Report No. July 2011

Headquarters, US Army Corps of Engineers

US Army Corps of Engineers®

MILCON Energy Efficiency and Sustainability Study of Five Types of Army Buildings

Summary Report

USACE
ERDC – CERL
NREL
PNNL

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Executive Summary

ES.1 Purpose and Goals

The purpose of this *Military Construction (MILCON) Energy Efficiency and Sustainability Study of Five Army Buildings* was to investigate current building features and construction methods and materials to optimize energy reduction and sustainability. At a minimum, the study was to ensure that the five selected standard designs meet all applicable energy reduction and sustainable design policies. The building types studied were:

- Unaccompanied Enlisted Personnel Housing (UEPH, 72111)
- Tactical Equipment Maintenance Facility (TEMF, 21410)
- Company Operations Facility (COF, 14185)
- Brigade Headquarters (Bde HQ, 14182)
- Dining Facility (DFAC, 72210).

The goals for the study were as follows:

- Determine the difference in initial investment or "first" cost of the proposed baseline buildings with energy enhancements to meet the energy and sustainability mandates as compared to the original baseline buildings without energy enhancements.
- Compare and analyze the five United States Army Corps of Engineers (USACE) standard designs as-is to designs with full compliance of energy and sustainability mandates.
  - The main purpose of this study was to comply with the Energy Independence and Security Act (EISA) of 2007 target of a 65 percent fossil fuel-generated energy reduction by 2015 achieved by reducing building energy consumption.
  - Simultaneously, the study determined compliance with the energy performance option of the American Society of Heating, Refrigerating and Air-Conditioning (ASHRAE) Standard 189.1.
- Determine whether scope, which includes mission requirements, architectural features and building function, would have to be reduced to build the standard design with full compliance of energy and sustainability mandates.
- Develop energy models for buildings that support net zero ready installations and that achieve 65 percent fossil fuel-generated energy reduction compared to a similar building in fiscal year 2003 (FY03) Commercial Building Energy Consumption Survey (CBECS).
  - For this study, the German Passivhaus (passive house) standards were used to go beyond the current ASHRAE standards and develop ultra-low energy buildings. The basic concept behind the passive house approach is to superinsulate a building to reduce the amount of energy required to heat, ventilate, and cool it in addition to other considerations such as building orientation, glazing areas, envelope geometry, etc.
- Reduce both indoor and outdoor potable water usage.

- Account for the impact on operations and maintenance by energy systems.
- Comply with the High Performance Sustainable Building Guiding Principles as stated in Executive Order (EO) 13514.

During the course of this study, several tools were developed to help the U.S. Army Corps of Engineers (USACE) Center of Standardization (COS), District, and Army Installations staff better understand the technologies and mandates they are facing. Nineteen TechNotes, brief summaries of new technologies, were developed and posted to the Whole Building Design Guide website (http://mrsi.usace.army.mil/cos/TechNotes/Forms/AllItems.aspx) to provide brief overviews of specific technologies that are either new or not widely used. The research team also reviewed current mandates, policies, and standards and compared them to LEED 2009 using an Excel spreadsheet format to illustrate potentially attainable levels of LEED certification from meeting current requirements (Mapping to LEED). Finally, a similar Excel spreadsheet format found in the Mapping to LEED tool was developed for the measures evaluated in this study and their compliance with ASHRAE 189.1.

ES.2 Approaches

The approaches used during the study included a preliminary meeting/charrettes with the COS for the five building types as well as integrated schematic charrettes with COS representatives for each professional discipline both before and after energy modeling was completed. A lead Cost Estimator worked with the COS estimators and the U.S. Army Engineer Research and Development Center/Construction Engineering Research Laboratory (ERDC/CERL) to assess what study findings may be incorporated under current project programming and how much additional funding will be necessary to incorporate all study findings into each facility type for the FY13 MILCON program. A webinar was held with representatives from affected installations in the FY13 MILCON program and lessons learned will be shared with COSs and Army Installations staff. Operations and maintenance (O&M) impacts on staff at the Installations level and long-term energy efficiency of the buildings were also considered.

ES.3 Collaborators

Achieving the deliverables required the following contributions from collaborators:

- USACE Headquarters provided coordination with COSs and participated in scheduled working meetings conducted at respective COSs, set and maintained schedule milestones for the entire effort, tracked and revised energy/sustainability targets.
- ERDC CERL, the National Renewable Energy Laboratory (NREL), and private contractors conducted energy use reduction studies for the five selected building types using modeling and computer simulation analysis.
- ERDC CERL and Pacific Northwest National Laboratory (PNNL) provided sustainability and LEED validation/analysis of the standard designs and proposed alternatives.
- Fort Worth COS and PNNL provided estimating and life-cycle cost analysis for the proposed alternatives to the standard designs.

ES.4 Barriers

The final savings determination was difficult because there is no clearly defined baseline for these Army building types within the CBECS. In other words, these buildings do not have equivalent building categories within CBECS. Assumptions and compromises had to be made in terms of category selection and Energy Use Intensity (EUI) figures used. Further, since there will be EUI figures from DOE, the results reported in this study will no doubt change when the rule is finalized.

There was also initial confusion over the different energy baselines found in ASHRAE standards (modeled building energy) and Section 433 of EISA 2007 (measured building and plug load energy). This created a challenging "apples to oranges" scenario.

Because of the uncertain baseline, the focus became creating the most efficient building within the constraints of the analysis rather than trying to create an exact match with what were basically arbitrary CBECS targets. Modeling and calculations were done, however, to provide results in terms of EISA 2007 and CBECS requirements.

The study was able to show the energy effectiveness of a range of efficiency measures, but it was not able to show the cost effectiveness of individual measures, nor was it able to optimize the designs for the highest energy performance at the lowest costs. This typically is done early in the design phase.

ES.5 Summary Findings

Summary findings for each of the building types are listed in Table ES.1.

Table ES.1 MILCON Energy Study Summary

Findings	UEPH	TEMF	COF	Bde HQ	DFAC
Range of energy savings	36-66%	37-63%	34-80%	9-53%	16-38%
Range of cost increase	4.4-28.1%	6.6-10.3%	7.7-19.7%	4.8-19.1%	2.0-4.4%
Buildings that support net zero ready installations	Yes	Yes	Yes	Yes	Yes
Achieve energy savings 30% better than ASHRAE 90.1-2007	Yes	Yes	Yes	Yes	Yes
Buildings achieve 65% fossil fuel reduction compared to *source* CBECS 2003 (based on Section 433 of EISA 2007 requirement for 2015 by 2013)	0 climate zones, not met due to plug loads	All 15 climate zones	0 climate zones, 1 climate zones within 10%	0 climate zone, not met due to plug loads	0 climate zones, not met due to plug loads
30% domestic water reduction	Yes	Yes	Yes	Yes	Yes
O&M considered in energy package selection	Yes	Yes	Yes	Yes	Yes
20% reduction in use of indoor potable hot water	Yes	Yes	Yes	Yes	Yes
30% of hot water energy usage supplied by solar hot water	Yes	No	No	No	No

Findings	UEPH	TEMF	COF	Bde HQ	DFAC
Transpired solar collectors?	No	Yes	Yes	No	No
50% less outdoor potable water use	Yes	Yes	Yes	Yes	Yes
75% daylighting factor in all occupied spaces, 2% space for Critical visual tasks	Yes	Yes	Yes	No	Yes, in dining and serving areas
Inclusion of enhanced commissioning and measurement and verification	Yes	Yes	Yes	Yes	Yes
LEED 2009 Silver rating	Yes, may reach Gold on some projects	Yes, may reach Gold on some projects	Yes	Yes	Yes
Compliance with the Guiding Principles as stated in EO 13514	Yes	Yes	Yes	Yes	Yes

ES.6 Conclusions

The analysis showed that significant energy savings are possible for all climates. However, it is very difficult to reach the EISA 2007 target for the 2015 goal of 65 percent fossil fuel reduction with building-specific efficiency measures alone. The extent of energy savings achieved is site- and facility-specific. Additional savings may be achievable, but the current study shows the energy savings picture as follows:

- 25 to 35 percent energy savings: The building yields the maximum energy savings for the lowest cost
- 35 to 60 percent energy savings: Each increment of energy saved comes at an increasingly higher cost (plug load reduction, small scale renewable energy, building orientation, site specific design)
- Above 60 percent: May be cost prohibitive without looking beyond the building (significant plug load reduction, clustering, renewable energy, cogeneration, etc.)
- Some facility types in certain regions will never achieve the 65 percent energy target through energy efficiency measures alone

At the start of this study, the EISA 2007 target for a 65 percent energy reduction by 2015 was analyzed in terms of site energy (not based on the source of energy used). However during the study in 2010, a new rule interpreting EISA 2007 and the energy targets was released by DOE (see References section for citation) that shifted the analysis from site energy to source energy, which is based on the reduction of fossil fuels at the point of energy production.

This resulted in fewer building types meeting the targets within climate zones and also resulted in installation of all-electric appliances and equipment to minimize retrofitting from gas or oil to electric at a later date to meet even more stringent requirements. In other words, in this study, the buildings reduced energy usage at the site to meet source energy reduction targets.

In addition, CBECS building categories and their related EUIs are not directly comparable to these five Army building types in most cases. This also negatively affected the ability of the buildings to meet CBECS source energy targets.

With regards to ASHRAE 189.1, there is a high level of confidence from this study that the five building types would meet or exceed the goal of ASHRAE 189.1 to achieve a 30 percent reduction in energy use compared to an ASHRAE 90.1-2007 building including plug loads.

In terms of costs, the cost increases for the recommended Low Energy Packages for the five building types typically ranged from 2 percent to 10 percent with a high of 28 percent. This study also performed a life-cycle cost analysis for two buildings in three climate zones. Three of the four building combinations had multiple low-energy packages that were life-cycle cost effective. These results reflect the impact of all regulatory drivers on the standard designs for the five building types.

While using a passive house approach can reduce the heating, ventilation, and air-conditioning (HVAC) system costs, this is balanced against increased costs for technologies or processes like triple-pane windows that would meet Anti-Terrorism/Force Protection (AT/FP) blast-resistant windows, rainwater harvesting, enhanced commissioning that did not previously exist or have not seen widespread use across MILCON projects within a given fiscal year. As can be seen from the building energy reduction results, the increased cost only takes the buildings up to a certain point in terms of energy efficiency unless and until plug loads are reduced. In other words, the buildings are as energy efficient as possible while remaining life-cycle cost effective and would meet the 65 percent energy reduction target in a number of climate zones and for the building types if proportionately high plug loads are not considered.

Assuming proper construction and commissioning, energy savings in these buildings would be immediate. In terms of renewables, however, their cost is over six times higher than the current investment in energy efficiency measures in today's dollars.

The most effective energy efficiency measures for the building types analyzed in this study are summarized in Table ES.2.

Table ES.2 Summary of Most Effective EEMs

All Buildings
• Increased fan, pump, and HVAC efficiency • Increased daylighting and lighting power density reduction • Increased wall and roof insulation • Reduced infiltration rates • High-efficiency fixtures to reduce potable water demand • Cool roofs in climate zones 1–5 and window shading • Triple pane windows (can be extremely orientation and site specific)
UEPH
• Radiant heating and cooling • Solar hot water for 30% domestic hot water • Improved boiler and chiller efficiencies • DOAS for ventilation and humidity control • Separate ventilation for living and laundry areas
TEMF
• Reduced ventilation in repair bays • Radiant floors • Transpired solar collectors
COF
• Alternate construction option - reduced volume of conditioned air in readiness bays • VAV fans, ERV, IDEC, DOAS depending on climate zone • Transpired solar collectors depending on climate zone
Bde HQ
• Radiant heating and cooling • High efficiency chiller and boiler with GSHP
DFAC
• High efficiency or high-efficiency all-electric kitchen equipment • Exhaust hood design and flow control • Demand control ventilation on make-up air units • Passive house insulation levels for limited climate zones
DOAS = dedicated outdoor air system; ERV = energy recovery ventilation; GSHP = ground-source heat pump; HVAC = heating, ventilation, and air-conditioning; IDEC = indirect/direct evaporative cooling; VAV = variable air volume.

ES.7 Lessons Learned

The study derived the following lessons learned:

- Fully integrated design is a requirement and not an option with high-efficiency buildings. All subject matter experts, including the commissioning agent and O&M staff, need to be involved from the earliest stages of the project. If this is not done, much time is wasted passing the design back and

forth for changes and systems, particularly HVAC systems, are not designed to their maximum efficiency to work with exterior insulation levels, roofing materials, etc.

