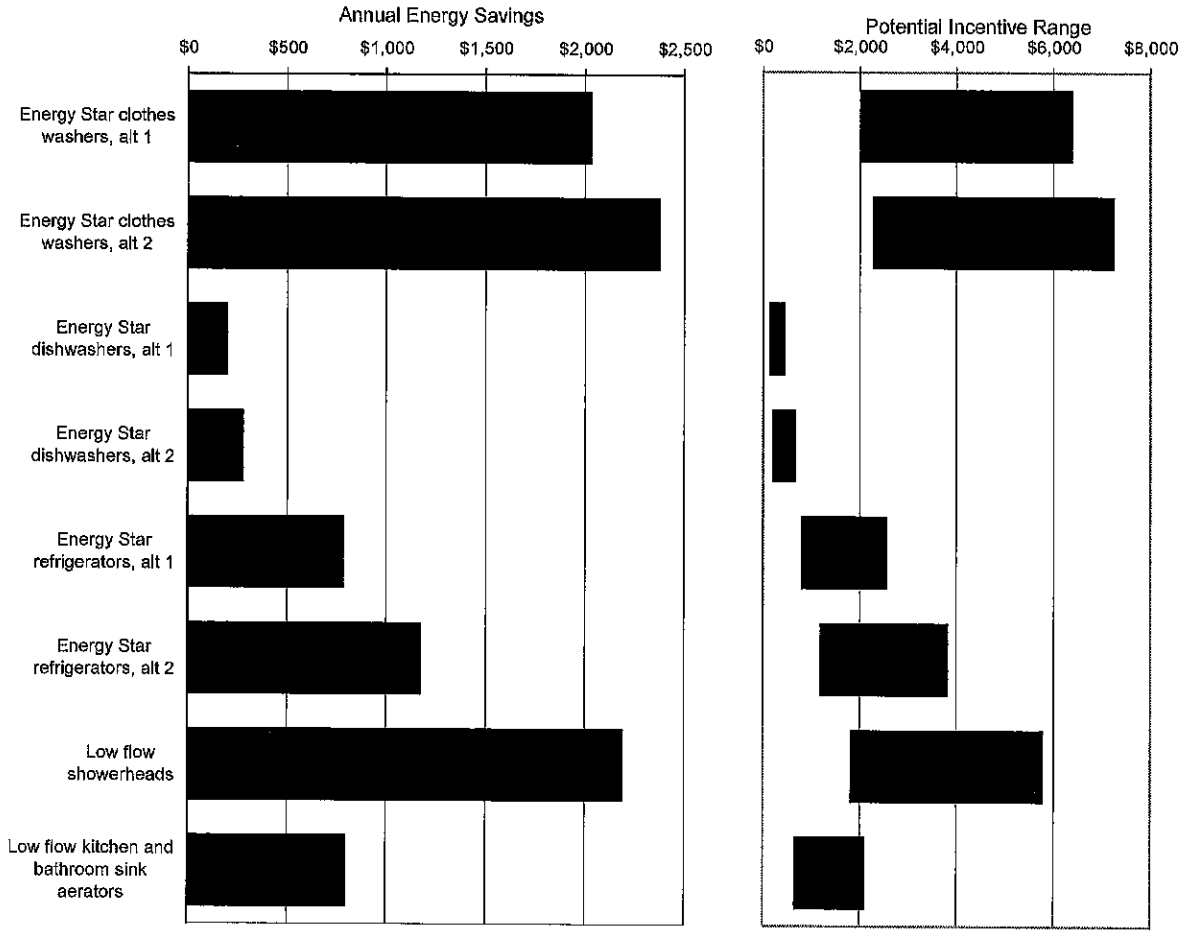
Appliance Efficiency Results



Key Points

- All appliances save energy dollars; cost effectiveness is dependent on added appliance cost
- Dishwashers show an electric penalty because they use more motor energy to wash dishes with less hot water, thus dollar savings come from hot water savings
- Low flow showerheads and faucets save gas energy

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Appendix A. Building Characteristics

The following pages show some key building modeling parameters forwarded from the Design Team and incorporated into the energy model.

These parameters have been used to characterize the building in the DOE-2.2 model.

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Building Location

Address:	
City:	Altoona
State:	Iowa

Envelope Characteristics

Select all envelope construction characteristics that apply

Walls	
Wood frame	x
Steel frame	
Frame w/ masonry exterior	
Masonry	
Metal	

Roof Construction	Select	Insulation Position
Wood Frame	x	C
Steel Frame		
Concrete		

Roof Insulation Position Key	
A	Entirely above deck/ continuous
B	Entirely below metal deck
C	Other/ Combination

Interior Floors	
Wood frame	x
Steel frame	
Concrete	

Window frame types	
Nonmetal	x
Metal curtainwall/ storefront	
Metal punched opening	

Window characteristics	Value
Total U-Factor (winter)	0.27
Center of glass U-Factor (winter)	0.24
Solar heat gain coefficient	0.25
Visible light transmittance	0.44

Window treatment (list building areas w/ blinds or shades)

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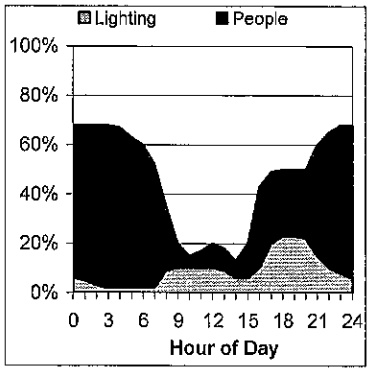
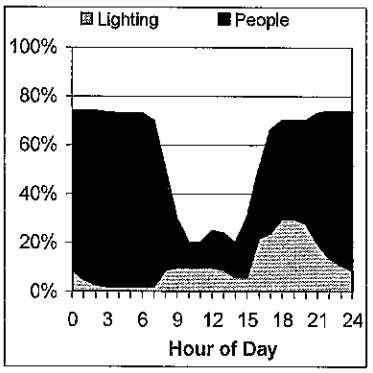
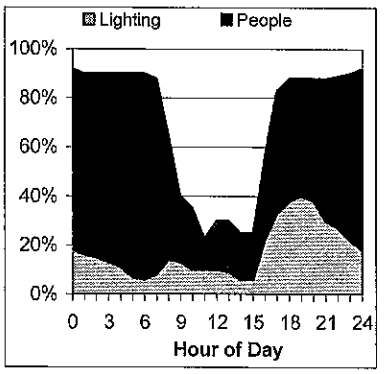
Building Operation Schedules

Select schedule that best describes operational use for lights and people use

Light Use		Medium Use	x	Heavy Use	







Building Type: Housing

Operation Notes

Typical apartment schedule

Office space follows typical schedule with weekend operation

MidAmerican Energy - Large General Service with Electric Space Heating Price Schedule LES, Secondary Voltage		
Fixed Monthly Charge	$138.37	per meter
Demand Charge - Summer	$7.07	per kW
Demand Charge - Winter	$4.65	per kW
Electric Summer Consumption:	$0.04213	per kWh, first 250 hours x kW of demand
	$0.02885	per kWh, next 150 hours x kW of demand
	$0.02055	per kWh, over 400 hours x kW of demand
Electric Winter Consumption:	$0.02664	per kWh, first 250 hours x kW of demand
	$0.02442	per kWh, next 150 hours x kW of demand
	$0.02055	per kWh, over 400 hours x kW of demand
Adjustments:		
Alternate Energy Producer Cost Recovery Clause	$0.00021	per kWh
Energy Efficiency Cost Recovery	$0.00206	per kWh
Cooper Nuclear Station Capital Additions Tracker	$0.00000	per kWh
Carbon Reduction Cost Recovery, CR	($0.00030)	per kWh
Revenue Adjustment Clause	$0.00	per kW
Revenue Adjustment Clause	($0.00006)	per kWh
Please note that charges listed above do not include the tax adjustment charges or reactive demand charges that may apply to this building. Please see tariff and riders for more information on those charges.		

Summer months: June - September Winter months: October - May

Gas Rate Assumed for Model **		
Natural gas consumption rate:	$0.720	per therm**

**Natural gas rates tend to fluctuate significantly from season to season, based on market pricing. The rate above is an arbitrary choice, with no particular prediction or endorsement of this rate by MidAmerican Energy implied. The owner and design team may use this rate in this analysis, or suggest a rate based upon the teams' outlooks, with regard to gas futures.

MidAmerican Energy - Residential, Apartment With Electric Space Heating Price Schedule RHS		
Fixed Monthly Charge	$9.41	per month / meter
Energy Charge - Summer	$0.09003	per kWh, first 600 kWh
	$0.09003	per kWh, over 600 kWh
Energy Charge - Winter	$0.08728	per kWh, first 600 kWh
	$0.03204	per kWh, over 600 kWh
Adjustments:		
Alternate Energy Producer Cost Recovery Clause	$0.00021	per kWh
Energy Efficiency Cost Recovery	$0.00321	per kWh
Cooper Nuclear Station Capital Additions Tracker	$0.00000	per kWh
Carbon Reduction Cost Recovery, CR	($0.00057)	per kWh
Revenue Adjustment Clause	($0.00010)	per kWh
Please note that charges listed above do not include the tax adjustment charges that may apply to this building. Please see tariff and riders for more information on those charges.		

Summer months: June - September Winter months: October - May

Space Type Building Characteristics

Enter design values.

If ceiling height is unknown, enter a safety factor value to allow for over-design.

If design reflectances are unknown, enter the assumed reflectances.

Horizonal footcandle levels will be used in daylighting strategies. IESNA FC levels are from the Ninth Edition IESNA Lighting Handbook.

Equip W/sf defines the average internal loads from computers, appliances,and production process within each space type. It should include factors for diversity, meaning it should be the peak value for a typical day.

	Ceiling Height FT	Design Reflectances			IESNA FC Level		Design FC Level		Equip W/SF	
		Ceiling	Wall	Floor	Horiz	Vert	Horiz	Vert	Default	Actual
Apartment	9.0	0.7	0.4	0.2	5	N/A	10		1.05	
Efficiency Apartment	9.0				5	N/A			1.05	
Circulation	9.0				3	3			0.10	
Storage	10.0				10	10			0.10	
Mech/elec	10.0	0.7	0.4	0.2	30	3	25		0.20	
Restroom	10.0				10	3			0.10	
Exercise	9.0	0.7	0.4	0.2	30	5	30		0.10	
Locker Room & Shower	10.0				5	3			0.50	
Community Room	9.0	0.7	0.4	0.2	5	N/A	10		0.50	
Computer	9.0				3	3			0.10	
Private office	9.0	0.7	0.4	0.2	30	5	40		1.20	
Open office	9.0				30	5			1.20	
Laundry	9.0	0.7	0.4	0.2	30	3	30		7.31	
Serving	9.0				50	3			5.00	
Stairs	9.0				3	3			0.10	

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Residential Housing Characteristics	
General Apartment Information	Data
Total number of apartments	120
Average number of bedrooms per apartment	1.8
Average number of bathrooms per apartment	1.6
Average number of people per apartment	2.6
Number of apartments with laundry in unit	97
Is there a public laundry area?	yes
Are clothes dryers Gas or Electric?	Electric
Are cooking stoves Gas or Electric?	Electric
Does each apartment have its own electric meter?	Yes
Does each apartment have its own gas meter?	No
Apartments have baseboard heat for central boiler strategies?	No

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Service Water Heating System Characteristics	
Number of hot water heater units	2
Hot water tank size, gal per unit	100
Hot water heat source (Gas, Electric, or Steam)	gas
Hot water heater input rate (per unit, kBTU/hr)	399
Hot water system combustion efficiency (baseline)	80%
Hot water system supply temperature, deg F	140
Hot water circulation pump flow, gpm	20
Hot water circulation pump head, feet	20

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Mechanical Zone Type Characteristics

- *Enter or select actual values for each parameter, default values are approximate based on standard space type conditions*
- *Enter an "X" to identify what type of equipment will be used.*

Space Type		Apartment	Efficiency Apartment	Circulation	Storage	Mech/elec	Restroom	Exercise	Locker Room & Shower	Community Room	Private office	Open office	Laundry
Air Flow Type	CV	x	x	x	x	x	x	x	x	x	x	x	x
	VAV												
Cooled Zone		x	x		x		x	x	x	x	x	x	
Heated Zone		x	x		x	x	x	x	x	x	x	x	x

Perimeter Zones

Zones have fan powered boxes?													
Terminal fan power (W/cfm)													
Supply CFM/SF		0.46		0.00									
Min CFM ratio	Default	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Design												

Core zones

Zones have fan powered boxes?													
Terminal fan power (W/cfm)													
Supply CFM/SF		0.46		0.00									
Min CFM ratio	Default	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Design												

Ventilation

OA CFM/SF	Default	0.00	0.00	0.06	0.07	0.06	0.01	0.26	0.50	0.30	0.09	0.09	0.17
	Design	0.08	0.13	0.00		0.00							

Zone heat source

HW coil													
HW base board													
Electric coil													
Electric baseboard													
Heat Pump													
Gas furnace													

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Mechanical Zone Type Characteristics

- *Enter or select actual values for each*
- *Enter an "X" to identify what type of equipment will be used.*

		Serving	Stairs										
Space Type													
Air Flow Type	CV	x	x										
	VAV												
Cooled Zone		x											
Heated Zone		x	x										
Perimeter Zones													
Zones have fan powered boxes?													
Terminal fan power (W/cfm)													
Supply CFM/SF													
Min CFM ratio	Default	1.00	1.00										
	Design												
Core zones													
Zones have fan powered boxes?													
Terminal fan power (W/cfm)													
Supply CFM/SF													
Min CFM ratio	Default	1.00	1.00										
	Design												
Ventilation													
OA CFM/SF	Default	0.30	0.06										
	Design		0.00										
Zone heat source													
HW coil													
HW base board													
Electric coil													
Electric baseboard													
Heat Pump													
Gas furnace													

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Air handler and fan characteristics

Air Handler Number	1	2	3	4	5	6	7	8	9	10
Region of building served	Apartment	Efficiency Unit	Fitness	Common room	Stairs	Corridors	DOAS			
Air Handler Type	*Place an "X" for type*									
Central cooling/ terminal reheat										
Central cooling/ fan powered terminal reheat										
Four pipe fan coil										
Water loop heat pump										
Ground heat pump										
Packaged single zone units					x					
Packaged terminal A/C	X	X	X	X						
Heating and ventilation unit										
Dedicated outside air system (DOAS)							x			
Exhaust fan										
Fan Control	*Place an "X" for type*									
Constant volume	x	x	x	x	x					
Variable air volume										
Airflow Variables	*Enter data for each air handler*									
Supply cfm										
Minimum outside air cfm										
Design Min % outside air			35%				100%			
Is Outside air delivered by DOAS?			Y							
Expected Exhaust cfm (1)										
(1) This is the expected exhaust from the air handler after accounting for building pressurization and toilet exhaust										
Economizer control	*Place an "X" for control type*									
None										
Air-side economizer (non-integrated)										
Air-side econo (Integrated)										
Drycooler										
Water-side economizer										
Outside air control	*Place an "X" for control type, this applies to VAV systems only*									
Fixed cfm										
Proportional to supply cfm										
Fan Static estimate	*Note: Fan static values should include effects of ductwork, diffusers, coils, filters, etc*									
Supply (Including filters), inches wc	0.36	0.68	1.00	1.00	0.50		0.75			
Filters only, inches wc										
Return, inches wc							0.75			
Exhaust, inches wc	0.25	0.25								
Fan horsepower										
Supply fan hp										
Return fan hp										
Exhaust fan hp										
Humidity Control	*Enter data for each air handler*									
Maximum setpoint										
Minimum setpoint										
Heating Plant / System	*Place an "X" for system type*									
Hot water coil										
Gas burner										
Electric resistance				x	x					
Heat pump	x	x	x							
Other:										
Cooling Plant / System	*Place an "X" for system type, for chiller systems make detailed entry in Plant form*									
No cooling					x	x				
Air cooled chiller										
Water cooled chiller										
Heat pump										
District cooling										
Direct expansion system data below										
Air cooled DX packaged or split	x	x	x	x						
Air cooled DX condensing units										
Evap. Cooled DX Rooftops										
Base design efficiency, EER										
- Include evaporator fan?										
Alternate design efficiency, EER										
- Include evaporator fan?										

Heat Recovery Characteristics

Sensible heat wheel		
Recovery effectiveness (winter)	65%	
Recovery effectiveness (summer)	65%	
Supply Static	0.75	
Exhaust Static	0.75	
Bypass when heat recovery not needed?	Yes	
Wheel motor hp	0.25	
Capacity/Frost control	**Capacity**	**Frost**
Wheel speed	X	X
Outside air bypass		
Exhaust air bypass		
Trim economizer		
No control		
Frost control calculation		
Keep exhaust air above 33 F		

Total enthalpy wheel		
Sensible effectiveness (winter)	65%	
Sensible effectiveness (summer)	65%	
Latent effectiveness	65%	
Supply Static	0.75	
Exhaust Static	0.75	
Bypass when heat recovery not needed?	Yes	
Wheel motor hp	0.25	
Capacity/Frost control	**Capacity**	**Frost**
Preheat outside air		
Preheat exhaust air		
Wheel speed		
Outside air bypass	X	X
Exhaust air bypass		
Trim economizer		
No control		
Frost control calculation		
Keep exhaust air above 33 F		
Based on winter design OA condition		
Done by real time calculations	X	

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Appendix B. Detailed Results

The following pages provide detailed energy analysis results in terms of cost, consumption, and demand calculations for the base building and all strategies.

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Energy Costs
130,751 SQ.FT.