- O&M staff must be properly trained on new systems and technologies or high-efficiency buildings will quickly become less efficient or worse than buildings constructed in the past. Both time and money will have been wasted. Enhanced commissioning is important to ensure that design, installation, and startup of systems are done correctly and measurement and verification (M&V) are important to verify modeling results. Many of the mechanical systems will only operate properly within a narrow set of parameters. Once operating outside of those parameters for extended periods of time, systems will either not function efficiently or fail to function at all.
- There is no single, "silver bullet" answer for these buildings. Climate zone, building site conditions, and other factors play major roles in building performance.
- When buildings are designed to be minimally energy efficient, it is relatively easy to use a one-size-fits-all, prescriptive approach because the results in terms of energy efficiency are not a factor. With these buildings, the burden is on the designers to take a performance-based rule set and apply it to an individual building by defining strategies that result in achieving overall energy reduction targets.
- While this study focused on passive house approaches and technologies, these should not be the prescribed path for the design team to take when it comes to incorporating measures into standard designs. For example, climate zone 1A may not be found to be appropriate for passive house insulation levels may be slightly relaxed but stringent air tightness and a DOAS system must be applied to ensure moisture/humidity control. Climate zone 5A may achieve much better results. Another example, it may not be optimal to design triple-pane windows on all four walls of a building if further study and modeling reveal that it is not appropriate on the north side of the building or if a taller building or landscaping shades one or more sides of the building and two-pane, low-e windows can be used with little or no impact on energy performance. In this example, it would be beneficial to also take a look at the window U-value to maintain an acceptable occupant thermal comfort and not just the solar heat gain.
- It is expected that for some buildings in some climate zones, current practices or current practices with relatively few changes, will result in achieving the performance targets. In other buildings and climate zones, real innovation will be needed to achieve the same results.
- In the future, to meet ever more stringent energy targets on the path to net zero energy, buildings will need to be:
  - grouped together to take advantage of larger, more energy efficient technologies. This will allow for the sharing of resources between buildings, e.g., waste heat in a cogeneration facility.
  - combined into one building for multiple life/work purposes (e.g., UEPH on the upper floors, DFAC on the main floor of a barracks complex, and a COF either on the first floor or in the basement of the barracks complex).
- Reducing the plug loads to a level that would achieve the EISA 2007 target for 2015 fossil fuel energy reduction would require a reevaluation of mission and quality of life requirements for some standard designs, for example:
  - UEPH – Prescribe the types of electronic equipment that soldiers can put in their modules, e.g., light-emitting diode (LED) TVs only of a maximum size—no plasma TVs, LED computer screens only, limit kitchen appliances to a microwave, centralized laundry facilities—no in-module facilities, two-person modules versus one person.

  - Bde HQ – Procure only LED computer screens, limit the number per person, procure only top-tier ENERGY STAR® central processing units, laptops, and related/support equipment, mandate and enforce a low maximum wattage usage per person.
  - DFAC – Change the menu to eliminate or minimize the need for high-energy-usage kitchen appliances and equipment. Extend the meal periods over a longer period of time to reduce the peak demand loads currently needed by kitchen appliances and equipment.

- Occupant behavior needs to change. Whether it is turning off lights when not in use, properly using of operable windows, or not blocking HVAC vents, occupants determine the ultimate efficiency of a building. Changing these behavior patterns through education and training is essential to the long-term goal of having a net zero installation.
- Educate everyone to have a uniform goal. Education must be provided to USACE COSs, Army Installations staff, general contractors, architects and engineers (A&Es), and trades on new features, technologies, systems, and approaches.
- Enhanced commissioning needs to be fully incorporated into the design phase of MILCON projects which has not been done routinely in the past. This will require a reexamination of the current strategy of waiting until after the RFP is awarded before a commissioning agent is designated.
- Cost optimization needs to be completed for all energy models that were a part of this study and should ideally be completed at the early stages of a project. It is important to complete it early so that the highest energy and cost efficiencies can be determined.
- Determine which technologies need further development/improvement then work with industry directly to make the changes so improved or new products can be brought to market and leverage the buying power of all of the armed services.

ES.8 Recommendations

The following recommendations were derived from the study:

- Complete the cost optimization for each of the energy efficiency packages.
- Conduct a study of other technologies in combination with current practices in some climate zones for the five building types that could produce similar energy savings to those found in this study.
- In cooperation with the COSs, develop guidance on how to achieve a truly integrated design regardless of building type.
- Provide technical assistance as needed to the COSs to determine what changes need to be made to the standard designs to achieve maximum, life-cycle cost effective energy efficient buildings.
- Develop protocols that will ensure performance targets are met for individual projects that are building type- and site-specific.
- Develop tools that will help COSs, Army Installations staff, general contractors, A&Es, trades, and occupants understand what needs to be done to design, implement, operate, maintain, and properly use the technologies and packages that were analyzed in this study. These would need to include tools such as additional TechNotes, guide specs, United Facilities Criteria, and training materials.

- Evaluate and prioritize these study results in terms of major renovations that will be conducted within the next 5 years of specific types of buildings in specific climate zones, e.g., VOLAR barracks.
- Ensure compliance with ASHRAE 189.1 and the results of this study.
- Review mission and quality of life requirements that affect high plug loads for some building types and implement changes as appropriate.
- Develop industry partnerships for specific technologies and products to ensure availability and lower cost over time.
- Work with master planners to redesign the location of several types of buildings and multiple usages for a single building or connected complex of buildings; e.g., barracks, to take maximum advantage of shared resources. Evaluate energy savings for various options and institute changes.
- Some buildings or locations are optimal for minimizing energy demands and should be the preferred ones for upgrades. For example those located below a hill outside of the prevailing wind have much less exposure to the elements and could have a better orientation for renewable technologies like roof top solar.
- Explore strategies related to making good use of the thermal mass of the structure.
- Instrumentation and controls play a vital role in ensuring that HVAC, lighting, and other building systems are functioning as intended. Additional emphasis needs to be given in these areas starting in the design phase and following all the way through construction to operations and maintenance. This includes addressing the issue of where controls/sensors are located within the building and who has authority to change settings, e.g., one person who prefers a specific temperature range due to their office location creates a significant energy impact to a site by changing the setting and impacting an entire area or section of the building.
- Procure only top-tier ENERGY STAR® appliances and equipment.
- Procure appliances and equipment that can be shown to be in the top 10 percent in terms of energy efficiency where an ENERGY STAR® labeling program is unavailable.
- Energy costs vary by season and region and the DoD could take advantage of cost effective renewable energy technology during peak demand periods, avoiding the most expensive fossil fuel based resources and their associated environmental externalities.
- Lessons learned from operators of large portfolios of buildings with similar use to the DOD could offer some very practical and cost effective insights into the payback of various options within specific regions. Many large real estate firms that have taken over BRAC and other facilities and transformed them into profitable and energy efficient installations should be consulted and site visits conducted to see how this “reuse” has progressed and why landowners elected to invest in different building improvements to achieve their financial and other ownership objectives. Has the private sector done better than existing DOD installations in making progress toward similar goals in the last 5-10 years.
- Coordinate work with U.S. Department of Energy commercial building projects and research.
- Demonstrate energy use reduction possibilities outlined in this study and obtain real cost data through pilot construction projects.

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Acronyms and Abbreviations

A&E	architect and engineer
ACF	Area Cost Factor
ACH	air changes per hour
ACSIM	Assistant Chief of Staff for Installation Management
AHU	air handling unit
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
AT/FP	Anti-Terrorism/Force Protection
Bde HQ	Brigade Headquarters
BLCC	Building Life-Cycle Cost
BOC	Brigade Operations Center
BOD	Basis of Design
Btu/hr/ft^2/°F	British thermal units per hour per square foot/per degree Fahrenheit (U-value, overall heat transfer coefficient)
CBECS	Commercial Building Energy Consumption Survey
CDD	Cooling Degree Days
CEE	Consortium for Energy Efficiency
CERL	Construction Engineering Research Laboratory (USACE)
cfm	cubic (foot) feet per minute
cfm/ft^2	cubic (foot) feet per minute/square feet (outdoor air ventilation rate)
CFR	Code of Federal Regulations
COF	Company Operations Facility
COP	coefficient of performance
COS	(U.S. Army Corps of Engineers) Center of Standardization
CxA	Commissioning Authority
DCV	demand control ventilation
DFAC	Dining Facility
DHW	domestic hot water
DOAS	dedicated outdoor air system
DoD	Department of Defense
DOE	Department of Energy
ECB	(USACE) Engineering Construction Bulletin
EEM	energy efficiency measure
EISA	Energy Independence and Security Act
EPA	Environmental Protection Agency
EPACT	Environmental Protection Act
EO	Executive Order
ERDC	Engineer Research and Development Center (USACE)
ERV	energy recovery ventilation
ET	evapotranspiration
EUI	Energy Use Intensity
°F	degree(s) Fahrenheit
FCx	Fundamental Commissioning
ft^2	square (foot) feet
FY	fiscal year

gal	gallon(s)
gpm	gallons per minute
GSHP	ground-source heat pump
GSA	General Services Administration
h	hour(s)
HDD	Heating Degree Days
HET	high-efficiency toilet
HPSB GP	High Performance and Sustainable Buildings Guiding Principles
HQ	Headquarters
hr	hour(s)
HVAC	heating, ventilation, and air-conditioning
IAQ	indoor air quality
IDEC	indirect/direct evaporative cooling
IEA ECBCS	International Energy Agency Energy Conservation in Buildings and Community Systems
IEQ	indoor environmental quality
IPT	Integrated Process Team
K	Kelvin
$kBtu/ft^2/yr$	thousand British thermal units per square foot per year (Energy Use Intensity)
kWh	kilowatt hour(s)
$kWh/m^2/yr$	kilowatt hours per square meter per year (annual energy use per area)
L	liter(s)
LCC	life-cycle cost
LCCA	life-cycle cost analysis
LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design
LID	low impact development
MII	Army Detailed Cost Estimating System (MCACES)
MAU	make-up air units
Mbtu	one million British thermal units
M&V	measurement and verification
MILCON	Military Construction
MPS	mandates, policies, and standards
NIST	National Institute of Standards and Technology
NOC	Network Operations Center
NPV	net present value
NREL	National Renewable Energy Laboratory
O&M	operations and maintenance
OM&R	operations, maintenance, and repair
OPR	Owner's Project Requirements
Pa	pascal(s)
PACES	Parametric Cost Estimating System
PAX	Programming Accounting Execution System
PNNL	Pacific Northwest National Laboratory
s	second(s)
SCIF	Sensitive Compartmented Information Facility

SFA	skylight to floor area
SHGC	solar heat gain coefficient
R	R-value, thermal resistance
TEMF	Tactical Equipment Maintenance Facility
TER	Total Energy Recovery
TSC	Transpired Solar Collectors
U-value	overall heat transfer coefficient
UEPH	Unaccompanied Enlisted Personnel Housing
UFC	United Facilities Criteria
UFGS	Unified Facilities Guide Specifications
USACE	United States Army Corps of Engineers
USGBC	United States Green Building Council
US IP	US Customary System/British Units
VAV	variable air volume
VFD	variable frequency drive
W	watt(s)
w.g.	water gauge
Wh/m^3	internal heat generation
W/mK	thermal conductivity
$W/m^2/K$	U-value, overall heat transfer coefficient
yr	year(s)

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1.0 Introduction

In early 2010, a Military Construction (MILCON) Energy Integrated Process Team (IPT) was formed to bring together all the Army stakeholders involved with new construction. Members of this group included the Assistant Chief of Staff for Installation Management (ACSIM), Installation Management Command (IMCOM), U.S. Army Corps of Engineers (USACE), Engineer Research and Development Center–Construction Engineering Research Laboratory (ERDC-CERL), Army Reserves, and invitations were extended to members of other services such as Navy and Air Force. The goals of this group were as follows:

- Determine what measures are necessary to meet Federal energy and sustainability mandates.
- Determine the cost impact of compliance.
- Recommend the path forward to move Army Installations toward full compliance.
- Determine the delta in cost to meet the energy and Leadership in Energy and Environmental Design (LEED)/sustainability mandates.

1.1 Project Purpose

The USACE was tasked to take the lead in determining the building features, construction methods and materials that will optimize energy reduction and sustainability for new construction standard designs in fiscal year 2013 (FY13) for the five most commonly constructed Army building types:

- Unaccompanied Enlisted Personnel Housing (UEPH – barracks, 72111)
- Tactical Equipment Maintenance Facility (TEMF – repair facility, 21210)
- Company Operations Facility (COF – government office and other public assembly, 14185)
- Brigade Headquarters (Bde HQ – government office and data center, 14182)
- Dining Facilities (DFAC, 72210)

At a minimum, the selected standard designs were required to meet all applicable energy reduction and sustainable design mandates (e.g., LEED Silver, Environmental Protection Act [EPACT] 2005, Energy Independence and Security Act [EISA] 2007, Executive Order [EO] 13423, and EO13514), discussed in detail in Section 2 of this report. USACE was asked to evaluate the design of each facility for full mission scope and full energy and sustainability compliance. Specifically, comply with Section 433 of EISA 2007 target of achieving a 65 percent reduction in source energy usage by 2015, provide an indication on how much scope would have to be reduced to build the standard design with full compliance of energy and sustainability mandates, and determine the delta in cost to meet the energy and sustainability mandates. It is important to note that results in this study were based on total energy use as opposed to the fossil-fuel based portion of total energy use alone.

As a reference, in FY08–09 the Army developed revised building designs by working with industry experts and A&E firms to develop a “best of the best” design for each Army facility. The requirements of this effort were to optimize the mission, function, quality, and cost of the buildings. The International Building Code was used as the baseline building code. The baseline design was amended and

supplemented to include anti-terrorism and force protection, EPACT 2005 compliance, LEED Silver certifiable, Army Installations, and mission-specific requirements, and select Department of Defense (DoD) Unified Facility Criteria considered critical to life safety and mission.

The approach of this study was to take these existing building designs and optimize the energy performance of each building in order to build the most energy efficient buildings possible before looking at options like renewables and cogeneration. Energy models were developed with various energy packages and options and sustainability features were identified for each building in order to meet Federal mandates. Meetings were held with USACE Centers of Standardization (COSs) to discuss how to improve the energy performance of the buildings and to have a reality check on assumptions, ideas, and options. Cost estimates were developed to determine the cost delta between the baseline buildings and proposed enhanced design options. Lastly, a LEED analysis was completed as an outcome of the energy modeling and estimating.

Specific targets for the study included the following:

- Design Army buildings to be net zero ready.
- Achieve a 65 percent reduction in overall energy consumption compared to the 2003 Commercial Building Energy Consumption Survey (CBECS, by the U.S. Department of Energy's [DOE's] Energy Information Agency).
- Reduce both indoor and outdoor potable water usage.
- Account for the impact of energy systems on operations and maintenance (O&M).
- Comply with the High Performance Sustainable Buildings Guiding Principles (Guiding Principles) as stated in EO 13514.