Strategy	Itemized Costs						Totals per bldg sq. ft			Totals for Building	
	Heating $/sf	Cooling $/sf	Fan/ pump $/sf	SWH $/sf	Lights $/sf	Equip $/sf	Annual Energy $/sf	Annual Savings $/sf	% $ Savings	Energy $/yr	Annual Savings
Baseline; CODE1	$.417	$.114	$.080	$.087	$.149	$.269	$1.12			$146,007	
R-20 wall for non-residential, R-20 wall for residential; EWN01	$.415	$.115	$.080	$.087	$.149	$.269	$1.12	$0.00	0.1%	$145,796	$211
R-25 wall for non-residential, R-25 wall for residential; EWN02	$.409	$.116	$.080	$.087	$.149	$.269	$1.11	$0.01	0.6%	$145,118	$889
R-30 wall for non-residential, R-30 wall for residential; EWN03	$.404	$.116	$.081	$.087	$.149	$.269	$1.11	$0.01	0.9%	$144,667	$1,340
R-50 roof for non-residential, R-50 roof for residential; ERN01	$.415	$.115	$.080	$.087	$.149	$.269	$1.11	$0.00	0.2%	$145,702	$305
R-60 roof for non-residential, R-60 roof for residential; ERN02	$.413	$.115	$.080	$.087	$.149	$.269	$1.11	$0.00	0.3%	$145,557	$450
Design Glass: M1 Casement; WGB01	$.416	$.111	$.080	$.087	$.149	$.269	$1.11	$0.00	0.4%	$145,418	$589
Design Glass: Sliding Doors; WGC01	$.417	$.113	$.080	$.087	$.149	$.269	$1.11	$0.00	0.2%	$145,771	$236
Reduced Infiltration; EWRF2	$.411	$.116	$.080	$.087	$.149	$.269	$1.11	$0.00	0.4%	$145,414	$593
Window Quilts; EWWQ2	$.420	$.109	$.080	$.087	$.149	$.269	$1.11	$0.00	0.3%	$145,637	$370
Exercise Stepped Daylighting; DGA02	$.418	$.114	$.080	$.087	$.148	$.269	$1.12	$0.00	0.1%	$145,928	$79
Exercise Dimming Daylighting; DGA03	$.418	$.114	$.080	$.087	$.147	$.269	$1.12	$0.00	0.1%	$145,891	$116
Common Room Stepped Daylighting; DGA04	$.418	$.114	$.080	$.087	$.149	$.269	$1.12	$0.00	0.0%	$145,972	$35
Common Room Dimming Daylighting; DGA05	$.418	$.114	$.080	$.087	$.148	$.269	$1.12	$0.00	0.0%	$145,963	$44
Stairs Stepped Daylighting; DGA06	$.418	$.115	$.080	$.087	$.147	$.269	$1.12	$0.00	0.1%	$145,885	$122
Stairs Dimming Daylighting; DGA07	$.418	$.115	$.080	$.087	$.147	$.269	$1.12	$0.00	0.1%	$145,904	$103
Circulation occupancy sensor control; LCCI1	$.420	$.115	$.080	$.087	$.142	$.269	$1.11	$0.00	0.4%	$145,489	$518
Circulation occupancy sensor control to 1/2 level; LCCI2	$.419	$.115	$.080	$.087	$.145	$.269	$1.11	$0.00	0.2%	$145,750	$257
Storage occupancy sensor control; LCST1	$.418	$.114	$.080	$.087	$.149	$.269	$1.12	$0.00	0.0%	$146,001	$6
Mechelec occupancy sensor control; LCME1	$.418	$.115	$.080	$.087	$.147	$.269	$1.12	$0.00	0.1%	$145,910	$97
Restroom occupancy sensor control; LCRR1	$.417	$.114	$.080	$.087	$.149	$.269	$1.12	$0.00	0.0%	$146,002	$5
Exercise occupancy sensor control; LCFT1	$.419	$.114	$.080	$.087	$.146	$.269	$1.12	$0.00	0.1%	$145,853	$154
Locker Room & Shower occupancy sensor control; LCLR1	$.417	$.114	$.080	$.087	$.149	$.269	$1.12	$0.00	0.0%	$146,002	$5
Community Room occupancy sensor control; LCCM1	$.418	$.114	$.080	$.087	$.148	$.269	$1.12	$0.00	0.0%	$145,979	$28
Private office occupancy sensor control; LCPO1	$.418	$.114	$.080	$.087	$.148	$.269	$1.12	$0.00	0.0%	$145,982	$25
Private office dual level occupancy sensor control; LCPO3	$.418	$.114	$.080	$.087	$.148	$.269	$1.12	$0.00	0.0%	$145,977	$30
Private office dual level fixture; LCPO4	$.418	$.114	$.080	$.087	$.149	$.269	$1.12	$0.00	0.0%	$145,996	$11
Open office occupancy sensor control; LCOO1	$.418	$.114	$.080	$.087	$.149	$.269	$1.12	$0.00	0.0%	$145,988	$21
Laundry occupancy sensor control; LCLA1	$.417	$.114	$.080	$.087	$.149	$.269	$1.12	$0.00	0.0%	$146,002	$5
Serving occupancy sensor control; LCSV1	$.417	$.114	$.080	$.087	$.149	$.269	$1.12	$0.00	0.0%	$146,002	$5
Stairs occupancy sensor control; LCSW1	$.419	$.115	$.080	$.087	$.146	$.269	$1.12	$0.00	0.1%	$145,878	$129
Stairs occupancy sensor control to 1/2 level; LCSW2	$.418	$.115	$.080	$.087	$.148	$.269	$1.12	$0.00	0.0%	$145,939	$68
Corridor and stairs at As-designed LPD, Other public spaces at 10% lower than 90.1-2007 LPD (excludes apartments); L01BW	$.422	$.115	$.080	$.087	$.137	$.269	$1.11	$0.01	0.5%	$145,239	$768
Corridor and stairs at As-designed LPD, Other public spaces at 20% lower than 90.1-2007 LPD (excludes apartments); L02BW	$.423	$.115	$.080	$.087	$.135	$.269	$1.11	$0.01	0.6%	$145,156	$851
Corridor and stairs at As-designed LPD, Other public spaces at 30% lower than 90.1-2007 LPD (excludes apartments); L03BW	$.424	$.115	$.080	$.087	$.134	$.269	$1.11	$0.01	0.6%	$145,071	$936
Apartment lighting alt 1, 30% lower than baseline (includes efficiency units); L01AP	$.429	$.110	$.080	$.087	$.120	$.269	$1.10	$0.02	1.8%	$143,311	$2,696
Apartment lighting alt 2, As-designed (includes efficiency units); L02AP	$.445	$.103	$.081	$.087	$.081	$.269	$1.07	$0.05	4.5%	$139,410	$6,597
As-designed through the wall units (Efficiency Apartments); MPT02	$.417	$.114	$.080	$.087	$.149	$.269	$1.12	$0.00	0.1%	$145,925	$82
As-designed mini-split heat pumps (Apartments); MPT01	$.369	$.076	$.080	$.087	$.149	$.269	$1.01	$0.11	9.5%	$132,101	$13,906
As-designed heat pump (Community and Fitness); MPT03	$.417	$.113	$.080	$.087	$.149	$.269	$1.12	$0.00	0.1%	$145,833	$174
Baseline fan system power limitation; MFD00	$.417	$.114	$.080	$.087	$.149	$.269	$1.12	$0.00	0.0%	$146,007	$0
Proposed fan system design at 0.17 bhp/1000 cfm; MFD04	$.433	$.109	$.044	$.087	$.149	$.269	$1.09	$0.02	2.2%	$142,752	$3,255
OS control of bathroom exhaust fan; MOA02	$.372	$.125	$.084	$.087	$.149	$.269	$1.09	$0.03	2.7%	$142,022	$3,985
Sensible heat recovery (Fitness); MHRS1	$.412	$.115	$.080	$.087	$.149	$.269	$1.11	$0.00	0.4%	$145,389	$618
Total heat recovery (Fitness); MHRT1	$.412	$.114	$.081	$.087	$.149	$.269	$1.11	$0.00	0.4%	$145,366	$641
91.7% service water heating efficiency; MHW01	$.417	$.114	$.080	$.076	$.149	$.269	$1.11	$0.01	1.0%	$144,563	$1,444
92.5% service water heating efficiency; MHW02	$.417	$.114	$.080	$.075	$.149	$.269	$1.10	$0.01	1.1%	$144,472	$1,535
94.1% service water heating efficiency; MHW03	$.417	$.114	$.080	$.072	$.149	$.269	$1.10	$0.01	1.3%	$144,065	$1,942
Energy Star clothes washers, alt 1; ACW01	$.422	$.113	$.080	$.083	$.149	$.254	$1.10	$0.02	1.4%	$143,978	$2,029
Energy Star clothes washers, alt 2; ACW02	$.422	$.113	$.080	$.079	$.149	$.255	$1.10	$0.02	1.8%	$143,629	$2,378
Energy Star dishwashers, alt 1; ADW01	$.417	$.115	$.080	$.084	$.149	$.271	$1.12	$0.00	0.1%	$145,809	$198
Energy Star dishwashers, alt 2; ADW02	$.417	$.115	$.080	$.084	$.149	$.270	$1.11	$0.00	0.2%	$145,731	$276
Energy Star refrigerators, alt 1; ARF01	$.420	$.114	$.080	$.087	$.149	$.261	$1.11	$0.01	0.5%	$145,222	$785
Energy Star refrigerators, alt 2; ARF02	$.422	$.113	$.080	$.087	$.149	$.257	$1.11	$0.01	0.8%	$144,836	$1,171
Low flow showerheads; AHW01	$.417	$.114	$.080	$.070	$.149	$.269	$1.10	$0.02	1.5%	$143,817	$2,190
Low flow kitchen and bathroom sink aerators; AHW02	$.417	$.114	$.080	$.081	$.149	$.269	$1.11	$0.01	0.5%	$145,211	$796

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Annual Energy by End Use

130,751 SQ.FT.

Strategy	Itemized KBtu/sf						Totals	
	Heat	Cool	Fan/ Pump	SWH	Lights	Equip	Total KBtu/sf	Savings
Baseline; CODE1	19.0	5.2	3.6	12.1	6.8	12.3	59.03	
R-20 wall for non-residential, R-20 wall for residential; EWN01	18.9	5.2	3.6	12.1	6.8	12.3	58.92	0.2%
R-25 wall for non-residential, R-25 wall for residential; EWN02	18.5	5.2	3.6	12.1	6.8	12.3	58.49	0.9%
R-30 wall for non-residential, R-30 wall for residential; EWN03	18.2	5.2	3.6	12.1	6.8	12.3	58.20	1.4%
R-50 roof for non-residential, R-50 roof for residential; ERN01	18.8	5.2	3.6	12.1	6.8	12.3	58.84	0.3%
R-60 roof for non-residential, R-60 roof for residential; ERN02	18.8	5.2	3.6	12.1	6.8	12.3	58.74	0.5%
Design Glass: M1 Casement; WGB01	18.9	5.1	3.6	12.1	6.8	12.3	58.77	0.4%
Design Glass: Sliding Doors; WGC01	19.0	5.1	3.6	12.1	6.8	12.3	58.93	0.2%
Reduced infiltration; EWRF2	18.6	5.2	3.6	12.1	6.8	12.3	58.63	0.7%
Window Quilts; EWWQ2	19.2	5.0	3.6	12.1	6.8	12.3	58.96	0.1%
Exercise Stepped Daylighting; DGA02	19.1	5.2	3.6	12.1	6.8	12.3	59.00	0.1%
Exercise Dimming Daylighting; DGA03	19.1	5.2	3.6	12.1	6.7	12.3	58.97	0.1%
Common Room Stepped Daylighting; DGA04	19.0	5.2	3.6	12.1	6.8	12.3	59.02	0.0%
Common Room Dimming Daylighting; DGA05	19.0	5.2	3.6	12.1	6.8	12.3	59.01	0.0%
Stairs Stepped Daylighting; DGA06	19.1	5.2	3.6	12.1	6.7	12.3	58.95	0.1%
Stairs Dimming Daylighting; DGA07	19.1	5.2	3.6	12.1	6.7	12.3	58.97	0.1%
Circulation occupancy sensor control; LCCI1	19.0	5.2	3.6	12.1	6.4	12.3	58.68	0.6%
Circulation occupancy sensor control to 1/2 level; LCCI2	19.0	5.2	3.6	12.1	6.6	12.3	58.85	0.3%
Storage occupancy sensor control; LCST1	19.0	5.2	3.6	12.1	6.8	12.3	59.03	0.0%
Mech/elec occupancy sensor control; LCME1	19.0	5.2	3.6	12.1	6.7	12.3	58.97	0.1%
Restroom occupancy sensor control; LCRR1	19.0	5.2	3.6	12.1	6.8	12.3	59.03	0.0%
Exercise occupancy sensor control; LCFT1	19.1	5.2	3.6	12.1	6.7	12.3	58.93	0.2%
Locker Room & Shower occupancy sensor control; LCLR1	19.0	5.2	3.6	12.1	6.8	12.3	59.03	0.0%
Community Room occupancy sensor control; LCCM1	19.0	5.2	3.6	12.1	6.8	12.3	59.01	0.0%
Private office occupancy sensor control; LCPO1	19.0	5.2	3.6	12.1	6.8	12.3	59.02	0.0%
Private office dual level occupancy sensor control; LCPO3	19.0	5.2	3.6	12.1	6.8	12.3	59.01	0.0%
Private office dual level fixture; LCPO4	19.0	5.2	3.6	12.1	6.8	12.3	59.03	0.0%
Open office occupancy sensor control; LCOO1	19.0	5.2	3.6	12.1	6.8	12.3	59.02	0.0%
Laundry occupancy sensor control; LCLA1	19.0	5.2	3.6	12.1	6.8	12.3	59.03	0.0%
Serving occupancy sensor control; LCSV1	19.0	5.2	3.6	12.1	6.8	12.3	59.03	0.0%
Stairs occupancy sensor control; LCSW1	19.1	5.2	3.6	12.1	6.7	12.3	58.93	0.2%
Stairs occupancy sensor control to 1/2 level; LCSW2	19.1	5.2	3.6	12.1	6.7	12.3	58.98	0.1%
Corridor and stairs at As-designed LPD, Other public spaces at 10% lower than 90.1-2007 LPD (excludes apartments); L01BW	19.1	5.2	3.6	12.1	6.2	12.3	58.47	1.0%
Corridor and stairs at As-designed LPD, Other public spaces at 20% lower than 90.1-2007 LPD (excludes apartments); L02BW	19.1	5.2	3.6	12.1	6.1	12.3	58.41	1.1%
Corridor and stairs at As-designed LPD, Other public spaces at 30% lower than 90.1-2007 LPD (excludes apartments); L03BW	19.1	5.2	3.6	12.1	6.1	12.3	58.35	1.2%
Apartment lighting alt 1, 30% lower than baseline (includes efficiency units); L01AP	19.5	5.0	3.6	12.1	5.5	12.3	57.90	1.9%
Apartment lighting alt 2, As-designed (includes efficiency units); L02AP	20.0	4.6	3.6	12.1	3.6	12.3	56.27	4.7%
As-designed through the wall units (Efficiency Apartments); MPT02	19.0	5.2	3.6	12.1	6.8	12.3	59.00	0.1%
As-designed mini-split heat pumps (Apartments); MPT01	15.6	3.2	2.6	12.1	6.8	12.3	52.47	11.1%
As-designed heat pump (Community and Fitness); MPT03	19.0	5.2	3.6	12.1	6.8	12.3	58.95	0.1%
Baseline fan system power limitation; MFD00	19.0	5.2	3.6	12.1	6.8	12.3	59.03	0.0%
Proposed fan system design at 0.17 bhp/1000 cfm; MFD04	19.6	4.9	2.0	12.1	6.8	12.3	57.69	2.3%
OS control of bathroom exhaust fan; MOA02	16.1	5.4	3.6	12.1	6.8	12.3	56.24	4.7%
Sensible heat recovery (Fitness); MHRS1	18.7	5.2	3.7	12.1	6.8	12.3	58.76	0.5%
Total heat recovery (Fitness); MHRT1	18.8	5.2	3.7	12.1	6.8	12.3	58.76	0.5%
91.7% service water heating efficiency; MHW01	19.0	5.2	3.6	10.5	6.8	12.3	57.50	2.6%
92.5% service water heating efficiency; MHW02	19.0	5.2	3.6	10.4	6.8	12.3	57.41	2.8%
94.1% service water heating efficiency; MHW03	19.0	5.2	3.6	10.0	6.8	12.3	56.97	3.5%
Energy Star clothes washers, alt 1; ACW01	19.2	5.1	3.6	11.5	6.8	11.5	57.79	2.1%
Energy Star clothes washers, alt 2; ACW02	19.2	5.1	3.6	11.0	6.8	11.6	57.36	2.8%
Energy Star dishwashers, alt 1; ADW01	19.0	5.2	3.6	11.7	6.8	12.3	58.74	0.5%
Energy Star dishwashers, alt 2; ADW02	19.0	5.2	3.6	11.7	6.8	12.3	58.68	0.6%
Energy Star refrigerators, alt 1; ARF01	19.1	5.2	3.6	12.1	6.8	11.9	58.68	0.6%
Energy Star refrigerators, alt 2; ARF02	19.2	5.2	3.6	12.1	6.8	11.7	58.51	0.9%
Low flow showerheads; AHW01	19.0	5.2	3.6	9.7	6.8	12.3	56.71	3.9%
Low flow kitchen and bathroom sink aerators; AHW02	19.0	5.2	3.6	11.2	6.8	12.3	58.19	1.4%