Many of the features of the buildings, such as the building form and window geometries, were fixed and not allowed to be varied. These were primarily mission-related requirements. While the goal should be to design the most efficient building at the lowest life-cycle cost (LCC), all of the building functional requirements must also be met. Major design changes, e.g., reconfiguration of barracks' room layouts and new window placement, were not considered during this study which impacted the energy savings that could be achieved. It would be beneficial to approach building design without constraints to see what impact this would have on the results and costs.

1.2 Study Collaborators and Overview

This study is a result of work done by a group of government, institutional, and private sector parties. The National Renewable Energy Laboratory (NREL) and ERDC-CERL were responsible for energy modeling. ERDC-CERL and Pacific Northwest National Laboratory (PNNL) were responsible for water and sustainability information and data. Meetings were held with Savannah (COF, TEMF, Bde HQ), Fort Worth (UEPH), and Norfolk (DFAC) COSs. In addition, Fort Worth staff provided all cost estimating work. Project management was provided by HQ USACE and PNNL staff. A complete list of contributors to this study is provided under the Acknowledgements.

For this analysis, parametric studies were conducted to determine energy savings for a suite of energy efficiency measures (EEMs). Subject matter experts consisting of government, institutional, and private

sector parties were consulted to recommend certain technologies based on the function and energy use of the buildings. EEMs considered the building envelope construction, lighting and plug load power densities and design, as well as heating, ventilation, and air-conditioning (HVAC) strategies.

Representative model buildings were developed based on typical designs provided by the COS for the respective building types. Target energy budgets were developed using different sets of technologies and were analyzed by running energy simulations. Energy savings were determined compared to the 2003 CBECS database as required by EISA 2007.

Energy simulations were completed using EnergyPlus version 5.0 (DOE 2010), and modeling assumptions are shown in the appendices for each building type (Appendices A–E). The approach to modeling the energy efficiency improvements was to first evaluate each efficiency measure independently, then evaluate the measures that yielded the highest energy savings as a "package," in a single model. Evaluating the efficiency measures as a package is important, because the savings from each individual measure are not additive.

EEMs were modeled for each building type across 15 locations. The 15 locations were selected to represent 15 American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) climate zones in the United States. The locations selected were representative cities for the climate zones. Colorado Springs was selected for climate zone 5B instead of Boise, Idaho, to more closely align with the installations at Fort Carson, Colorado. The 15 climate zones and the cities used to represent them are listed in Table 1.1.

Table 1.1 Climate Zones and Cities Used for Simulations

Climate Zone	City	HDD (Base 65ºF)	CDD (base 50ºF)
1A	Miami, FL	200	9474
2A	Houston, TX	1599	6876
2B	Phoenix, AZ	1350	8425
3A	Memphis, TN	3082	5467
3B	El Paso, TX	2708	5488
3C	San Francisco, CA	3016	2883
4A	Baltimore, MD	4707	3709
4B	Albuquerque, NM	4425	3908
4C	Seattle, WA	4908	1823
5A	Chicago, IL	6536	2941
5B	Colorado Springs, CO	6415	2312
6A	Burlington, VT	7771	2228
6B	Helena, MT	7699	1841
7A	Duluth, MN	9818	1536
8A	Fairbanks, AK	13940	1040

CDD = Cooling Degree Days; HDD = Heating Degree Days

The energy efficient packages started with a base package of low-energy features determined by CERL and NREL. These features focused specifically on a passive house approach (see Section 4.1.2.1), low infiltration rates, improved lighting strategies, reduced hot water usage and improved plug load levels that could then be modeled in combination with various HVAC features and technologies in an iterative

process. By modeling the various packages across different climate zones, energy usage and savings could be compared between the low-energy features.

A number of mandates are in effect concerning sustainable design features (see Section 2). EISA 2007 in particular has requirements other than energy targets. In addition to providing component information for sustainable technologies and system for cost estimating purposes, TechNotes were developed to assist USACE staff by providing brief (5- to 6-page) summaries of energy and sustainability measures/technologies. TechNotes are discussed in detail in Section 5.6.2. Another tool, a series of Excel spreadsheets, maps mandates to LEED. Details of this tool are in Section 5.6.3. To address the recent adoption of ASHRAE 189.1 by the Army, an Excel spreadsheet was developed that maps ASHRAE 189.1 requirements to the measures proposed by this study. Section 5.6.1 provides more information about this tool.

The task of cost estimating was to identify the difference in upfront cost for changes to standardized projects. Changes in the projects are reflected in systems selected based on probable life-cycle benefits.

Projects in the award selection stage, or in the case of the UEPH recent award, were used to establish the estimates. These projects were at various locations in the United States: TEMF and DFAC from Fort Bragg, North Carolina, COF and Bde HQ from Fort Stewart, Georgia, and UEPH from Fort Leavenworth, Kansas. As a result, the estimates used COS Adapt Build-level construction drawings that reflected the facilities up-to-date requirements and design solutions. In the case of the UEPH, an estimate using the Parametric Cost Estimating System (PACES) was used to develop an estimate to the same level of detail as the other facilities.

A 40-year life-cycle cost analysis (LCCA) was completed for the UEPH and TEMF buildings using the National Institute of Standards and Technology (NIST) Building Life-Cycle Cost Program (BLCC) version 5.3, which complies with the requirements of Title 10 of the Code of Federal Regulations Part 436 (10 CFR 436). Specifically, the MILCON Analysis, Energy Project module of BLCC was used in the analysis.

1.3 Report Contents and Organization

The ensuing sections of this report present the associated regulatory drivers (Section 2), descriptions of the five building types (Section 3), strategies analyzed to achieve maximum energy efficiency (Section 4), outputs and results (Section 5), recommendations for implementation (Section 6), and a summary of findings (Section 7). References not spelled out in the text, tables, or footnoted are listed in Section 8. In addition, there are appendixes for each building type (A through E), a copy of the advanced lighting report prepared for the study (Appendix F), and Appendix G, which contains general information. The appendixes provide more detailed tables and figures that support the information in the body of the report.

2.0 Regulatory Drivers

Many regulatory drivers affect the design and operation of Federal buildings. Some of the drivers are agency goals that are affected by sustainable design and operations, while others are building-specific. The drivers address energy use, water use, renewable energy, stormwater management, greenhouse gas emissions, pollution prevention, materials selection, integrated design, and indoor environmental quality. Sustainable design is the mechanism that integrates these requirements into a cohesive design. Although all of the drivers were considered during this project, the primary focus was on the following:

- Energy Independence and Security Act of 2007 (EISA 2007), Public Law 110-140 (December 19, 2007) Section 433 Federal Building Energy Efficiency Performance Standards for building fossil fuel based energy requirements, and
- Executive Order 13514 (EO13514) Federal Leadership in Environmental, Energy, and Economic Performance (October 5, 2009) High Performance Sustainable Buildings Guiding Principles (hereafter Guiding Principles).

This project's energy use baselines were established in anticipation of the updated, energy efficiency performance standards, Federal rulemaking associated with section 433 of EISA 2007. This section of EISA 2007 states that all new Federal buildings "shall be designed so that the fossil fuel-generated energy consumption of the buildings is reduced, as compared with such energy consumption by a similar building in fiscal year 2003 (as measured by Commercial Buildings Energy Consumption Survey or Residential Energy Consumption Survey data from the Energy Information Agency), by the percentage specified in the following table:

Fiscal Year	Percentage Reduction
2010	55
2015	65
2020	80
2025	90
2030	100"

The actual data reported by CBECS 2003 is site EUI (Energy Use Intensity) on a national basis for 53 commercial and residential building types all located in the United States. Determining the fossil fuel generated EUIs for the facilities reported in the CBECS 2003 database requires considerable analysis of the CBECS data.

Selecting the CBECS facility types that best represent the five facility types being studied in this project was the first step (see Chapter 5). CBECS categories are not an exact match to EPAs Portfolio Manager, but they help establish the basis for selecting the appropriate building categories within Portfolio Manager and related EUIs provided below. In addition, the Performance Targets Table values in Portfolio Manager helped establish EUI values. The site and source CBECS values that were used for the comparison are listed below in Table 2.1.

The median national EUI value for each building category of interest was then determined in the CEBECS 2003 database. The EUIs for each facility type for all 15 DOE climates were determined by

adjusting the CBECS national median EUI values with climate zone multipliers for each building type from energy simulations of the DOE Reference Building Models.

Finally, the median source energy EUIs were calculated with conversion factors of 3.34 kBtu/kBtu for electricity, 1.047 kBtu/kBtu for natural gas, and 1.145 kBtu/kBtu for fuel oil. The resulting Site and Source Energy EUIs for the five facility types of interest in this study are shown below in Table 2.1.

Table 2.1 Site and Source 2003 CBEC EUIs

CBECS 2003 Median Site EUI [kBtu/ft2]	UEPH	TEMF	COF	Bde HQ	DFAC
	Dormitory	Other Service	Composite Building (Government Office + Other Public Assembly)	Government Office	Fast Food
1A Miami	68	85	56	73	377
2A Houston	69	84	57	75	387
2B Phoenix	67	82	56	73	380
3A Memphis	68	84	55	71	396
3B El Paso	64	79	52	66	381
3C San Francisco	58	76	50	65	370
4A Baltimore	75	93	61	79	430
4B Albuquerque	66	83	53	68	400
4C Seattle	68	86	56	72	406
5A Chicago	84	100	66	85	463
5B Colorado Springs	73	90	57	73	426
6A Burlington	97	111	73	94	503
6B Helena	86	101	65	83	467
7A Duluth	105	119	77	98	540
8A Fairbanks	135	158	104	133	669

CBECS 2003 Mediuan Source EUI [kBtu/ft2]	UEPH	TEMF	COF	Bde HQ	DFAC
	Dormitory	Other Service	Composite Building (Government Office + Other Public Assembly)	Government Office	Fast Food
1A Miami	191	325	160	203	1244
2A Houston	169	198	143	198	1212
2B Phoenix	168	208	149	193	1187
3A Memphis	161	180	122	183	1175
3B El Paso	143	158	121	160	1032
3C San Francisco	141	160	106	163	1161
4A Baltimore	164	187	118	188	1067
4B Albuquerque	155	182	111	170	1221
4C Seattle	148	172	105	168	1159
5A Chicago	170	207	121	185	1142
5B Colorado Springs	158	201	109	170	1256
6A Burlington	180	226	125	194	1188
6B Helena	166	218	116	178	1311
7A Duluth	185	242	123	193	1242
8A Fairbanks	217	317	159	228	1348

Although CBECS 2003 is the basis for EUI targets under EISA 2007, unfortunately, during the timeframe of this study, the underlying rule for determining the CBECS categories and EUIs was being developed. This meant that the team members had to use their best judgment, not only in terms of which targets to use but in dealing with the lack of appropriate categories for Army buildings, e.g., data

centers/Sensitive Compartmented Information Facility (SCIF), COF building configuration, and DFAC classification (it does not compare to a small fast food restaurant). The hybrid uses of the buildings and mission requirements initially created a situation of moving EUI targets.

Under the new rule, an alternative method involving calculations of EUI targets could address this issue. USACE would need to justify the basis for its calculations, but this could result in more accurate EUI targets that would better align with the use of the measures recommended by this study. That final determination has not been made.

It is important to note that the final Federal Rule for implementing the Fossil Fuel Reduction Requirement of EISA 2007 may compute the CBECS Fossil Fuel-Generated EUIs by some other method. The above EUIs represent the best available approach and information when the study was completed.

As an example, the following method may be another way to calculate the fossil-fuel source EUIs for EISA 2007 compliance based on a required percentage reduction of a National average estimate of fossil fuel usage of the facilities reported in the CBECS 2003 database rather than relying on climate zone multipliers. This approach is due to the baseline for EISA 2007 not being a total source energy EUI, but only a fossil-fuel generated component of it. This is a "what if" scenario and it is yet to be determined what the final method to determine compliance will be.

Under this scenario, if the DOE FEMP determined that the National average percentage of electricity generated from fossil fuels is 71% then the total source energy EUIs would be adjusted to reflect the fact that, on average, only 71% of electricity is generated from fossil fuels. The resulting Fossil Fuel-Generated EUIs under this scenario for the five facility types of interest in this study are shown in Table 2.2 below. It is important to note that this reduction would also apply in converting the recommended improved Army design site EUIs in Chapter 5 of this report.

Table 2.2 CBECS 2003 Median Total Fossil Fuel Generated Source EUIs

CBECS 2003 Median Total Fossil Fuel Generated EUI [kBtu/ft2]	UEPH	TEMF	COF	Bde HQ	DFAC
	Dormitory	Other Service	Composite Building (Government Office + Other Public Assembly)	Government Office	Fast Food
1A Miami	136	200	129	165	888
2A Houston	133	186	122	157	856
2B Phoenix	111	152	99	128	728
3A Memphis	127	163	107	139	737
3B El Paso	114	150	98	127	737
3C San Francisco	105	132	86	109	629
4A Baltimore	144	164	109	142	746
4B Albuquerque	95	114	75	97	585
4C Seattle	106	116	78	99	592
5A Chicago	153	164	108	141	731
5B Colorado Springs	131	157	96	124	681
6A Burlington	183	184	125	163	818
6B Helena	142	144	97	126	761
7A Duluth	181	175	117	153	880
8A Fairbanks	248	219	158	210	1028

EO 13514 requires all new construction to meet the Guiding Principles. The Guiding Principles drove sustainable design features beyond energy efficiency in the standard designs. The Guiding Principles include requirements for the following:

- Employ Integrated Design Principles
  - Integrated Design
  - Commissioning
- Optimize Energy Performance
  - Energy Efficiency
  - Measurement and Verification
- Protect and Conserve Water
  - Indoor Water
  - Outdoor Water
- Enhance Indoor Environmental Quality
  - Ventilation and Thermal Comfort
  - Moisture Control
  - Daylighting
  - Low-Emitting Materials
  - Protect Indoor Air Quality during Construction
- Reduce Environmental Impact of Materials
  - Recycled Content
  - Biobased Content
  - Construction Waste
  - Ozone Depleting Compounds.

Additional requirements are listed in Table 2.3.

Table 2.3 Additional Regulatory Drivers for Sustainable Design

Agency-Wide	
Reference	**Requirement**
Energy Policy Act of 2005 (EPACT 2005), Public Law 109-58 (August 8, 2005)	At least half of the statutorily required renewable energy (7.5 percent by FY13) from new renewable sources.
Executive Order (EO) 13423, Strengthening Federal Environmental, Energy, and Transportation Management (January 29, 2007)	Improve energy efficiency and reduce greenhouse gas emissions of the agency, through reduction of energy intensity by 30 percent by the end of FY15, relative to an agency FY03 baseline.
EO13423	Reduce water consumption intensity relative to agency FY07 baseline by 16 percent by end of FY15.
EO13423	Ensure that 15 percent of an Agency's building inventory complies with the Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings.
EISA 2007, Section 431	Reduce Agency Btu per gross square foot 3 percent per year, from a 2003 baseline: o 9% in 2008 21% in 2012 o 12% in 2009 24% in 2013 o 15% in 2010 27% in 2012 o 18% in 2011 30% in 2015
EO13514	Reduce Agency greenhouse gas emissions.
EO13514	Extends the EO13423 goal of reducing potable water consumption intensity by 2 percent annually, by requiring a 26 percent reduction by the end of FY20, relative to baseline of FY07. To be accomplished, at least in part, by using water efficient and low-flow fixtures, and efficient cooling towers.
EO13514	Reduce industrial, landscaping, and agricultural water consumption intensity by 2 percent annually or 20 percent by end of FY20, relative to baseline of FY10 for each use.
EO13514	Divert from disposal at least 50 percent of construction and demolition debris by FY15.
EO13514	Agencies implement and achieve objectives identified in the U.S. Environmental Protection Agency's (EPA's) Stormwater Guidance for Federal Facilities (EPA 841-B- 09-001 issued guidance in December 2009).
EO13514	Minimize the quantity of toxic and hazardous chemicals and materials acquired, used, and disposed of.
EO13514	Implement integrated pest management and other landscape management practices.
EO13514	Ensure that 95 percent of all new contract actions for products and services are energy efficient, water-efficient, bio-based, environmentally preferable, non-ozone depleting, contain recycled content, or are non-toxic or less-toxic than traditional alternatives, where such products and services meet agency performance requirements.
Building Specific	
Reference	**Requirement**
EPACT 2005	New Federal buildings must achieve 30 percent beyond ASHRAE 90.1-2004, if life-cycle cost effective.
EO13423	Ensure that new construction complies with the Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings.
EISA 2007, Section 433	Sustainable design principles shall be applied to the siting, design, and construction of buildings subject to the standards,

Table 2.3 (Cont'd)

EISA 2007, Section 438	To address stormwater runoff, predevelopment hydrology shall be maintained or restored to the maximum extent technically feasible by the sponsor of any development or redevelopment project for any Federal facility with a footprint over 5,000 ft^2. Stormwater runoff strategies listed included site planning, design, construction and maintenance.
EISA 2007, Section 523	Requires 30 percent of the hot water demand in new Federal buildings (and major renovations) to be met with solar hot water equipment, provided it is life-cycle cost-effective.
EO13514	Identify, promote and implement water reuse strategies to reduce potable water consumption (consistent with State law).
EO13514	Minimize consumption of energy, water and materials by pursuing cost-effective, innovative strategies such as highly reflective and vegetated roofs.

In addition to the Federal drivers, the Army has clarified its expectations for building design in the Army Sustainable Design and Development Policy Update (Environmental and Energy Performance, October 27, 2010). In summary, the additional requirements provided in the policy include the following:

- All new construction will follow the guidance in ASHRAE 189.1 and achieve U.S. Green Building Council LEED Silver certification.
- Solar hot water heating will be included on all new construction projects meeting specific size and location requirements.

The initial goal of this project was to prepare standard designs that, at a minimum, met the current Federal and Army requirements for sustainable design.

3.0 Five Baseline Building Type Descriptions

The study focused on five building types: UEPH, TEMF, COF, Bde HQ, and DFAC. These most commonly built MILCON facilities each year are described in the following sections. Detailed information about modeling protocols, the rationale behind decisions made, and modeling and cost estimation outputs are found in later sections of this report.

3.1 UEPH

Unaccompanied Enlisted Personnel Housing (UEPH or barracks) is a cross between apartment buildings and college dormitories. Within the Army, the different sizes of barracks are based on the number of soldiers living in them. The model for this study had a capacity of 112 personnel in rooms. Each unit has two bedrooms (one soldier per room), one shared bathroom, a small mechanical room, and a kitchen/common area, as shown in Figure 3.1. The first floor has 18 units, a laundry room, a common area, a mechanical room, and a storage area. Figure A1 (in Appendix A) shows an architectural rendering of the first floor. The second and third floors have 19 units. Each floor is 18,257 ft^2 and the building is 54,771 ft^2. An elevation view of the building and a rendering of the baseline computer model is shown in Figure A2 in Appendix A. The baseline building used is at Fort Campbell, Kentucky.

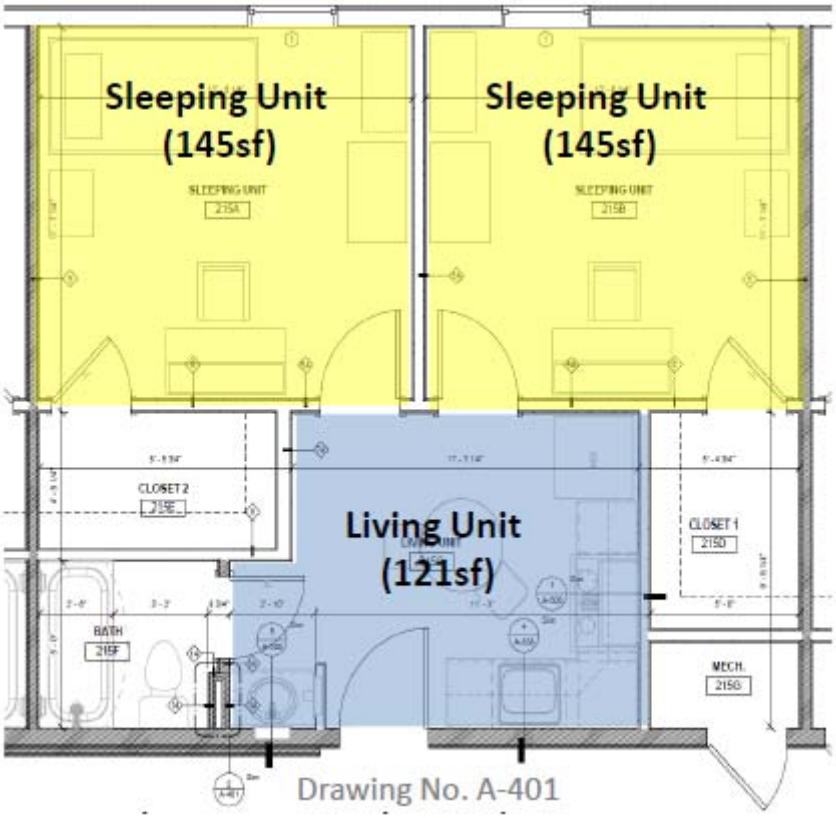

Figure 3.1 UEPH Living Unit Drawing

Modeling was completed for the baseline building. An enhanced baseline Low Energy Package and 12 additional packages were completed for all 15 climate zones. Section 5.1.1 describes the comparison of the modeled packages with the baseline building. Cost estimates for the Low Energy Package and three additional packages were completed for three climate zones: 1 (Fort Shafter, Hawaii), 2A (Fort Hood, Texas), and 8 (Fort Wainwright, Arkansas).

3.2 TEMF

The Tactical Equipment Maintenance Facility (TEMF) is a large-sized vehicle or equipment repair facility with equipment and parts, storage, and administrative offices. Within the Army, the different sizes of TEMFs are based on the type of equipment being maintained. The total square footage of the two-story building is 32,929 ft^2. The baseline building used is located at Fort Bragg, North Carolina. The building is nominally occupied from 8 a.m. to 5 p.m., Monday through Friday. A rendered view of the energy simulation model is shown in Figure B1 and a floor plan is shown in Figure B2 (both in Appendix B).

3.3 COF

Company Operations Facilities (COF) are a hybrid of an open gymnasium-type area (readiness bays) used to store soldiers' equipment in lockers, ammunition vaults, and administrative office space. These facilities house Company administrative operations and are used to store and move supplies. The facilities comprise administrative modules and readiness modules. Within the Army, the different sizes of COFs are based on the number of soldiers assigned to use them. The readiness module has a readiness bay for storing TA50 equipment for 100-, 150-, or 200-person companies; an arms vault; nuclear, biological, and chemical NBC storage; communications storage; and general storage. This report focuses on a three- and four-company version of the COF. The model for both the readiness bays and office are two stories, which combined have a footprint area of approximately 60,712 ft^2. An alternative design was also modeled that uses the same footprint but reduces the height of the ceiling in the readiness bays to decrease the energy needed for heating and cooling. The baseline building used is the 4th Brigade Combat Team Complex (Heavy) in Fort Stewart, Georgia. An architectural drawing of a typical COF first floor plan is presented in Figures C1 through C4 and a floor plan in Figure C2 (all in Appendix C).

3.4 Bde HQ

Brigade Headquarters (Bde HQ), is a hybrid of a government office building and a secure data center. A typical Bde HQ comprises administrative offices, special function rooms, classrooms, and/or a secure section. Private offices are provided for select officers and other staff. Other types of space include conference rooms, staff duty stations, message center and mail sorting, reception areas, secure documents room, showers, supplies, and vending. Within the Army, there are five different sizes of brigade headquarters. The large size of the Brigade HQ was the subject of this study. The building accommodates 122 to 156 personnel and is intended for Brigade Combat Team, battlefield surveillance, and combat support brigades. Bde HQ includes a Brigade Operations Center (BOC), Network Operations Center (NOC), and SCIF (Sensitive Compartmented Information Facility), which equates to a secure data center on the first floor. The total square footage of the two-story building is 39,600 ft^2 and each floor has 19,800 ft^2. The baseline building used is located at Fort Campbell, Kentucky. An EnergyPlus rendering of the building is found in Figure D.1 (Appendix D).

3.5 DFAC

Dining Facilities (DFACs) are a hybrid of a cafeteria and a high-volume fast food restaurant. Within the Army different sizes of dining facilities are based on the number of soldiers served during any one meal period: breakfast, lunch, or dinner. There are three DFAC sizes based on feeding capacity ranges of 251–500, 501–800, or 801-1300 personnel. Functionally, the DFAC consists of a patron dining area, a food service area, a kitchen, and food storage and receiving areas. The baseline building for this study serves 1,300 soldiers per meal period. Total square footage of the one-story building is 27,458 ft^2. The baseline building used is located at Fort Bragg, North Carolina. An architectural drawing of a typical dining facility plan is represented in Figure E.1 and a floor plan in Figure E.2 (Appendix E).

4.0 Strategies

A number of strategies were modeled and reviewed during the course of the study. These included strategies focused on energy savings as well as sustainability measures.

4.1 Energy

Energy strategies were at the heart of this study. For the five building types, this included an analysis of options considered for HVAC systems, building envelope impacts on energy efficiency, control of air infiltration, advanced interior and exterior lighting design, use of renewables, control of plug loads, water efficiency measures, and various sustainability measures, including daylighting.

4.1.1 HVAC Strategies

The general HVAC strategy for Army buildings was to provide high-efficiency HVAC systems which offset the sensible heating and cooling loads in the spaces and to provide separate high-efficiency dedicated outdoor air systems (DOASs), which includes a Total Energy Recovery (TER) exhaust air system to handle the ventilation requirements and the latent (moisture) load in the spaces. The outdoor air ventilation quantity provided by the DOAS should maintain the building, including the hallways, at a slightly positive pressure relative to outside to eliminate uncontrolled infiltration into the building. High-efficiency, variable-speed pumps and fans should be used throughout the HVAC system. High-efficiency boilers and chillers should be used in all cases. Although HVAC strategies vary somewhat from building to building, the following lists some common examples of energy efficient options that were considered:

- DOAS with condenser reheat and individual room fan coils for soldier comfort
- advanced HVAC systems; DOAS for ventilation, pressurization and make-up air, with condenser heat recovery and Energy Recovery Ventilators, both sensible and total
- central exhaust that is used for heat recovery to pre-condition the ventilation air with Energy Recovery, sensible and total recovery at 80 percent
- High Efficiency Air Cooled Chiller package, COP from 2.87 to 4.4
- condensing boilers, 80 percent to 95 percent efficient
- variable and high-efficiency fans and pumps.
- radiant heating and cooling in the ceilings
- ground-source heat pump (GSHP).

4.1.1.1 UEPH

The UEPH baseline HVAC system uses a DOAS with condenser reheat. The space loads are met with 4-pipe fan coil units connected to a central chiller and boiler in the baseline model and with radiant heating and cooling in one of the energy efficient models. The domestic water-heating system in the baseline building models uses an 80 percent efficient boiler and the energy efficient models use a 95 percent efficient condensing boiler. Options and modeling assumptions are shown in Tables A.1 of Appendix A.

The ventilation was set to provide 90 cfm of outside air to each apartment unit to make up for the bathroom exhaust and control humidity, which is greater than the ventilation requirements from ASHRAE 62.1-2004 for the baseline model. Additional outside air was added to the whole building to make up for the leakage rate at 0.02 in. w.g. (5 Pa) pressurization as shown in Table A.2 in Appendix A. For the efficient model, the ventilation air was reduced to 65 cfm per living unit with excess ventilation air as listed in Table A.2 of Appendix A. The 65 cfm was based on the standard design provided by the COS.