Peak Conditions
130,751 SQ.FT.

	Peak Electric				Gas		Cooling				Heating		
	Peak W/sf	Peak kW	kW Savings	% kW Savings	Peak gas KBTU/H	% peak gas savings	Cooling sf/ton	Cooling tons	Peak cooling savings	Possible cooling % downsize	Heating KBTU/H	Peak heating savings	Possible heating % downsize
Baseline; CODE1	2.9	381			590		897	146			2,783		
R-20 wall for non-residential, R-20 wall for residential; EWN01	2.9	381	0	0%	590	0%	899	145	1	1.0%	2,771	12	0.0%
R-25 wall for non-residential, R-25 wall for residential; EWN02	2.9	379	2	1%	590	0%	908	144	2	1.0%	2,735	48	2.0%
R-30 wall for non-residential, R-30 wall for residential; EWN03	2.9	378	3	1%	590	0%	916	143	3	2.0%	2,710	73	3.0%
R-50 roof for non-residential, R-50 roof for residential; ERN01	2.9	380	1	0%	590	0%	903	145	1	1.0%	2,769	14	1.0%
R-60 roof for non-residential, R-60 roof for residential; ERN02	2.9	379	2	1%	590	0%	906	144	2	1.0%	2,762	21	1.0%
Design Glass: M1 Casement; WGB01	2.9	377	4	1%	590	0%	924	141	5	3.0%	2,756	27	1.0%
Design Glass: Sliding Doors; WGC01	2.9	379	2	1%	590	0%	907	144	2	1.0%	2,772	11	0.0%
Reduced infiltration; EWRF2	2.9	379	2	1%	590	0%	906	144	2	1.0%	2,702	81	3.0%
Window Quilts; EWWQ2	2.9	376	5	1%	590	0%	926	141	5	3.0%	2,784	(1)	0.0%
Exercise Stepped Daylighting; DGA02	2.9	380	1	0%	590	0%	899	145	1	1.0%	2,783	0	0.0%
Exercise Dimming Daylighting; DGA03	2.9	380	1	0%	590	0%	899	145	1	1.0%	2,783	0	0.0%
Common Room Stepped Daylighting; DGA04	2.9	380	1	0%	590	0%	898	146	0	0.0%	2,783	0	0.0%
Common Room Dimming Daylighting; DGA05	2.9	380	1	0%	590	0%	898	146	0	0.0%	2,783	0	0.0%
Stairs Stepped Daylighting; DGA06	2.9	380	1	0%	590	0%	897	146	0	0.0%	2,783	0	0.0%
Stairs Dimming Daylighting; DGA07	2.9	380	1	0%	590	0%	897	146	0	0.0%	2,783	0	0.0%
Circulation occupancy sensor control; LCCI1	2.9	379	2	1%	590	0%	897	146	0	0.0%	2,783	0	0.0%
Circulation occupancy sensor control to 1/2 level; LCCI2	2.9	380	1	0%	590	0%	897	146	0	0.0%	2,783	0	0.0%
Storage occupancy sensor control; LCST1	2.9	381	0	0%	590	0%	897	146	0	0.0%	2,783	0	0.0%
Mech/elec occupancy sensor control; LCME1	2.9	380	1	0%	590	0%	897	146	0	0.0%	2,783	0	0.0%
Restroom occupancy sensor control; LCRR1	2.9	381	0	0%	590	0%	897	146	0	0.0%	2,783	0	0.0%
Exercise occupancy sensor control; LCFT1	2.9	380	1	0%	590	0%	899	145	1	1.0%	2,784	(1)	0.0%
Locker Room & Shower occupancy sensor control; LCLR1	2.9	381	0	0%	590	0%	897	146	0	0.0%	2,783	0	0.0%
Community Room occupancy sensor control; LCCM1	2.9	381	0	0%	590	0%	898	146	0	0.0%	2,783	0	0.0%
Private office occupancy sensor control; LCPO1	2.9	381	0	0%	590	0%	897	146	0	0.0%	2,783	0	0.0%
Private office dual level occupancy sensor control; LCPO3	2.9	381	0	0%	590	0%	898	146	0	0.0%	2,783	0	0.0%
Private office dual level fixture; LCPO4	2.9	381	0	0%	590	0%	897	146	0	0.0%	2,783	0	0.0%
Open office occupancy sensor control; LCOO1	2.9	381	0	0%	590	0%	897	146	0	0.0%	2,783	0	0.0%
Laundry occupancy sensor control; LCLA1	2.9	381	0	0%	590	0%	897	146	0	0.0%	2,783	0	0.0%
Serving occupancy sensor control; LCSV1	2.9	381	0	0%	590	0%	897	146	0	0.0%	2,783	0	0.0%
Stairs occupancy sensor control; LCSW1	2.9	380	1	0%	590	0%	897	146	0	0.0%	2,785	(2)	0.0%
Stairs occupancy sensor control to 1/2 level; LCSW2	2.9	381	0	0%	590	0%	897	146	0	0.0%	2,784	(1)	0.0%
Corridor and stairs at As-designed LPD, Other public spaces at 10% lower than 90.1-2007 LPD (excludes apartments); L01BW	2.9	378	3	1%	590	0%	896	146	0	0.0%	2,785	(2)	0.0%
Corridor and stairs at As-designed LPD, Other public spaces at 20% lower than 90.1-2007 LPD (excludes apartments); L02BW	2.9	378	3	1%	590	0%	899	145	1	1.0%	2,786	(3)	0.0%
Corridor and stairs at As-designed LPD, Other public spaces at 30% lower than 90.1-2007 LPD (excludes apartments); L03BW	2.9	377	4	1%	590	0%	900	145	1	1.0%	2,786	(3)	0.0%
Apartment lighting alt 1, 30% lower than baseline (includes efficiency units); L01AP	2.6	360	21	6%	590	0%	932	140	6	4.0%	2,802	(19)	-1.0%
Apartment lighting alt 2, As-designed (includes efficiency units); L02AP	2.5	330	51	13%	590	0%	984	133	13	9.0%	2,827	(44)	-2.0%
As-designed through the wall units (Efficiency Apartments); MPT02	2.9	380	1	0%	590	0%	897	146	0	0.0%	2,783	0	0.0%
As-designed mini-split heat pumps (Apartments); MPT01	2.5	328	53	14%	590	0%	860	152	(6)	-4.0%	2,783	0	0.0%
As-designed heat pump (Community and Fitness); MPT03	2.9	379	2	1%	590	0%	897	146	0	0.0%	2,783	0	0.0%
Baseline fan system power limitation; MFD00	2.9	381	0	0%	590	0%	897	146	0	0.0%	2,783	0	0.0%
Proposed fan system design at 0.17 bhp/1000 cfm; MFD04	2.8	371	10	3%	590	0%	914	143	3	2.0%	2,808	(26)	-1.0%
OS control of bathroom exhaust fan; MOA02	2.9	379	2	1%	590	0%	916	143	3	2.0%	2,508	275	10.0%
Sensible heat recovery (Fitness); MHRS1	2.9	381	0	0%	590	0%	897	146	0	0.0%	2,732	51	2.0%
Total heat recovery (Fitness); MHRT1	2.9	380	1	0%	590	0%	907	144	2	1.0%	2,732	51	2.0%
91.7% service water heating efficiency; MHW01	2.9	381	0	0%	520	12%	897	146	0	0.0%	2,783	0	0.0%
92.5% service water heating efficiency; MHW02	2.9	381	0	0%	510	14%	897	146	0	0.0%	2,783	0	0.0%
94.1% service water heating efficiency; MHW03	2.9	381	0	0%	500	15%	897	146	0	0.0%	2,783	0	0.0%
Energy Star clothes washers, alt 1; ACW01	2.9	373	8	2%	580	2%	909	144	2	1.0%	2,789	(6)	0.0%
Energy Star clothes washers, alt 2; ACW02	2.9	374	7	2%	570	3%	908	144	2	1.0%	2,789	(6)	0.0%
Energy Star dishwashers, alt 1; ADW01	2.9	382	(1)	0%	590	0%	896	146	0	0.0%	2,783	0	0.0%
Energy Star dishwashers, alt 2; ADW02	2.9	382	(1)	0%	580	2%	896	146	0	0.0%	2,783	0	0.0%
Energy Star refrigerators, alt 1; ARF01	2.9	379	2	1%	590	0%	901	145	1	1.0%	2,786	(3)	0.0%
Energy Star refrigerators, alt 2; ARF02	2.9	377	4	1%	590	0%	903	145	1	1.0%	2,788	(5)	0.0%
Low flow showerheads; AHW01	2.9	381	0	0%	450	24%	897	146	0	0.0%	2,783	0	0.0%
Low flow kitchen and bathroom sink aerators; AHW02	2.9	381	0	0%	540	8%	897	146	0	0.0%	2,783	0	0.0%