4.1.1.2 TEMF

A large potential for energy savings is associated with the HVAC system in the TEMF, especially when considering the current ventilation requirements of the repair bays. The closest ASHRAE 62.1-2007, Appendix B, occupancy category available for a TEMF—shipping and receiving—was used to model a flow-reduction strategy for the repair bays.

The original baseline building model ran the ventilation fans at 1.5 cfm/ft^2 during occupied hours. For this study, ventilation fan flow rates were reduced to 1.5 cfm/ft^2 for 2 hours and 0.12 cfm/ft^2 for the remainder of the operating hours each day. The reduced flow rates are acceptable under the condition that ventilation rates could increase to 1.5 cfm/ft^2 if contaminant levels from vehicle exhaust rose to detectable levels and would continue run at a 1.5-cfm/ft^2 level for as long as necessary to decrease the contaminant level to meet indoor air quality (IAQ) requirements.

The 2-hour-a-day run time was based on information from district staff that have hands-on experience with TEMF demand controls. The district staff felt that this would be a conservative run time.

Increased fan and cooling coil efficiencies were also considered along with savings associated with transpired solar collectors, radiant floors, and GSHPs. A more detailed analysis needs to be completed to determine contaminant sources, contaminant concentration targets, and perceived acceptability targets. A summary of the EEMs considered in this study is presented and described in greater detail in Table B.1 of Appendix B.

4.1.1.3 COF

An area for energy savings in the COF is the design of the readiness bay modules. In the current design, the platoon offices are located on a second-floor mezzanine. The mezzanine allows the footprint of this building to remain the same, but it increases the volume of conditioned air in the readiness bays significantly. The volume of conditioned air can drastically be reduced by slightly increasing the footprint of the readiness bays and moving the platoon offices to the first floor. An illustration of this model is presented below in Figure 4.1.

Increased fan efficiencies and chiller COP, variable-air-volume (VAV) fans instead of constant-volume fans, and a condensing boiler were also modeled. A condensing boiler is currently in the baseline building design as well. Energy recovery was modeled for climate zones 1A through 4B in both the readiness bays and the administration building. Indirect evaporative cooling and demand control ventilation was modeled for the administration building alone for climate zones 4C-8A, and a DOAS with fan coils was modeled in climate zones 2B and 3B for the readiness bays.

Transpired solar collectors were also considered for installation on the south façade of each building in climate zones 2B and 3B. The baseline and energy efficient building model assumptions are summarized in Table C.1 in Appendix C.

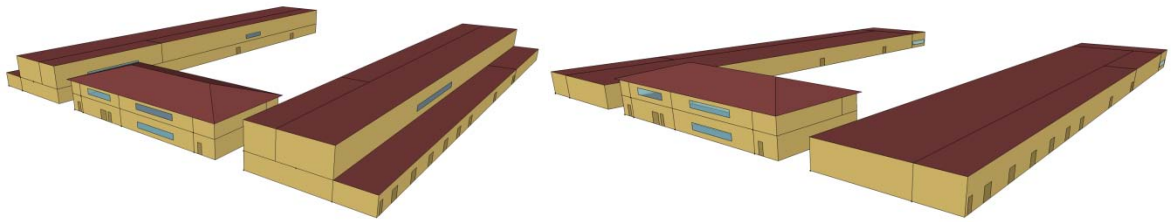

Figure 4.1 Standard and Alternative COF Design. Left: whole building as modeled in EnegyPlus, based on drawings from the 4th Brigade Combat Team Complex in Fort Stewart, Georgia. Right: alternative construction option for the readiness bays, reducing the volume of conditioned air in each readiness bay module.

4.1.1.4 Bde HQ

The office and NOC/BOC/SCIF sections of the building were modeled separately and together. The baseline HVAC system uses a VAV system with a central cooling coil, an outside air economizer, and terminal reheat boxes to meet space loads connected to a central chiller and boiler. Several building specific energy efficient options were considered, as follows:

- advanced VAV modeled with energy recovery ventilation (ERV), indirect/direct evaporative cooling (IDEC) for outside air pre-cooling
- Pre-cooling with indirect evaporative coolers for VAV and DOAS systems
- DOAS system with radiant heating and cooling system in the ceilings.

Cold (free) outside air brought in through air economizer provides (free) cooling required to condition interior space that has been heated by equipment that produces a lot of heat. With the high internal loads in the building, the VAV system was hard to improve upon because it can use free cooling with the temperature controlled outside air economizer. The problem with air-free cooling is the introduction of moisture or latent load from the outside air. Something to consider is water-free cooling when larger systems are used or the air-cooled chillers with an integrated free cooling system. Integrated free cooling systems and coil with variable frequency drive (VFD) fan speed control offers unmatched efficiencies using cold ambient air to pre-cool or completely cool the process load. The baseline and energy efficient building model assumptions are summarized in Table D.1 in Appendix D.

4.1.1.5 DFAC

Process loads for a commercial kitchen are very large and make up a significant portion of HVAC and overall building energy use. For the DFAC, the army supplied the layout of the kitchen, equipment specification sheets, a 21-day menu, and the number of meals served per day. Based upon this information, the cooking energy for each piece of equipment was evaluated and high-efficiency kitchen equipment, exhaust hood and make-up air layout and design, and control strategies were recommended. The baseline and energy efficient building model assumptions are summarized in Table E.1 in Appendix E.

Exhaust air requirements are significantly reduced with the use of high-efficiency appliances and by changing the exhaust hood design and control. Adding side panels and installing close-proximity hoods reduces exhaust flow rates as well as the amount of air flowing through the make-up air unit. Control strategies to modulate flow based on temperature and particulates can also be used to drive down flow rates for both the exhaust and make-up air units. To further reduce energy consumption, all-electric kitchen equipment was also considered. Increased fan efficiencies and chiller COPs were also modeled, as well as reduced lighting power densities and increased daylighting with dimmable daylighting controls in the office, dining, and serving areas.

On the HVAC side of the DFAC, a number of EEMs were considered. Roof-top unit fans were modeled as VAV fans and compared to constant-volume fans as specified in the drawings provided by the Army. Fan efficiencies were also increased as well as cooling coil COPs, reaching a COP of 3.85.

Passive house insulation was recommended for climate zones 4A to 8A. With a tighter envelope construction, infiltration rates were reduced, which contributes to a reduction in heating and cooling loads to the space. Lowered exhaust and make-up air ventilation requirements were also recommended. This was achieved by using high-efficiency or all-electric kitchen equipment and exhaust hood design strategies. With efficient equipment, good hood design and the use of demand-control ventilation strategies, exhaust flow requirements can be significantly reduced.

4.1.2 Building Envelope

Studies have shown that significant reductions in energy use can be achieved by minimizing the impact of the external environment on the building heating and/or cooling loads. The building envelope is critical if the energy reduction targets of EISA 2007are to be achieved.

4.1.2.1 Passive House

While the current advanced buildings practice in the United States is based on ASHRAE 90.1 (2010) and ASHRAE 189.1 (2010), the most rigorous standards for building energy efficiency resulting in ultra-low energy buildings are the German Passivhaus standards.

Typical passive house characteristics for central European locations include the following:

- Airtight building shell ≤0.6 ACH @ 50 Pa pressure difference (~0.11 cfm/ft^2 of the building envelope area at 75 Pa pressure difference) measured by a blower-door test.
- Annual heat requirement ≤15 kWh/m^2/year (<4.75 kBtu/ft^2/yr)
- Primary Energy ≤120 kWh/m^2/yr (38.1 kBtu/ ft^2/yr)
- Window u-value ≤0.8 W/m^2/K (0.14 Btu/hr/ft^2/°F)
- Ventilation system with heat recovery with ≥75 percent efficiency and low electric consumption @ 0.45 Wh/m^3
- Thermal Bridge Free Construction ≤0.01 W/mK.

In addition to energy conservation, improved building insulation and airtightness result in a more stable room temperature between day and night, higher internal wall surface temperature in winter, and

lower component internal wall temperature in summer, which improves occupant thermal comfort. Higher wall temperature in winter reduces the risk that mold or mildew may occur on the internal wall surfaces and improves the quality of life in a building.

Since 1996, more than 20,000 buildings meeting these standards were built and retrofitted around the world, primarily in Germany, Austria, and Switzerland, and they include residential and office buildings, kindergartens, and supermarkets. A great many of these buildings have been extensively monitored by the Passivhaus Institut in Darmstadt, Germany. The European Union Commission (EU Parliament resolution of 31 January 2008 on an Action Plan for Energy Efficiency) intends to require that all new buildings needing to be heated and/or cooled must be constructed to passive house or equivalent non-residential standards from 2011 onward.

ERDC-CERL researchers, in collaboration with Architekturbüro Zielke Passivhäuser and Passivhaus Institut, have developed an interpretation of passive house characteristics of the building envelope to be applied to U.S. construction specifics and all 15 DOE climate zones (see Table 1.1).

4.1.2.2 Insulation of Non-Transparent Building Components

Types of insulation materials used depend on construction practices, the climate, and other factors. Typical insulating materials used in the United States include wood-fiber boards, cellulose, foam glass, mineral wool, fiberglass, extruded polystyrene, expanded polystyrene, polyurethane boards, perlite, etc. The most commonly used materials are fiberglass (R-3.5 $ft^2 \cdot °F \cdot hr/(Btu \cdot in)$), expanded polystyrene (R-4 $ft^2 \cdot °F \cdot hr/(Btu \cdot in)$), and extruded polystyrene (R-5 $ft^2 \cdot °F \cdot hr/(Btu \cdot in)$). These low-cost materials are well suited for most new construction and retrofit situations. Table 4.1 shows insulation requirements (R-values) for walls and roof in different climate conditions resulted from this study compared to current Army requirements as well as requirements from the ASHRAE 90.1 (2010, 2007), ASHRAE 189.1, and the ASHRAE Advanced Energy Design Guides (http://www.ashrae.org/technology/page/938).

Recommended building insulation levels follow the passive house standard, which are noted in Table 4.1 Overhead door insulation levels were also increased to R-4 $ft^2 \cdot hr \cdot °F/Btu$.

Table 4.1 Insulation Requirements (R-values). In order from most stringent to least stringent (ci = continuous insulation).

Climate Zone	1A Miami, FL	2A Houston, TX	2B Phoenix, AZ	3A Memphis, TN	3B El Paso, TX	3C San Francisco, CA	4A Baltimore, MD	4B Albuquerque, NM	4C Seattle, WA	5A Chicago, IL	5B Colorado Springs, CO	6A Burlington, VT	6B Helena, MT	7A Duluth, MN	8A Fairbanks, AK
Wall Insulation Passive Haus [R-value]	R-19 + R7.5ci	R-19 + R15ci	R-19 + R15ci	R-19 + R20ci	R-19 + R20ci	R-19 + R10ci	R-19 + R25ci	R-19 + R25ci	R-19 + R20ci	R-19 + R30ci	R-19 + R30ci	R-19 + R40ci	R-19 + R40ci	R-19 + R50ci	R-19 + R60ci
WBDG, Army Specs - Steel Framed Walls	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-12.5ci	R-13 + R-12.5ci	R-13 + R-12.5ci	R-13 + R-12.5ci	R-13 + R-18.8ci	R-13 + R-18.8ci	R-13 + R-18.8ci	R-13 + R-18.8ci
90.1 -2010 addenda bb - Steel Framed Walls	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-10.0ci	R-13 + R-10.0ci	R-13 + R-10.0ci	R-13 + R-12.5ci	R-13 + R-12.5ci	R-13 + R-15.0ci	R-13 + R-15.0ci	R-13 + R-18.8ci	R-13 + R-18.8ci
189.1 -2009 - Steel Framed Walls	R-13 + R-5.0ci	R-13 + R-5.0ci	R-13 + R-5.0ci	R-13 + R-5.0ci	R-13 + R-5.0ci	R-13 + R-5.0ci	R-13 + R-10.0ci	R-13 + R-10.0ci	R-13 + R-10.0ci	R-13 + R-10.0ci	R-13 + R-10.0ci	R-13 + R-10.0ci	R-13 + R-10.0ci	R-13 + R-10.0ci	R-13 + R-10.0ci
ASHRAE AEDG - Steel Framed Walls	R-13.0	R-13.0	R-13.0	R-13.0 + R-3.8 c.i.	R-13.0 + R-3.8 c.i.	R-13.0 + R-3.8 c.i.	R-13.0 + R-7.5 c.i.	R-13.0 + R-7.5 c.i.	R-13.0 + R-7.5 c.i.	R-13.0 + R-7.5 c.i.	R-13.0 + R-7.5 c.i.	R-13.0 + R-7.5 c.i.	R-13.0 + R-7.5 c.i.	R-13.0 + R-7.5 c.i.	R-13.0 + R-21.6 c.i.
90.1 -2007 - Steel Framed Walls	R-13.0	R-13.0	R-13.0	R-13.0 + R-3.8 c.i.	R-13.0 + R-3.8 c.i.	R-13.0 + R-3.8 c.i.	R-13.0 + R-7.5 c.i.	R-13.0 + R-7.5 c.i.	R-13.0 + R-7.5 c.i.	R-13.0 + R-7.5 c.i.	R-13.0 + R-7.5 c.i.	R-13.0 + R-7.5 c.i.	R-13.0 + R-7.5 c.i.	R-13.0 + R-7.5 c.i.	R-13.0 + R-7.5 c.i.
Roof Insulation Pasive Haus [R-value]	R-25	R-30	R-30	R-35	R-35	R-25	R-45	R-45	R-35	R-55	R-55	R-70	R-70	R-80	R-90
WBDG, Army Specs - Roofs Insulation DeckAbove	R-25	R-25	R-25	R-25	R-25	R-25	R-30	R-30	R-30	R-30	R-30	R-40	R-40	R-40	R-40
90.1 -2010 addenda bb - Roofs Insulation Above Deck	R-20	R-25	R-25	R-25	R-25	R-25	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-35	R-35
189.1-2009 - Roofs Insulation Above Deck	R-20	R-25	R-25	R-25	R-25	R-25	R-25	R-25	R-25	R-25	R-25	R-30	R-30	R-35	R-35
90.1 -2007 - Roofs Insulation Above Deck	R-15	R-20	R-20	R-20	R-20	R-20	R-20	R-20	R-20	R-20	R-20	R-20	R-20	R-20	R-20
ASHRAE AEDG - Roofs Insulation Above Deck	R-15	R-15	R-15	R-20	R-20	R-20	R-20	R-20	R-20	R-20	R-20	R-20	R-20	R-20	R-30
Slab-On-Grade Floors (Unheated) Recommended	NR	NR	NR	R-10 for 24 in.	R-10 for 24 in.	NR	R-15 for 24 in.	R-15 for 24 in.	R-10 for 24 in.	R-20 for 24 in.	R-20 for 24 in.	R-20 for 48 in.	R-20 for 48 in.	R-20 for 24 in. + R-5 ci below	R-20 for 24 in. + R-5 ci below
WBDG, Army Specs - Unheated Slab-on-Grade Floor	NR	NR	NR	NR	NR	NR	R-15 for 24 in.	R-15 for 24 in.	R-15 for 24 in.	R-15 for 24 in.	R-15 for 24 in.	R-20 for 24 in.	R-20 for 24 in.	R-20 for 24 in.	R-20 for 48 in.
189.1-2009 - Unheated Slab-on-Grade Floor	NR	NR	NR	NR	NR	NR	R-10 for 24 in.	R-10 for 24 in.	R-10 for 24 in.	R-10 for 24 in.	R-10 for 24 in.	R-15 for 24 in.	R-15 for 24 in.	R-15 for 24 in. + R-5 ci below	R-20 for 24 in. + R-5 ci below
Slab-On-Grade Floors (Heated) Recommended	R-7.5 for 12in. + R-5 ci below	R-10 for 24in. + R-5 ci below	R-10 for 24in. + R-5 ci below	R-15 for 24in. + R-5 ci below	R-15 for 24in. + R-5 ci below	R-15 for 24in. + R-5 ci below	R-20 for 24in. + R-5 ci below	R-20 for 24in. + R-5 ci below	R-20 for 24in. + R-5 ci below	R-20 for 48in. + R-5 ci below	R-20 for 48in. + R-5 ci below	R-20 for 48in. + R-5 ci below	R-20 for 48in. + R-5 ci below	R-25 for 48in. + R-5 ci below	R-25 for 48in. + R-5 ci below
WBDG, Army Specs - Heated Slab-on-Grade Floor	R-7.5 for 12in.	R-10.0 for 24in.	R-10.0 for 24in.	R-15.0 for 24in.	R-15.0 for 24in.	R-15.0 for 24in.	R-20 for 24 in.	R-20 for 24 in.	R-20 for 24 in.	R-20 for 48 in.	R-20 for 48 in.	R-20 for 48 in.	R-20 for 48 in.	R-25 for 48 in.	R-25 for 48 in.
189.1-2009 - Heated Slab-on-Grade Floor	R-7.5 for 12in. + R-5 ci below	R-7.5 for 12in. + R-5 ci below	R-7.5 for 12in. + R-5 ci below	R-7.5 for 12in. + R-5 ci below	R-7.5 for 12in. + R-5 ci below	R-7.5 for 12in. + R-5 ci below	R-10.0 for 24in. + R-5 ci below	R-10.0 for 24in. + R-5 ci below	R-10.0 for 24in. + R-5 ci below	R-15.0 for 36in. + R-5 ci below	R-15.0 for 36in. + R-5 ci below	R-15.0 for 36in. + R-5 ci below	R-15.0 for 36in. + R-5 ci below	R-20.0 for 36in. + R-5 ci below	R-20.0 for 36in. + R-5 ci below

4.1.2.3 Windows

Windows play an important role in energy efficient buildings in two ways: first, they can reduce heat loss; second, they allow the sunlight to provide daylighting to naturally light the space. In addition, studies show that in a corporate facility, an effective daylighting scheme can improve employee productivity, health, and morale.[1] By using high-efficiency windows with heat-conserving glazing, it is possible to achieve low U-values with two low emissivity coatings and filled with either krypton or argon gas. In addition, the glazing has "warm edge" insulating glass spacers along with thermal breaks throughout the framing. This means that the surface temperature of the glass inside the room is comparable with the air temperature of the room itself. The amount of total solar gain with triple-glazed windows can be as high as 60 percent, depending on glazing and gas-filling. This requires the window frame to incorporate insulation and triple glazing. Ideally, thermal bridging ideally needs to be eliminated. The Army also has a security requirement for blast-resistant windows that needs to be accounted for when the window is selected.

Efficient blast-resistant window options listed in Table 4.2 by climate zone are recommended based on the climate-specific considerations with a low solar heat gain coefficient (SHGC) for warm climates and a higher value in cold climates. Table 4.2 lists requirements for window characteristics in different climate conditions resulting from this study compared to current Army requirements as well as requirements from ASHRAE 90.1 (2010, 2007), ASHRAE 189.1, and the ASHRAE Advanced Energy Guides. ERDC/CERL staff are researching triple-pane glass manufacturers who would have products that meet both current AT/FP blast-resistant and passive house requirements.

[1] Edwards L and P Torcellini. 2002. "A Literature Review of the Effects of Natural Light on Building Occupants." [PDF]. NREL/TP-550-30769, pp. 4–6, National Renewable Energy Laboratory, Golden, Colorado. With direct reference to: Salares V and P Russell. 1996. "Low-E Windows: Lighting Considerations." "A Sustainable Energy Future: How do we get there from here?"

Table 4.2 Window Characteristics by Climate Zone (Units are US IP)

Windows	1A Miami, FL	2A Houston, TX	2B Phoenix, AZ	3A Memphis, TN	3B El Paso, TX	3C San Francisco, CA	4A Baltimore, MD	4B Albuquerque, NM	4C Seattle, WA	5A Chicago, IL	5B Colorado Springs, CO	6A Burlington, VT	6B Helena, MT	7A Duluth, MN	8A Fairbanks, AK
Passive Haus Window Specifications															
U-Value	0.26	0.26	0.26	0.26	0.26	0.26	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
SHGC	*0.25*	*0.25*	*0.25*	*0.39*	*0.39*	*0.39*	*0.39*	*0.39*	*0.39*	*0.49*	*0.49*	*0.49*	*0.49*	*0.49*	*0.49*
VT	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50
Army WBDG - Window Specifications															
U-Value	0.56	0.45	0.45	0.45	0.45	0.45	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.33	0.33
SHGC	*0.25*	*0.25*	*0.25*	*0.37*	*0.37*	*0.37*	*0.39*	*0.39*	*0.39*	*0.39*	*0.39*	*0.39*	*0.39*	*NR*	*NR*
VT	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
ASHRAE 90.1-2010 Window Specifications															
U-Value	0.73	0.50	0.50	0.46	0.46	0.46	0.38	0.38	0.38	0.38	0.38	0.36	0.36	0.29	0.29
SHGC	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.30*	*0.30*	*0.30*	*0.30*	*0.30*	*0.35*	*0.35*	*0.40*	*0.40*
Min VT/ SHGC	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
ASHRAE 189.1 Window Specifications															
U-Value	1.2	0.75	0.75	0.55	0.55	0.55	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.35	0.35
SHGC	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.35*	*0.35*	*0.35*	*0.35*	*0.35*	*0.4*	*0.4*	*0.45*	*NR*
VT	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
ASHRAE 90.1 -2007 Window Specifications															
U-Value	1.2	0.75	0.75	0.65	0.65	0.65	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.45	0.45
SHGC	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*NR*	*NR*
VT	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

4.1.3 Infiltration

USACE Engineering Construction Bulletin (ECB) 29-2009 states that the air leakage rate of a building envelope shall not exceed 0.25 cfm/ft^2 at a pressure differential of 0.3 in. w.g. (75 Pa) for new and renovation construction projects. In 2010, more than 200 buildings were constructed and renovated to meet or exceed this requirement (achieving airtightness of 0.10 cfm/ft^2 or better was not uncommon) at no or minimum additional cost. Based on this experience and industry consensus, for this study the assumed level for airtightness was lowered to 0.15 cfm/ft^2 at a pressure differential of 0.3 in. w.g. (75 Pa). However, design teams are encouraged to analyze the infiltration rate for each building type and climate zone to achieve maximum energy savings. Table 4.3 lists the infiltration for the UEPH at these two leakage rates.

Table 4.3 UEPH Infiltration Leakage Rates

Infiltration	0.25 cfm/ft^2	0.15 cfm/ft^2
ACH at 0.3 in. w.g. (75 Pa)	2.98	1.79
ACH at 0.02 in. w.g. (5 Pa)	0.51	0.31
Excess ventilation flow at 0.02 in. w.g. (cfm @ 5 Pa)	5832	3499
Excess ventilation flow at 5 Pa (L/s)	2752	1651

The mechanical ventilation system pressurizes the building by providing outside air equal to the building exhaust plus the air leakage at 0.02 in. w.g. (5 Pa). Infiltration is often assumed to go to zero when buildings are pressurized. It was assumed that the average uncontrolled infiltration when the building is pressurized is reduced to 10 percent of the value calculated at 0.02 in. w.g. (5 Pa). The difference in the leakage rates between the two airtightness levels was accounted for in the outdoor ventilation rates for the baseline and energy efficient models.

4.1.4 Vestibules

Vestibules were included in the energy models for the UEPH and administrative areas of the Bde HQ and COF to help reduce the cooling, heating, and latent load into the space. Vestibules help reduce the infiltration losses (or gains) from wind and stack effect by creating an air lock entry.

Figure 4.2 shows the annual energy savings for U.S. office buildings with vestibules for different climate zones. The analysis was conducted under the International Energy Agency Energy Conservation in Buildings and Community Systems (IEA ECBCS) Annex 46 study (www.annex46.org).

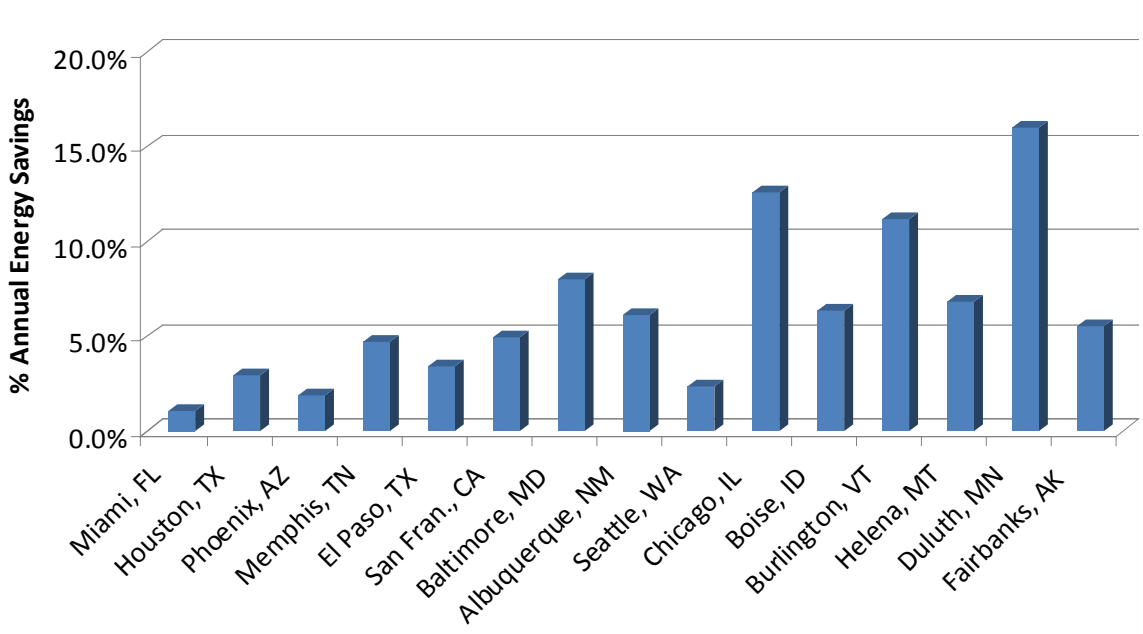

Figure 4.2 Estimated Annual Energy Savings for U.S. Office Buildings with Vestibules

4.1.5 Lighting

Advanced lighting measures also play an important role in energy savings. Both interior and exterior lighting systems were examined during the study.

4.1.5.1 Interior

The UEPH lighting analysis was completed by Atelier Ten. The analysis focused on efficient lighting design and was based on an example of the control strategies in Table 4.4. The complete Atelier Ten report is found in Appendix F.

Table 4.4 Lighting Design by Atelier Ten

	Design Criteria			Control Strategies				Technologies				Approach				
				Levels	Automatic Interface											
Space	Target Illuminance at Task [fc] (Design Goal)	Target Lighting Power Density [W/ft^2] (Project Design Goal)	Allowable Lighting Power Density [W/ft^2] (ASHRAE/IESNA Std 90.1-2004/2007)	Switching - (blank) Multi-Level - M Full Dimming - D	V - Vacancy [Manual ON / Auto OFF] O - Occupancy [Auto ON / Auto OFF]	Daylight (e.g. Photosensors)	Schedule (e.g. Astronomical time-clock)	Linear Fluorescent	Compact Fluorescent	Ceramic Metal Halide	Light Emitting Diodes	Overhead General Lighting	Overhead Ambient Lighting	Task Lighting	Wallwash / Perimeter Lighting	Adjustable Accent Lighting
Corridor	10	0.50	0.5		O			✓				•			•	
Living Quarters	5 - 30	0.60	1.1		V		🕒	✓	✓		✓	•	•	•		
Mechanical / Electrical	30	0.70	1.5		V			✓				•				
Restroom / Shower	20	0.80	0.9		V			✓	✓		✓	•			•	
Stair	10	0.50	0.6	M	O			✓				•				
Storage (General)	10	0.50	0.8		V			✓				•				•

Lighting efficiency measures include lighting power density reductions with control strategies for each zone. Plug load power densities were assumed to be the same in all building models. An example is provided below in Table 4.5.