Annual Energy by Fuel Source

130,751 SQ.FT.

	Annual Energy			Annual Electric			Annual Gas		
	MMBTU (incl. electric)	MMBTU Savings	% Savings	kWh	kWh Savings	% kWh Savings	Gas MMBTU	Gas MMBTU Savings	% Gas Savings
Baseline; CODE1	7,719			1,800,053			1,577.1		
R-20 wall for non-residential, R-20 wall for residential; EWN01	7,703	15	0%	1,795,554	4,499	0%	1,577.1	0.0	0%
R-25 wall for non-residential, R-25 wall for residential; EWN02	7,648	71	1%	1,779,161	20,892	1%	1,577.1	0.0	0%
R-30 wall for non-residential, R-30 wall for residential; EWN03	7,610	109	1%	1,768,165	31,888	2%	1,577.1	0.0	0%
R-50 roof for non-residential, R-50 roof for residential; ERN01	7,693	26	0%	1,792,459	7,594	0%	1,577.1	0.0	0%
R-60 roof for non-residential, R-60 roof for residential; ERN02	7,681	38	0%	1,788,844	11,209	1%	1,577.1	0.0	0%
Design Glass: M1 Casement; WGB01	7,685	34	0%	1,790,112	9,941	1%	1,577.1	0.0	0%
Design Glass: Sliding Doors; WGC01	7,706	13	0%	1,796,194	3,859	0%	1,577.1	0.0	0%
Reduced infiltration; EWRF2	7,667	52	1%	1,784,735	15,318	1%	1,577.1	0.0	0%
Window Quilts; EWWQ2	7,709	10	0%	1,797,214	2,839	0%	1,577.1	0.0	0%
Exercise Stepped Daylighting; DGA02	7,714	5	0%	1,798,729	1,324	0%	1,577.1	0.0	0%
Exercise Dimming Daylighting; DGA03	7,711	8	0%	1,797,773	2,280	0%	1,577.1	0.0	0%
Common Room Stepped Daylighting; DGA04	7,717	2	0%	1,799,403	650	0%	1,577.1	0.0	0%
Common Room Dimming Daylighting; DGA05	7,716	3	0%	1,799,254	799	0%	1,577.1	0.0	0%
Stairs Stepped Daylighting; DGA06	7,708	10	0%	1,797,010	3,043	0%	1,577.1	0.0	0%
Stairs Dimming Daylighting; DGA07	7,710	9	0%	1,797,403	2,650	0%	1,577.1	0.0	0%
Circulation occupancy sensor control; LCCI1	7,672	47	1%	1,786,293	13,760	1%	1,577.1	0.0	0%
Circulation occupancy sensor control to 1/2 level; LCCI2	7,695	23	0%	1,793,185	6,868	0%	1,577.1	0.0	0%
Storage occupancy sensor control; LCST1	7,718	1	0%	1,799,805	248	0%	1,577.1	0.0	0%
Mech/elec occupancy sensor control; LCME1	7,710	9	0%	1,797,502	2,551	0%	1,577.1	0.0	0%
Restroom occupancy sensor control; LCRR1	7,718	1	0%	1,799,819	234	0%	1,577.1	0.0	0%
Exercise occupancy sensor control; LCFT1	7,705	14	0%	1,796,000	4,053	0%	1,577.1	0.0	0%
Locker Room & Shower occupancy sensor control; LCLR1	7,718	1	0%	1,799,871	182	0%	1,577.1	0.0	0%
Community Room occupancy sensor control; LCCM1	7,716	3	0%	1,799,286	767	0%	1,577.1	0.0	0%
Private office occupancy sensor control; LCPO1	7,717	2	0%	1,799,412	641	0%	1,577.1	0.0	0%
Private office dual level occupancy sensor control; LCPO3	7,716	3	0%	1,799,290	763	0%	1,577.1	0.0	0%
Private office dual level fixture; LCPO4	7,718	1	0%	1,799,728	325	0%	1,577.1	0.0	0%
Open office occupancy sensor control; LCOO1	7,717	2	0%	1,799,464	589	0%	1,577.1	0.0	0%
Laundry occupancy sensor control; LCLA1	7,718	0	0%	1,799,909	144	0%	1,577.1	0.0	0%
Serving occupancy sensor control; LCSV1	7,718	1	0%	1,799,898	155	0%	1,577.1	0.0	0%
Stairs occupancy sensor control; LCSW1	7,706	13	0%	1,796,246	3,807	0%	1,577.1	0.0	0%
Stairs occupancy sensor control to 1/2 level; LCSW2	7,712	7	0%	1,798,124	1,929	0%	1,577.1	0.0	0%
Corridor and stairs at As-designed LPD, Other public spaces at 10% lower than 90.1-2007 LPD (excludes apartments); L01BW	7,645	74	1%	1,778,444	21,609	1%	1,577.1	0.0	0%
Corridor and stairs at As-designed LPD, Other public spaces at 20% lower than 90.1-2007 LPD (excludes apartments); L02BW	7,637	82	1%	1,776,161	23,892	1%	1,577.1	0.0	0%
Corridor and stairs at As-designed LPD, Other public spaces at 30% lower than 90.1-2007 LPD (excludes apartments); L03BW	7,629	89	1%	1,773,885	26,168	1%	1,577.1	0.0	0%
Apartment lighting alt 1, 30% lower than baseline (includes efficiency units); L01AP	7,571	148	2%	1,756,739	43,314	2%	1,577.1	0.0	0%
Apartment lighting alt 2, As-designed (includes efficiency units); L02AP	7,358	361	5%	1,694,265	105,788	6%	1,577.1	0.0	0%
As-designed through the wall units (Efficiency Apartments); MPT02	7,715	4	0%	1,798,815	1,238	0%	1,577.1	0.0	0%
As-designed mini-split heat pumps (Apartments); MPT01	6,860	859	11%	1,548,442	251,611	14%	1,577.1	0.0	0%
As-designed heat pump (Community and Fitness); MPT03	7,707	11	0%	1,796,724	3,329	0%	1,577.1	0.0	0%
Baseline fan system power limitation; MFD00	7,719	0	0%	1,800,053	0	0%	1,577.1	0.0	0%
Proposed fan system design at 0.17 bhp/1000 cfm; MFD04	7,543	175	2%	1,748,673	51,380	3%	1,577.1	0.0	0%
OS control of bathroom exhaust fan; MOA02	7,353	365	5%	1,692,973	107,080	6%	1,577.1	0.0	0%
Sensible heat recovery (Fitness); MHRS1	7,683	36	0%	1,789,461	10,592	1%	1,577.1	0.0	0%
Total heat recovery (Fitness); MHRT1	7,683	36	0%	1,789,458	10,595	1%	1,577.1	0.0	0%
91.7% service water heating efficiency; MHW01	7,518	201	3%	1,800,053	0	0%	1,376.5	200.6	13%
92.5% service water heating efficiency; MHW02	7,506	213	3%	1,800,053	0	0%	1,363.9	213.2	14%
94.1% service water heating efficiency; MHW03	7,449	270	3%	1,800,053	0	0%	1,307.4	269.7	17%
Energy Star clothes washers, alt 1; ACW01	7,556	163	2%	1,773,893	26,160	1%	1,502.8	74.3	5%
Energy Star clothes washers, alt 2; ACW02	7,500	219	3%	1,775,380	24,673	1%	1,442.3	134.8	9%
Energy Star dishwashers, alt 1; ADW01	7,680	39	1%	1,802,375	(2,322)	0%	1,530.4	46.7	3%
Energy Star dishwashers, alt 2; ADW02	7,672	47	1%	1,801,914	(1,861)	0%	1,523.5	53.6	3%
Energy Star refrigerators, alt 1; ARF01	7,673	46	1%	1,786,568	13,485	1%	1,577.1	0.0	0%
Energy Star refrigerators, alt 2; ARF02	7,650	69	1%	1,779,944	20,109	1%	1,577.1	0.0	0%
Low flow showerheads; AHW01	7,415	304	4%	1,800,053	0	0%	1,272.9	304.2	19%
Low flow kitchen and bathroom sink aerators; AHW02	7,608	111	1%	1,800,053	0	0%	1,466.5	110.6	7%

Appendix C. Lighting Control Sequences and Schematics

The following guidelines provide greater background through conceptual schematics and sequences toward effective installation of lighting controls.

Introduction

The sections on each space type are laid out in the same manner and include the following elements.

Each lighting control design strategy contains a plan-view diagram for each control scenario. The text describes the device types to use, the device features and settings that work best, and suggestions for sensor locations.

Pattern Symbol Legend

Below are the symbols for lighting controls and electrical devices that are used.

Dimmer wall switch	D	Photoswitch	PS
Wallbox occupancy sensor	OS	Photosensor	LS
Ceiling-mount occupancy sensor	OS	Local master controller	LMC
Wall-mount occupancy sensor	OS	Junction box	●
Transformer relay	TR	110V or 277V power line	———
Time Clock		Low voltage power line.	·····

Note: Generic control devices are used in the strategies. To use the strategies most effectively, you should consult the manufacturer's technical specifications to check actual coverage templates (pattern, distance, and sensitivity), required coverage overlap, control feature options, calibration setting limits, ambient temperature sensitivity range, and electric load requirements (where applicable).

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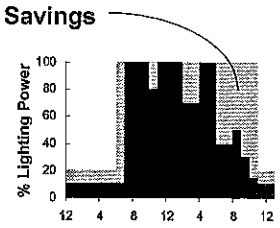
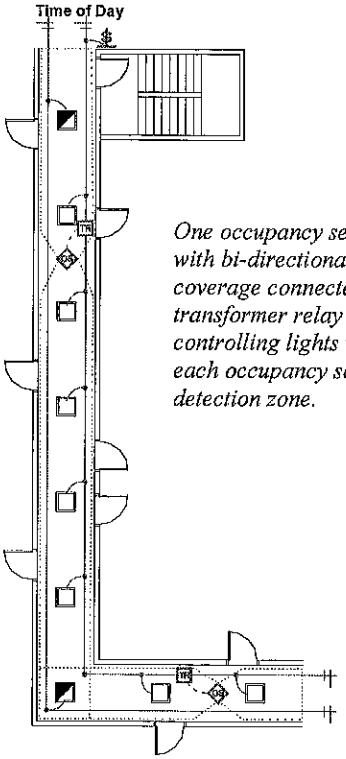
Circulation Spaces
Design Pattern

Occupancy Responsive
Occupancy Sensor



Application and Savings

Occupancy sensors are good in situations where there are long periods (over 1/2 hour) of no occupancy in circulation spaces or on stairs when the building is open. Buildings where this is typical include elementary schools, auditoriums, and offices with very long hours of operation. Energy savings may range from 20-40%.



One occupancy sensor (OS) with bi-directional coverage connected to a transformer relay (TR) controlling lights within each occupancy sensors detection zone.

Control Devices

- **Occupancy Sensor**

– Use Passive Infrared sensors in circulation spaces where the line of site is unobstructed and exact detection coverage limits are required to reduce "false-ons."

– Use Ultrasonic sensors in circulation spaces and stairways that are completely enclosed and where ceilings are below 14'.

Cautions:

– Don't use ULT sensors in locations with high air flow through doorways or vestibules.

Device Locations

- Center ceiling-mounted sensors in the corridor with the receiver openings pointed down the corridor.
- Locate high-wall or corner-mounted sensors to favor coverage at points of entry such as lobby entrances and main doorways. Good overlap of sensor coverage is mandatory.

Design Considerations

- Don't connect the emergency lighting circuit to the sensor controlled circuit.

Recommended Features

- Automatic on/ off
- Time-out setting range to 30 minutes
- Sensitivity calibration adjustment for ultrasonic sensors
- Sensor design with long linear coverage (50-90')

Recommended Settings

- Set a 5-10 minute time-out setting for K-12 schools with traditional one-hour long classes.
- Set a 10-15 minute time-out setting for circulation spaces with long hours of operation and light use during non-traditional hours. A time-out setting in the high range will reduce the inconvenience of "false-offs."

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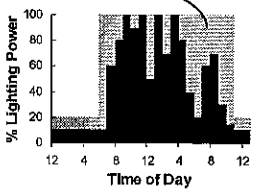
Open Offices
Design Pattern

Occupancy Responsive
Occupancy Sensor

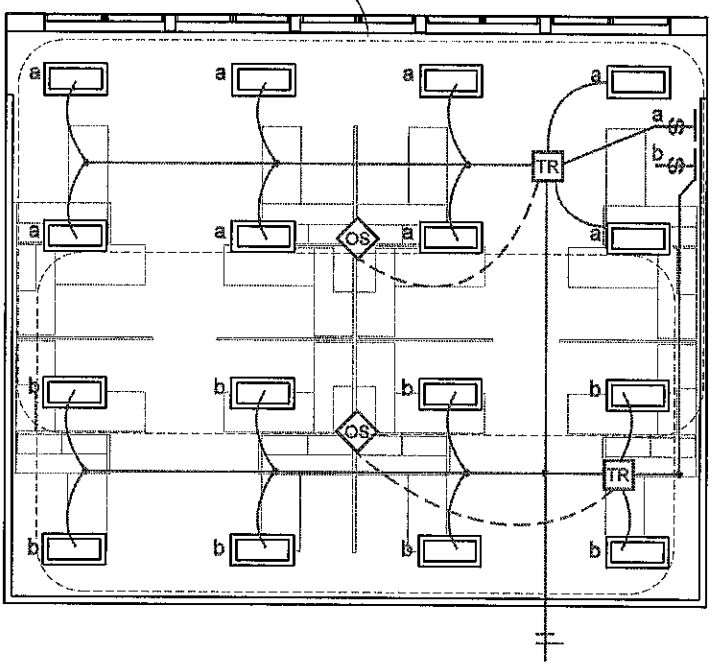
Savings



Application and Savings

Occupancy sensor control is good for open plan offices that have long total hours of operation (10–12 hr/day or more) but have fewer users outside of traditional office hours. Without controls, cleaning crews or one worker may keep lights on in large unoccupied areas for long periods. Large open office areas can be divided into zones controlled by occupancy sensors so that lights are turned down or off in areas that aren't occupied. Most of the lighting energy will be saved outside of traditional working hours since it is unusual for all workers within a coverage zone to be absent during regular working hours. Energy savings typically range from 15-25%.

Typical sensor coverage zone



One occupancy sensors (OS) and one transformer relay (TR) for each of two overlapping detection zones.

Design Considerations

- Small separate lighting zones will give the most energy savings because it is often the case that not all work zones are occupied at the same time.
- Use transformer relays (TR) to control fixtures from low-voltage sensor signals.
- Provide manual switches to turn lights off also.

Control Devices

- **Occupancy Sensor**

– Use ultrasonic sensors for spaces with high partitions. In most cases, 6–8 work stations can be sensed from one ultrasonic sensor.

– Use passive-infrared or dual-mode sensors when partitions are low or not present and coverage limits need to be tightly controlled to reduce "false ons."

– Use personal-work-station occupancy sensors in spaces with task lights and multiple electrical devices.

Device Locations

- Good overlap of sensor coverage is mandatory. The design pattern shows two sensors controlling two separate switch legs. The coverage zones overlap the fixtures controlled by one row to maintain adequate far-field illumination for the work stations in adjacent areas.

Cautions:

- Inadequate sensor overlap will turn lights off too close to occupied work stations.
- Avoid detecting motion in main circulation aisles.

Recommended Features

- Automatic on/off
- Time-out setting range to 30 minutes

Recommended Settings

- Set the time-out setting in the high range, (15–25 minutes) to reduce the inconvenience of "false-offs."
- Adjust the sensitivity calibration after all furnishings are in place. When work stations are rearranged or altered, it is a good idea to verify and adjust sensor coverage.

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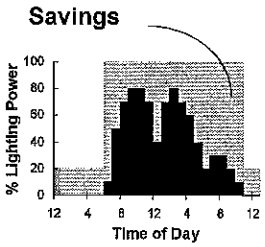
Private Offices
Design Pattern

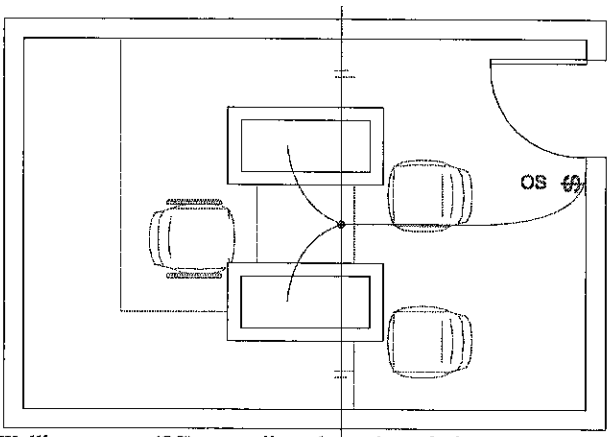
Occupancy Responsive
Occupancy Sensor

Savings

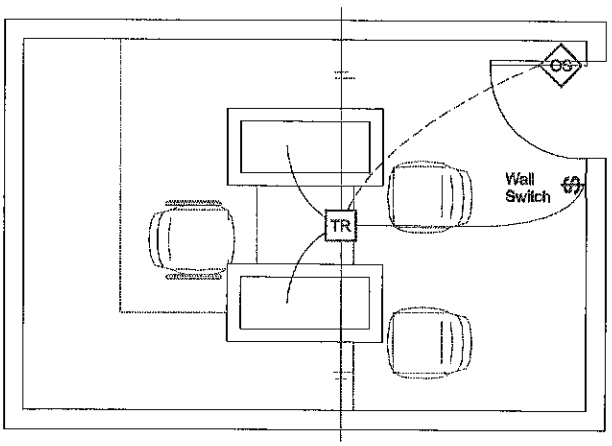


Application and Savings

Occupancy sensor control is good for most private offices where it is common for the occupant to be "in the office" but away from their desk for short or long periods throughout the day. Sensor type is dependent on size of room, furniture arrangement, and door opening locations. Energy savings typically range from 35–65% based on how much the room is occupied and how diligently the occupant turns the lights off when leaving. Energy savings may coincide with peak building electrical use.



Wallbox sensor (OS) controlling the ambient lighting circuit.



Wall mount sensor (OS) connected to a transformer-relay (TR) controlling all ambient lights.

Design Considerations

- Manual on/auto off control gives the occupant greater control of the space and may increase energy savings in rooms with daylight.

Control Devices

- **Occupancy Sensor**

– Wallbox sensors are the most cost-effective "packages" and work well in small private offices where furnishings will not obstruct the sensor's view of the task area. Both ULT and PIR technology is available.

– Ceiling or high-wall mounted sensors are less likely to be obstructed when furnishings are rearranged or added to an office. Consider ULT, PIR, or dual-mode technology.

– Personal-work-station occupancy sensors work well to control task lights and other electrical loads besides the ambient lighting.

Device Locations

- Locate wallbox sensors on the same wall as the entrance door on the latch side of the door.
- Mount ceiling sensors near the center of room over the main desk area.
- Locate high-wall sensors in the corner of the room near the main doorway.