The lighting power density for Bde HQ was assumed to be the same as for a typical office building. For the baseline model, the lighting power density of 0.9 W/ft^2 was used. This value came from Savannah District for their standard for the Bde HQ. For the efficient model, the advanced lighting design specifications were supplied by Atelier Ten. When the spaces are averaged together, an overall value of 0.7 W/ft^2 is derived.

Table 4.5 TEMF Lighting Design by Atelier Ten. (Tables for other building types found in Appendix F – Atelier Ten Lighting Report)

	Design Criteria			Control Strategies				Technologies				Approach				
				Levels	Automatic Interface											
Space	Target Illuminance at Task [fc] (Design Goal)	Target Lighting Power Density [W/ft²] (Project Design Goal)	Allowable Lighting Power Density [W/ft²] (ASHRAE/IESNA Std 90.1-2004/2007)	Switching - (blank) Multi-Level - M Full Dimming - D	V - Vacancy [Manual ON / Auto OFF] O - Occupancy [Auto ON / Auto OFF]	Daylight (e.g Photosensors)	Schedule (e.g Astronomical time-clock)	Linear Fluorescent	Compact Fluorescent	Ceramic Metal Halide	Light Emitting Diodes	Overhead General Lighting	Overhead Ambient Lighting	Task Lighting	Wallwash / Perimeter Lighting	Adjustable Accent Lighting
Classroom / Training	40	0.75	1.4	M	V	☼		✓				•			•	
Conference Room	40	0.80	1.3	M/D	V			✓				•			•	
Consolidated Bench Repair	50	0.55	1.9		V			✓			✓	•		•		
Corridor	10	0.50	0.5		O			✓				•			•	
Maintenance Pit	15	0.70	1.9					✓			✓			•		
Mechanical / Electrical	30	0.70	1.5		V			✓				•				
Office (Open)	40	0.70	1.1	M/D	V	☼	⏲	✓		✓	✓		•	•	•	•
Repair Bay	50	0.85	1.9		V	☼	⏲	✓				•				
Restroom / Shower	20	0.80	0.9		V			✓	✓		✓	•			•	
Stair	10	0.50	0.6	M	O			✓				•				
Storage (General)	10	0.50	0.8		V			✓				•				•
Storage / Vaults (Occupied)	40	0.65	1.9		V			✓			✓	•				
Telecom / SIPRNET	50	1.20	1.5		V			✓				•				
Vehicle Corridor	50	0.75	0.7		V		⏲	✓				•				

4.1.5.2 Exterior Lighting

Light-emitting diode (LED) parking area lights were recommended to be substituted for what had been the standard exterior lighting for the five building types. However, exterior lighting was not modeled. Exterior lighting studies in recent years have showcased the use and advantages of LED lighting in terms of long-term energy savings and O&M cost due to their longer life cycles. Based on this information, the decision was made to include them in the cost estimation for each building type.

4.1.6 Onsite Renewable Energy

4.1.6.1 Transpired Solar Collectors

A transpired solar collector (TSC) preheats ventilation air by drawing make-up air through perforated steel or aluminum cladding that is warmed by solar radiation. The TSC is typically attached to the south

façade of a building, with an air gap between the existing wall and the TSC cladding. The TSC is dark-colored to absorb the maximum amount of solar radiation. Air is drawn through the small holes in the wall and heated at the same time.

TSCs provide a cost-effective and energy efficient solution for preheating ventilation air, and have been recommended for buildings located in climate zones 2A to 8A. Energy savings are most significant in climate zones 3A to 7A, and the technology works particularly well for the COF and TEMF building types that have spaces of large volume that only require minimally conditioned ventilation air. The types of space that benefit from this technology the most are the readiness bay modules in the COF and the repair bays in the TEMF.

4.1.6.2 Solar Water Heating

The "Sustainable Design and Development Policy Update," dated October 27, 2010 from the Assistant Secretary of the Army – Installations, Energy, and Environment, mandates that beginning in FY13 "all new construction projects with an average daily non-industrial hot water requirement of 50 gallons or more, and located in an area shown on the NREL solar radiation maps (http://www.nrel.gov/gis/solar.html) as receiving an annual average of 4 kWh/m^2/day or more will be designed to provide a minimum of 30 percent of the facility's hot water demand by solar water heating." EISA 2007, Section 523, has a similar requirement for all new Federal buildings in all locations if cost-effective.

In the United States, different types of solar water heating systems are available for use in stand-alone buildings. Different design guidelines are available from NREL and ASHRAE for small size systems. These systems are usually complex given their size and application.

For this study, solar hot water was deemed feasible for UEPH, but based on the 30 percent renewable energy requirement; the TEMF and DFAC may also be candidates for solar hot water that is life-cycle cost effective. Energy savings were modeled and part of the cost estimates for those building types.

4.1.7 Plug Loads

The modeling supported the findings of the previous EPACT study for each of the building types that plug loads are a major source of energy usage, particularly in the UEPH, Bde HQ, and DFAC. Reducing the plug loads in these building types may be the only way to meet EISA 2007 requirements. For example, in UEPH, the fraction of the total power consumed by plug loads increased from 29 percent in the baseline model to 43 percent in the low-energy model. This would be indicative of all buildings where the overall energy usage is reduced without reducing the plug loads. The potential EEMs common to the five building types are as follows:

- Use high-efficiency LED computer monitors.
- Replace all desktop computers (100 W each) with laptop computers (30 W each).
- Change computer power settings to "standby when idle for 15 minutes."
- Implement the use of standby switching devices.

- Eliminate personal printers, copiers, fax machines, and scanners. Replace them with one or two multi-function print stations.
- If vending machines are in the building, use a load-managing device and de-lamp them.
- Turn miscellaneous electronics off when they are not being used or during unoccupied hours.
- Investigate more efficient task lighting, such as LED task lighting per work station.

All plug load appliances and equipment are not created equal in terms of energy usage. A prioritized list should be developed that results in the greatest energy savings for least cost increase.

4.1.7.1 UEPH

In the UEPH, the bedroom was assumed to have a computer, stereo, television, and other smaller electronic devices for a plug load density of 1.67 W/ft^2. Each kitchen contains a refrigerator and an electric range. The refrigerator was assumed to be efficient with an average power consumption of 76 W, and the range was assumed to have a peak power of 1,500 W. Three loads per occupant per week or 48 loads/day were assumed. ENERGY STAR® commercial washing machines use approximately 20 gallons of water per load and 0.60 kWh of electricity per load. The dryers were assumed to use 1.5 kWh of electricity per load. All internal loads were operated on the schedules shown in Table A.5 in Appendix A.

4.1.7.2 TEMF

There is no metered data and very little information about plug load equipment associated with the TEMF. Because this information was not available, plug load EEMs were not considered in this study and assumed power densities remained the same in all models. However, some EEMs could be considered in future analysis, especially in areas such as the office/administrative area.

4.1.7.3 COF

There is very little detailed information about the plug and process loads in COF buildings, and assumptions have to be made in order to include them in the models. Using engineering judgment, equipment power densities were assumed and are listed by zone in Tables C.8 through C.15 in Appendix A.

4.1.7.4 Bde HQ

Plug loads were modeled differently for the office spaces and the data center. For the office spaces baseline model the plug loads were supplied by the Savannah District COS for their standard design averaged at 1.7 W/ft^2. Using ENERGY STAR® equipment reduces the office plug loads to 1.35 W/ft^2. Further equipment reductions were made in office spaces using Consortium for Energy Efficiency (CEE) Tier 3 equipment reduced the office plug loads to 1.20 W/ft^2 for the final efficient model. The CEE Tier 1 is aligned with the ENERGY STAR® specification and represents performance that will realize energy savings and greenhouse gas reductions on a national basis. CEE Tier 2 and Tier 3 help distinguish equipment that is super-efficient and are often the basis for building-critical levels of demand reduction using these higher performing products.

The plug loads in the data center include all of the server racks, computer stations, and other electrical equipment. The loads were calculated based on the information provided in the standard brigade design specification (USACE Savannah 2010). The data center loads are recognized to be peak nameplate values only. The data center loads were simulated at 5.3 W/ft^2. The data center loads were not reduced for the efficient model due to lack of information for currently available advanced data center equipment. Further internal load reduction in the data center is possible when information on advanced server equipment becomes available from the U.S. Environmental Protection Agency (EPA) or CEE. All internal loads were operated on the schedules shown in Table D.4 in Appendix D.

4.1.7.5 DFAC

Plug and process loads for commercial kitchens are very large and have a significant impact on the HVAC and overall building energy use. The 2007 DOE Buildings Energy Data Book estimates that the cooking and refrigeration loads in a typical "Food Service" building is approximately 45 percent of the total energy use (DOE 2007). Significantly reducing the energy consumption associated with kitchen equipment is a challenging task, but a number of energy efficiency measures can be implemented.

The process loads associated with food preparation, serving, and cleaning for this model were estimated by Architectural Energy Corporation and Fisher Nickel, Inc. The Army supplied the kitchen layout, equipment specification sheets, a 21-day menu, and the number of meals served per day. The cooking energy for each piece of equipment was estimated for each space based on the menus, and aggregated schedules were created for each space including warm-up and idle times.

Based upon the current kitchen design, best-in-class high-efficiency gas and electric kitchen equipment was recommended, along with two alternative choices. The use of high-efficiency equipment also reduces exhaust and make-up air requirements, especially when paired with proper exhaust hood design, layout, and flow controls that are part of the ventilation system.

Going a step further, an all-electric kitchen equipment design was considered. The all-electric scenario also positions the facility to be able to operate using 100 percent renewable energy as opposed to having to convert gas appliances and equipment at a later date and increased cost. Plug loads are found in Table E.2 in Appendix E.

4.2 Water

Water use, technically seen as a sustainability measure, was modeled in terms of hot water usage. This section addresses interior potable water, including hot water, and exterior non-potable. The goals for the study were a 30 percent reduction in water usage and 50 percent reduction in wastewater.

4.2.1 Interior Potable

In the UEPH, water-use reduction can be achieved through the use of water-conserving fixtures. These include high-efficiency toilets (HETs), dual-flush toilets, composting toilets, low-flow lavatories, low-flow showers, and low-flow kitchen sinks. (See TechNotes for HETs and low-flow fixtures.)

The reduction rates are comparisons between the baseline model and three design proposals. The baseline model uses conventional water fixtures, whereas the design proposals use various water-conserving fixtures. All calculations evaluate annual wastewater volumes from fixtures.

Various assumptions were made with regard to occupancy, flow rates, and daily usage in order to compute the overall annual volume of water consumption. The baseline calculations use conventional fixtures. Conventional fixture flow rates were based on the values from the 2009 *LEED Reference Guide for Green Building Design and Construction* (USGBC 2009). The design calculations use various types of low-flow fixtures.

Daily uses were based on the 2009 *LEED Reference Guide for Building Design and Construction* for each occupant type. Values for soldiers were based on the resident occupant type for most instances. The calculations determine an approximate annual volume of water consumption. Volumes are determined based on the different occupants and their respective usage in that building.

4.2.2 Exterior – Non-Potable

No potable water was used for irrigation in conformance with current Army requirements. Stormwater measures that use captured gray water for irrigation and other purposes are described in Section 5.3.1. Reuse of interior potable water potentially for boot washing or other uses was researched and installation of "purple" pipe was part of the buildings' cost estimates.

4.3 Other Sustainability

A number of sustainability features were examined as part of the study. These measures were also included in the cost estimating.

4.3.1 Stormwater

Stormwater quantity control aims to limit the disturbance of natural movement, distribution, and quality of water. This can be achieved through various techniques that reduce impervious cover, increase filtration, and reduce pollution in water runoff.[2]

EISA 2007 Section 438 requires Federal projects with a footprint over 5,000 ft^2 to "maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow." The project footprint includes all hard, horizontal surfaces and areas of land disturbed by the project development. This includes the building area, roads, parking lots, and sidewalks. [3] The Deputy Under Secretary of Defense (Installations and Environment) memorandum, effective January 2010, directs DoD components to implement EISA 2007 Section 438 using LID techniques in accordance with the methodology described below. [4]

[2] LEED Reference Guide for Green Building Design and Construction. 2009. U.S. Green Building Council. Washington, D.C. p. 91.
[3] United States Environmental Protection Agency. Office of Water. Low Impact Development (LID): A literature review. EPA-841-B-00-005. October 2005. P. 1-4.
[4] United States Environmental Protection Agency. Office of Water. Low Impact Development (LID): A literature review. EPA-841-B-00-005. October 2005. P. 1-4.

LID practices fall into three main categories: infiltration, storage and reuse, and evapotranspiration (ET). ET is the process of evaporation, sublimation, and transpiration of water from the earth's surface as summarized in Table 4.6.

Table 4.6 Low Impact Development Techniques

Infiltration	Storage & Reuse	Evapotranspiration
Bioretention	Rain Barrels	Biorention
Vegetated Swales	Cisterns	Vegetated Swales
Permeable Pavement	Disconnected Downspouts	Vegetated Roofs
Sub-Surface Retention		
Vegetated Roofs		

All of these techniques were investigated and cost estimates were developed where applicable for each of the five building types in this study. Several of these techniques are site-specific, which resulted in assumptions being made in terms of what measures would be used most frequently. (See TechNotes for LID techniques.)