Cautions:

- Avoid locating the sensor behind a door or potential file cabinet locations.
- For PIR sensors, avoid locations where they "view" out the door.

Recommended Features

- Manual On/Auto Off
- Sensitivity calibration adjustment for ultrasonic sensors

Recommended Settings

- Set the time-out setting in the low range (8–10 minutes).
- Set the sensitivity calibration after all furnishings are in place.

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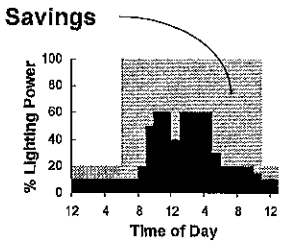
File/Storage Rooms
Design Pattern

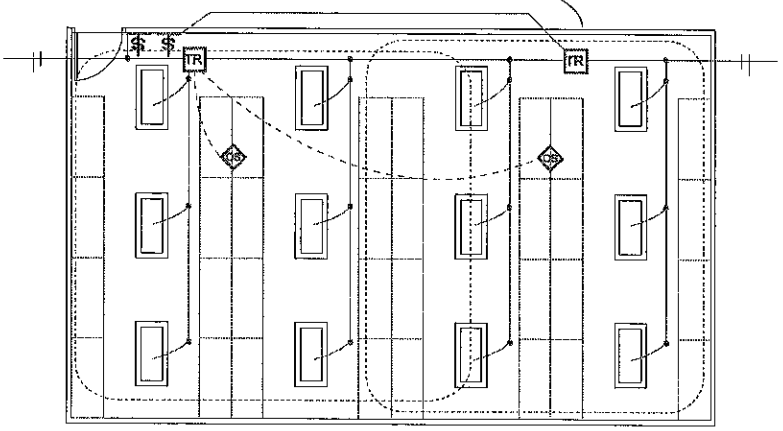
Occupancy Responsive
Occupancy Sensor



Application and Savings

Occupancy sensor control is good for most file/storage rooms that are used infrequently and for short periods. Lights tend to be left on all day due to the diversity of users and the enclosed nature of the space. Occupancy sensor type and placement is dependent on storage height and room layout. Energy savings range from 35–65%.

Typical sensor detection coverage zone



A occupancy sensor (OS) connected to a transformer relay (TR) controlling the lights within separate lighting control zones.

Design Considerations

- In rooms less than 800 ft^2, control all lights with a single control circuit (one transformer relay).
- Divide rooms greater than 800 ft^2 into separate control zones to improve energy savings. Use multiple transformer relays. Make sure to provide 15–20% coverage overlap (as shown).

Control Devices

- **Occupancy Sensor**

– Use ultrasonic (ULT) or audible/ microphonic ceiling sensors in spaces with high shelving.

– Use passive infrared (PIR) sensors in smaller filing/storage rooms where the center of the room is open and high shelving is located around the perimeter.

Device Locations

- Follow the manufacturer's recommendations for the specific device.

Generally:

- Spaces greater than 800 ft^2 with aisle shelving near the ceiling will typically require more than one sensor.

Recommended Features

- Automatic on/off is preferred
- Range and sensitivity control for ULT sensors

Recommended Settings

- Set time-out setting at 8–10 minutes
- Adjust ULT sensor sensitivity after furnishings are in place.

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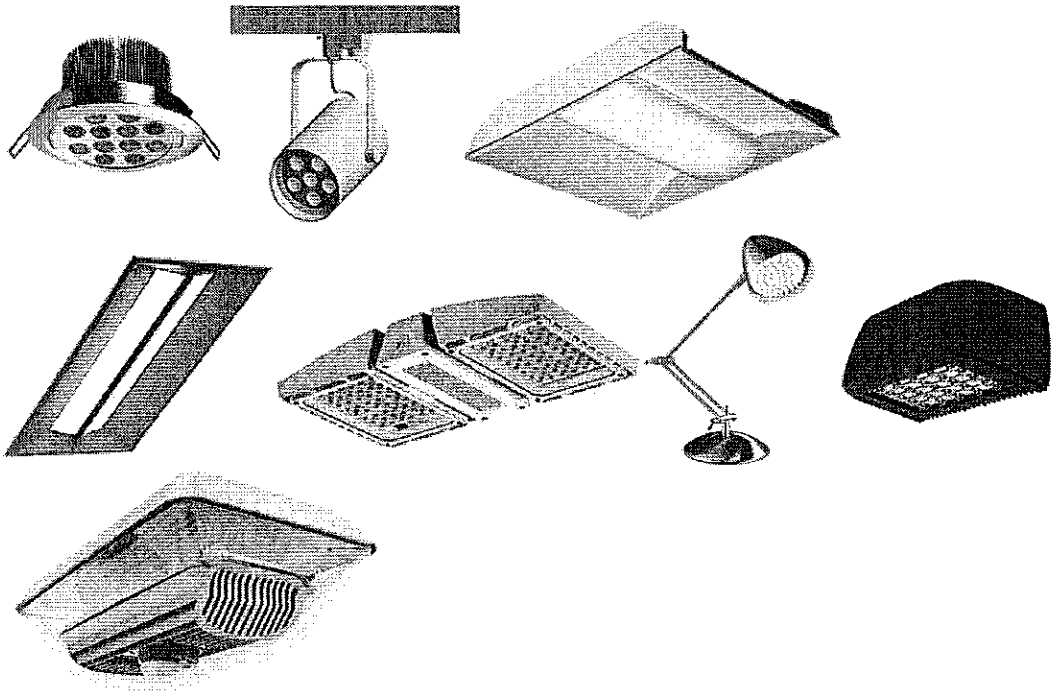
Appendix D. LED Lighting



Source: Manufacturers' product data sheets from Cree, Lithonia, Finelight and Philips.

Introduction

Light-emitting diode (LED) technology is developing rapidly into a universal light source as more price- and performance-competitive LED products are introduced to the market. New generations of LED devices become available approximately every 4 to 6 months. The best LED products currently meet or slightly exceed the efficacy of linear fluorescent luminaires used for general overhead lighting, previously the most efficient lighting technology on the market. However, the performance range for LEDs varies widely among product types and manufacturers. For this reason, lighting designers must be careful when selecting LED products and also because LEDs have unique characteristics and caveats compared to traditional light sources.

LED Characteristics

The following is a summary of the unique characteristics of LEDs. This information was gathered from the LIGHTFAIR® International 2012 conference and tradeshow in Las Vegas, NV.

- LED lamps do not "burn out" like traditional light sources, but instead they gradually dim over time. LED light sources are typically rated in terms of the runtime until the light output has decreased to 70% (L_{70}) of the initial value, about where it starts to become noticeable to the eye. LED lifespan is not affected by the number of starts the light source experiences, unlike linear fluorescents.
- LEDs also do not have ballasts. For a linear fluorescent lamp, the ballast factor determines the light output of the fixture and affects the lamp life. The higher the ballast factor, the more light output, but the shorter the lamp life. Because of the various factors that affect the lifespan of linear fluorescent lamps, comparisons of the expected lifetime maintenance savings of LED light sources to linear fluorescents is difficult.
- Many LED luminaires do not have replaceable components and are not field-serviceable. The designer should consider the expected lifespan of the product when selecting non-serviceable LED luminaires for areas that require long runtimes.

- The efficacy (lumen output per Watt) of traditional light sources is rated for the lamp only. Since LED lamps cannot be separated from their driver and heat-dissipation system (usually part of the housing), the lumens per Watt of the entire LED luminaire is measured. This often makes comparisons of the efficacy of LED luminaires to traditional light sources difficult.
- The efficacy of LED light sources varies by the correlated color temperature (CCT) of the light emitted. LED light sources with lower CCT values, 2700 to 3500 K, appear more traditionally yellowish in color, but have up to 30% reduced efficacy compared to those with higher CCT values and more bluish light.
- LEDs emit directional light. This is an advantage in luminaires such as downlights and track lights, but makes designing LED luminaires for general ambient lighting a challenge.
- The color of the light output from LEDs may change over time, when dimming, and when viewing the light source from different angles, as well as varying from luminaire to luminaire.
- LEDs may have a size advantage over traditional light sources. The light source itself is very compact and low-profile. However, the LED light source must be combined with driver/controller electronics and a thermal management system in order to operate, which may, depending on the design, make the LED product as bulky, or bulkier than, traditional light sources.
- LEDs do not have breakable glass bulbs or delicate filaments, which may make them more durable than traditional light sources for particular applications.
- The performance of LED light sources improves in cold temperatures, which makes them particularly suitable for walk-in cooler and freezer rooms, refrigerated warehouses, and unconditioned spaces in cold climates—areas where fluorescent light sources may suffer performance degradation.
- LEDs come to full brightness instantly when turned on.
- Many LED luminaires come with 0 – 10V dimming as a standard feature. This is important to note when comparing costs to linear fluorescent fixtures, which require special ballasts for dimming.
- LEDs do not produce any infrared (IR) or ultraviolet (UV) emissions, which makes them suitable for display lighting of food or delicate items.

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Comparison of Lighting Performance

The following tables compare performance of LEDs lighting with other lighting systems for various applications. This data is taken from the Mar 2007 – Oct 2011 Detailed Test Reports of the DOE Commercially Available LED Product Evaluation and Reporting (CALiPER) program (homepage: http://www1.eere.energy.gov/buildings/ssl/caliper.html), unless otherwise noted.

Comparison of Recessed Downlight Performance

Recessed Downlight	Total Light Output [lumens]	Absolute (Luminaire) Efficacy [lm/W]	CCT [K]	CRI
LED 11-104	962	55	2,946	77
LED 10-53	1,072	44	2,995	84
LED 10-52	983	36	3,436	76
CFL 09-66	952	29	3,392	82
CFL 09-45	872	31	3,166	83
CFL 07-21	514	42	2,729	82

Comparison of Track/Spotlight Performance

Track/Spotlight	Total Light Output [lumens]	Absolute (Luminaire) Efficacy [lm/W]	CCT [K]	CRI
LED 11-07	571	45	3,392	91
LED 11-02	643	44	3,193	81
LED 10-58	726	29	2,928	82
Benchmark Halogen TBD	(TBD)	(TBD)	(TBD)	(TBD)

Comparison of Overhead Troffer Performance

2X2 Troffer	Total Light Output [lumens]	Absolute (Luminaire) Efficacy [lm/W]	CCT [K]	CRI
LED 11-56	1,992	54	3,440	86
LED 11-55	2,007	65	2,899	76
LED 11-48	3,439	80	3,152	94
LED 11-47	2,915	66	3,588	83
32W T8 U-bent 11-62	3,160	56	3,207	84
28W T5 Single Tube CFL 11-49ii	3,987	64	3,435	83
40W Twin Tube CFL 11-49i	4,095	60	3,294	82
17W T8 2 ft. Linear 09-73	1,706	49	3,318	86

2X4 Troffer	Total Light Output [lumens]	Absolute (Luminaire) Efficacy [lm/W]	CCT [K]	CRI
LED M-1	4,886	93	~3,500	82
LED M-2	5,568	99	~4,000	83
LED M-3	~4,000	~90	~4,000	90
LED M-4	4,474	87	~3,500	82
Benchmark Fluorescent TBD	(TBD)	(TBD)	(TBD)	(TBD)

Source (this table only): Manufacturers' product data sheets dated Feb – July 2012. Where possible, the manufacturers' reported test results are listed, otherwise the values shown are nominal (indicated by ~).

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Comparison of High Bay Lighting Performance

Recessed Downlight	Total Light Output [lumens]	Absolute (Luminaire) Efficacy [lm/W]	CCT [K]	CRI
LED 11-61	11,930	66	4,066	67
LED 11-60	4,527	60	5,354	70
LED 11-52	11,020	80	5,989	71
32W T8 Linear 11-54	8,042	79	3,840	81
Metal Halide 11-44	9,782	53	4,411	51

Comparison of Under Cabinet Lighting Performance

Under Cabinet Light	Total Light Output [lumens]	Absolute (Luminaire) Efficacy [lm/W]	CCT [K]	CRI
LED 09-38	200	41	5,407	74
LED 09-32	235	21	2,973	96
LED 08-26	144	24	3,639	79
CFL 07-60	360	23	3,865	58
CFL 07-41	235	20	5,734	71
CFL 07-20	689	36	3,015	84

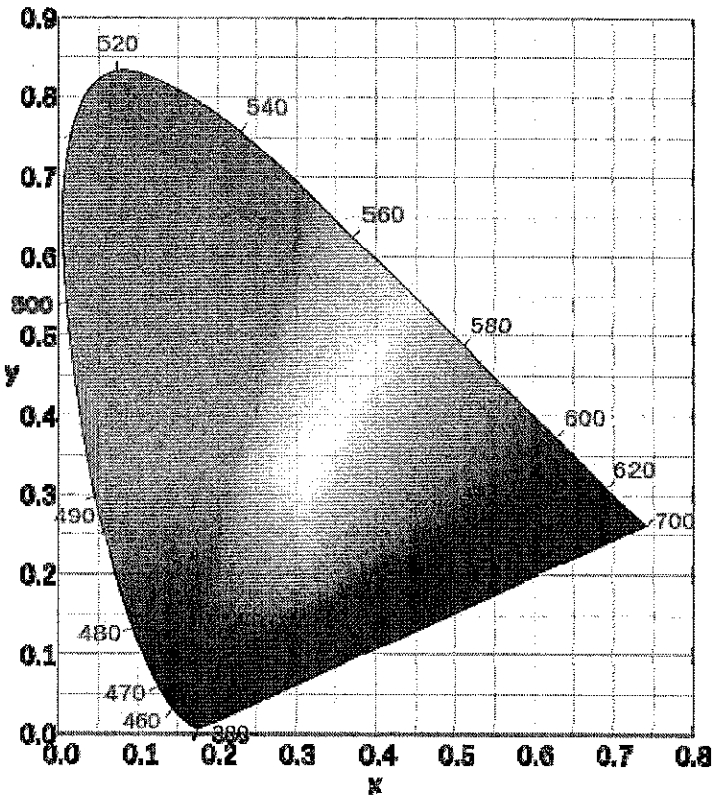
Comparison of Portable/Desk Lamp Performance

Portable/Desk Lamp	Total Light Output [lumens]	Absolute (Luminaire) Efficacy [lm/W]	CCT [K]	CRI
LED 09-42	213	28	2,940	93
LED 08-86	251	16	6,255	76
LED 08-85	254	22	3,588	78
CFL 07-49	700	43	2,819	81
CFL 07-02	236	24	3,432	79
Halogen 07-10	351	9	2,856	100

Glossary of Lighting Terms

Absolute Photometry: the light output of the complete luminaire is measured with a single test procedure. This method is used for LED luminaires since the light source cannot be isolated from its driver/controller electronics and thermal management system.

Chromaticity Diagram: a plot showing all of the colors within the visible light spectrum at a constant level of brightness. See figure below for an example.



Source: Wikimedia Commons (http://commons.wikimedia.org/wiki/File%3ACIExy1931.svg)

Color Rendering Index (CRI): a measure of a light source's ability to faithfully reproduce colors as compared to an ideal source or natural daylight. The CRI has been criticized for not always correlating well with subjective assessment, particularly for light sources with "spikes" in the emitted color spectrum, such as fluorescents and LEDs. Alternatives to the CRI have been developed, such as the Color Quality Scale (CQS), but have yet to see wide acceptance within the industry.

Correlated Color Temperature (CCT): the temperature, in Kelvin, of an ideal blackbody radiator that would most closely match the perceived color of a light source. Light sources with color temperatures below 3,000 K appear yellowish and are considered "warm" light, while color temperatures above 5,000 K appear bluish and are thought of as "cool." Note that, in this context, the terms "warm" and "cool" are inversely related to the numeric temperature.

Efficacy: the amount of light produced by a light source per unit of input power, listed in terms of lumens per Watt [lm/W]. The maximum possible efficacy is 683 lm/W, produced by an ideal light source at a wavelength of 555 nm (green light).

Efficiency: the amount of light produced relative to a maximum, expressed as a percentage or dimensionless ratio.

Footcandles: a measure of light intensity on a surface, in units of lumens per square foot. The SI equivalent to footcandles is lux, or lumens per square meter. 1 footcandle equals approximately 10 lux.

L_{70}: the lumen maintenance lifetime of an LED light source, or the time it takes, in hours of continuous operation, for the light output to drop to 70% of the initial value.

LM-79: a test specification developed by the Illuminating Engineering Society of North America (IESNA) that describes standard procedures for measuring the total light output, efficacy, and chromaticity of LED lighting products.

LM-80: a test specification developed by IESNA that describes standard procedures for measuring the lumen maintenance lifetime of LED lighting products.

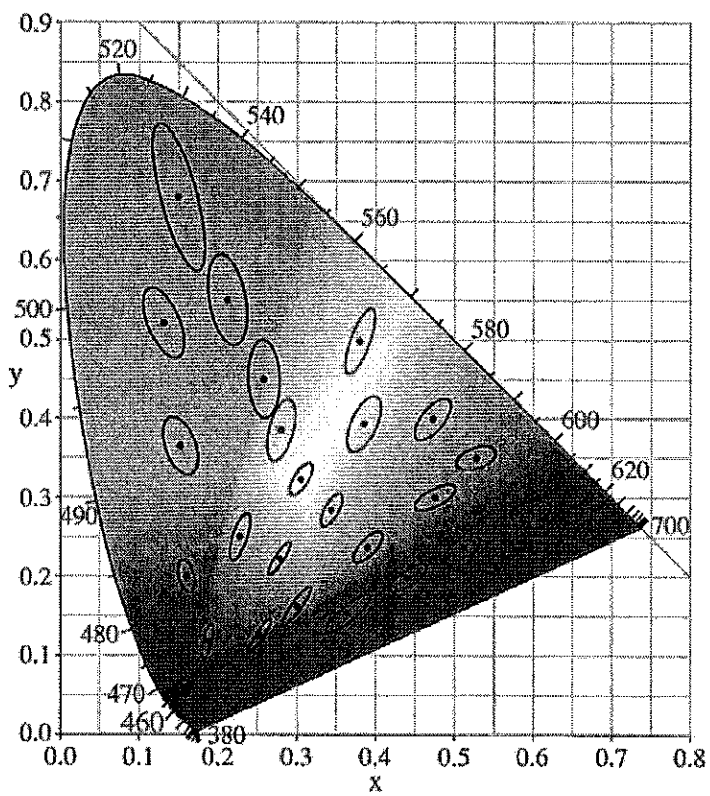
Lamp: a replaceable component that produces light; the "light bulb."

LED: an abbreviation for "light-emitting diode," a type of solid-state lighting (SSL) technology.

Lumens: a measure of the total light output of a light source.

Luminaire: a complete lighting unit that includes a lamp, fixture, and other components (e.g. ballast, reflector, lens, power supply, etc).

MacAdam Ellipse: the minimum change in the color of light that is perceivable to the "standard human observer," as plotted on a chromaticity diagram. Note that the MacAdam ellipses shown in the figure below are represented at 10 times their actual size for clarity.



Source: Wikimedia Commons (http://commons.wikimedia.org/wiki/File:CIExy1931_MacAdam.png)

Relative Photometry: the light output of the lamp is tested separately and then this measurement is combined with the fixture efficiency to yield the total luminaire light output.

Appendix E. Daylighting Guidelines

Critical Elements of the Daylighting System

Glass

- Windows located to optimize daylight
- High performance glass

Electric Lighting

- Lighting type that allows dimming or switching on/off quickly
- Circuits parallel to window/wall
- Circuits close to windows dim/off first

Photo Sensor and Dimming/Switching Controls

- For large open office areas, at least one sensor per orientation or more, depending on level of control desired
- For classrooms, at least one sensor per room controlling light in room
- Locate per manufacturer's recommendations
- Adjustable performance settings for light level and response time
- Switches lights off or dims lights to maintain desired light level

Solar Control Device such as Blinds (optional)

- Open when daylight available
- Closure or partial closure in direct sunlight

Wall and Ceiling Finishes with High Reflective Values

- Light colors to reflect daylight and reduce contract/glare at window areas

Furnishings Should Be Conducive to Daylighting

- Low furnishing heights to allow deep daylight penetration
- Light colored surfaces for maximum reflectance of daylight

Implementation Guidelines

Construction Documents sufficient to define daylighting system

- Intent of daylighting system
- Identify required system components
- Performance requirements
- Define lighting level minimum thresholds
- Electric light and control circuitry, linking auto controls with sensors and circuits

Construction Documents that clearly define the contractor's responsibilities

- Provide a system that functions as expected
- Install equipment according to manufacturer's instructions
- Calibrate sensors to specified performance using light meter
- Document calibration for each daylit space
- _____ fc electric lighting with no daylight
- _____ fc electric lighting begins to dim or shut off
- _____ fc electric lighting reaches minimum output
- _____ fc electric lighting minimum output
- Document glazing performance characteristics from manufacturer
- Instructions for owner/maintenance staff
- Written maintenance issues
- Written re-calibration process, suggested timetable
- On-site demonstration of calibration process

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