4.3.2 Enhanced Commissioning

Enhanced commissioning was driven by LEED 2009. The estimate considered the items listed below.

- Prior to the start of the construction documents phase, designate an independent Commissioning Authority (CxA) to lead, review, and oversee the completion of all commissioning process activities.
- The CxA shall conduct two commissioning design reviews of the Owner's Project Requirements (OPR), Basis of Design (BOD), and design documents prior to mid-construction documents phase and back-check the review comments in the subsequent design submission.
- The CxA shall review contractor submittals applicable to systems being commissioned for compliance with the OPR and BOD. This review shall be concurrent with A&E reviews and submitted to the design team and the owner.
- Verify that the requirements for training operating personnel and building occupants are completed.
- Develop a systems manual that provides future operating staff the information needed to understand and optimally operate the commissioned systems.
- Ensure the involvement by the CxA in reviewing building operation within 10 months after substantial completion with O&M staff and occupants. Include a plan for resolution of outstanding commissioning-related issues.

4.3.3 Measurement and Verification

Measurement and verification (M&V) is part of ASHRAE 189.1 and LEED 2009. While LEED requires a plan for measurement and verification, ASHRAE 189.1 has more detailed requirements, which

include the use of meters for various systems. This study acknowledged both of these sources and included M&V in the cost estimate for the building types.

At the Installations level, IMCOM is currently leading Phase I of a major metering project. During this phase, all buildings that are over 29,000 ft^2 or exceed $35,000 a year in utility costs will be required to be metered. Phase II of the program includes development of a Metered Building Energy Conservation Strategy that will capture and manage the resulting data. Metering is expected to be completed by the end of 2012.

4.3.4 Daylighting

LEED 2009 requires the determination of a building's "regularly occupied" space for calculating the following three indoor environmental quality (IEQ) credits:

1. IEQcr5: Indoor Chemical and Pollutant Source Control
2. IEQcr8.1: Daylight and Views—Daylight
3. IEQcr8.2: Daylight and Views—Views.

Regularly occupied space is defined as areas where occupants are seated or stand as they work inside a building. In residential applications such as the barracks, these areas include all spaces except bathrooms, utility areas, closets, or other storage rooms.[5] Regularly occupied spaces were calculated for each of the five building types based on drawings for their standard designs. Techniques and systems related to daylighting include the following:

- use of passive lighting ceiling systems (e.g. light shelves) that "stretch" light into spaces with no direct daylight exposure
- louvers and overhangs (to act as shading devices)
- daylight sensors (to minimize use of powered light fixtures in areas with free light sources)
- daylighting software (to predict and analyze how daylighting will affect the building and when electrical lighting can be dimmed or turned off)
- fiber optics (to act as a hybrid solar lighting system by bringing daylighting into the building via fiber-optic fibers, without requiring large penetrations in the building envelope as a skylight or window would)

TechNotes are available for daylight sensors and light shelves (see Section 5.6.2), and the Atelier Ten Lighting Report in Appendix F contains tables with daylighting values for the different building types.

4.3.4.1 UEPH

Skylights and light tubes were included in the UEPH with one skylight or light tube per module. Thirty-eight solar tubes direct additional lighting to the second and third floors. The exact locations and required floor area were not determined for this study. It may be possible to use the floor area from mechanical closets for light tubes when some of the HVAC system packages do not require mechanical rooms within the occupied space.

[5] LEED Reference Guide for Green Building Design and Construction, 2009.

4.3.4.2 TEMF

The door, window, and skylight sizes and distribution within the repair bays are the same in all energy models, with a skylight-to-floor-area (SFA) fraction of 4 percent. However, daylighting recommendations for the office and consolidated bench areas include an increase in the SFA fraction to 3 percent and an increase in vertical glazing by 50 percent. Dimmable daylighting controls to off with a 500 lux setpoint are also recommended for all daylit areas. Fenestration details are also listed in Table B.3 in Appendix B.

4.3.4.3 COF

Daylighting controls were not included in the baseline model. In the energy efficient model, dimmable daylighting controls to off with a 500 lux setpoint were recommended for all daylit areas. The SFA fraction was also increased to 3 percent over the readiness bays, platoon offices, mezzanine corridor, and storage space. The 3 percent SFA follows recommendations found in the *The ASHRAE 30 % Advanced Energy Design Guide for Small Retail Buildings* (http://www.ashrae.org/technology/page/938). Fenestration details are listed in Tables C.2 and C.3 in Appendix C.

4.3.4.4 Bde HQ

The Bde HQ standard design failed to successfully incorporate a sufficient daylighting scheme into the building. The distance from one exterior wall to the opposite exceeds 60 ft, which is the pre-determined maximum distance that allows for daylighting penetration[6]. Therefore, the calculated interior spaces did not receive sufficient daylight. Consequently, this particular design could not receive LEED credit for daylighting. Several strategies, including narrowing the building's footprint and using reflective finishes on surfaces, could have enabled the building to achieve the daylighting credit. Fenestration details are listed in Tables D2 and D3 in Appendix D.

4.3.4.5 DFAC

Currently, the standard DFAC design provides sufficient daylighting to the dining area, but the kitchen/preparation area and the dishwashing area lack daylighting. The standard design features clerestories and skylights in the dining area. Notably, the DFAC is a single-story building; therefore, the use of light tubes or additional skylights would provide enough natural light into spaces that are currently lacking daylighting. Fenestration details are listed in Tables E.3 and E.4 in Appendix E.

[6] (Lechner, N. 2009. Heating, Cooling, Lighting. Hoboken, New Jersey: John Wiley & Sons, Inc. P 380).

5.0 Outputs and Results

Following analysis of the regulatory drivers and potential strategies, energy modeling of selected packages of energy efficient features was conducted. The goal was to develop design improvements that would meet the EISA 2007 target for 2015 of a 65 percent fossil fuel-generated energy reduction based on 2003 CBECS data and that were also life-cycle cost effective and considered other factors such as O&M impacts.

5.1 Energy Savings

Modeling was completed for each of the five prototype Army Corps of Engineers standard designs, otherwise referred to in this report as the "baseline" buildings plus additional EEM packages for all 15 climate zones. Cost estimates for the baseline building and selected Low Energy Packages were also completed for climate zones based on the location of buildings in the FY13 construction program list. Appendices A through E include more detailed figures, tables, and cost estimates for each building type.

Low Energy Packages for all building types included increased exterior insulation, daylighting and daylighting controls, DOAS HVAC systems, improved pumps and fans, pressurization and make-up air, and top-tier ENERGY STAR® appliances and products. In addition, features such as solar hot water and transpired solar collectors were examined where appropriate.

As can be seen from the results discussed below, CBECS building categories and their related EUIs are not directly comparable to the five Army building types that were analyzed. This directly affects whether a building meets or falls short of the EISA 2007 targets for 2015. Annual target EUI for each climate zone was determined from the CBECS data and compared to the Corps baseline EUI for the designed building. The target EUI is 35 percent of the CBECS values, or a 65 percent increase in efficiency, which is a very aggressive target from the EISA 2007 legislation.

5.1.1 UEPH

For the UEPH, the "Dormitory" category was chosen from the CBECS for all comparisons to CBECS data, because it was determined to be the closest match to the UEPH facility. The simulated results for the energy efficient designs including the envelope, infiltration, lighting, equipment, and HVAC energy conservation measures are shown in tables and figures below with the cumulative percent savings compared to the baseline UEPH building (B) EUI for each EEM package (P1–P13). In the tables and figures below, the "Baseline Building" or "B" is the base building model from each of the COS standard designs (baseline building assumptions for each of the five facility types are listed in each building appendix [A–E]). Each EEM or Low Energy Package is applied cumulatively to the baseline B, starting with P1 (e.g., lighting load and electric power load density reduction for UEPH), then P2, P3, and finally P4. Package P4 is considered the improved baseline high-performance or low-energy package for each building and is called "Low Energy Package 1." Then, EEMs 5–13 are applied individually or in combination to P4 to compare the different HVAC alternatives. The results for each building are shown for both site and source. The source results are necessary for EISA 2007 compliance. The site results are necessary for all site energy reduction mandates, including EPAct 2005.

Table 5.1 Site Energy Use Intensities (EUIs) for Each Energy Efficiency Measure (EEM) Package. (Package 4 [P4], circled in red, is considered the improved baseline low-energy building.)

Site Energy Totals with Plug Loads [kBtu/ft2]	2003 CBECS Dormitory	CBECS Budget (65% Reduction)	Baseline Building	Low Energy Package 1												
			B	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
1A Miami	68	24	69	52	46	39	37	37	35	36	36	35	34	37	34	30
2A Houston	69	24	69	56	47	40	38	37	36	37	36	35	34	38	35	31
2B Phoenix	67	23	64	49	42	37	35	34	32	34	32	31	30	35	31	26
3A Memphis	68	24	72	61	50	43	41	37	39	39	36	36	34	38	35	31
3B El Paso	64	22	63	50	44	38	36	34	35	35	33	33	31	36	33	28
3C San Francisco	58	20	59	49	42	38	35	34	35	34	33	34	33	36	33	30
4A Baltimore	75	26	77	68	53	46	43	38	42	42	36	37	35	40	38	33
4B Albuquerque	66	23	69	58	48	42	40	35	38	38	34	34	33	39	35	30
4C Seattle	68	24	69	63	49	43	40	36	40	39	34	36	34	37	35	32
5A Chicago	84	29	84	77	59	51	48	39	47	46	38	39	37	40	37	35
5B Colorado Springs	73	26	75	65	54	47	44	37	43	42	36	36	35	41	38	32
6A Burlington	97	34	88	82	62	54	50	40	50	48	39	39	38	43	40	36
6B Helena	86	30	84	77	59	51	48	38	47	46	37	38	37	42	39	34
7A Duluth	105	37	98	93	70	60	56	42	55	54	41	42	41	45	43	39
8A Fairbanks	135	47	122	119	87	74	69	50	69	67	49	50	49	47	45	47

B	Baseline Energy Budget
P1	Lighting Load and Electric Power Load Density Reduction from 1.67 W/ft^2 to 0.835 W/ft^2 applied to B
P2	Passiv haus insulation specification; increased insulation and air tightness, reduce OA pressurization air to 65CFM due to air tightness with P1-B
P3	Increase chiller and boiler efficiencies and all variable high efficiency pumps and fans with P2-B
P4	Reduce hot water with 1.5gpm shower heads with P3-B
P5	Energy recovery ventilation (ERV) with P4
P6	Indirect evaporative pre-cooling with P4
P7	Radiant heating and cooling with P4
P8	ERV and radiant with P4
P9	ERV and indirect evaporative pre-cooling with P4
P10	ERV, indirect evaporative pre-cooling and radiant heating and cooling with P4
P11	Ground source heat pump (GSHP) and ERV with P4
P12	Reduction in equiment loads (0.5W/ft2) with premium equipment in soldiers rooms; added to P11
P13	Reduction in equiment loads (0.5W/ft2) with premium equipment in soldiers rooms, Added to P10

Table 5.2 Source EUI for Each EEM Package. (P4, circled in red, is considered the baseline low-energy building.)

Source Energy Totals with Plug Loads [kBtu/ft2]	2003 CBECS Dormitory	CBECS Budget (65% Reduction)	Baseline Building	Low Energy Package 1												
			B	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
1A Miami	191	73	209	151	133	113	111	110	103	108	108	103	99	111	99	87
2A Houston	169	68	195	143	124	108	106	104	99	102	101	98	95	108	97	83
2B Phoenix	168	68	186	132	115	101	100	96	89	95	92	88	84	101	89	72
3A Memphis	161	62	188	138	120	106	103	99	99	99	96	95	91	106	95	80
3B El Paso	143	60	171	119	107	97	95	92	90	91	89	88	84	100	88	72
3C San Francisco	141	52	152	107	98	91	88	87	88	85	84	87	84	95	85	73
4A Baltimore	164	62	183	138	117	105	102	96	99	98	93	93	90	108	98	79
4B Albuquerque	155	57	170	121	108	99	96	91	92	92	87	88	84	104	92	73
4C Seattle	148	56	162	120	104	96	93	88	92	90	85	88	85	97	87	74
5A Chicago	170	65	187	143	121	109	105	96	103	101	93	94	90	104	94	80
5B Colorado Springs	158	59	172	125	111	102	99	91	96	95	88	90	86	106	95	75
6A Burlington	180	71	186	144	121	109	105	95	104	102	92	93	90	111	101	80
6B Helena	166	64	179	136	115	105	102	92	100	98	89	91	87	108	97	77
7A Duluth	185	72	193	153	126	114	110	96	109	106	93	95	92	116	106	82
8A Fairbanks	217	83	215	178	142	127	123	102	122	119	100	102	99	117	107	90

Table 5.32 shows the incremental percent savings for each as it is added to the previous package. The baseline Low Energy Package consists of packages, P1 through P4, applied to the baseline energy model,

B. Packages P5, P8–11 appear to achieve the best results based on the energy modeling information, because they show the highest energy savings percentages. Low Energy Packages P12 and P13 are not considered in the final analysis because they assume that there is a further reduction in equipment loads in the soldier's rooms.

Table 5.3 Site Cumulative Percent Savings. (The red box indicates what is considered as the baseline Low Energy Package P4. The columns to the right show the incremental percent savings compared to the P4 package.)

UEPH	Incremental % Savings (Site)												
	P1-B	P2-P1	P3-P2	P4-P3	P5-P4	P6-P4	P7-P4	P8-P4	P9-P4	P10-P4	P11-P4	P12-P4	P13-P4
1A Miami	-25%	-11%	-15%	-4%	-1%	-7%	-3%	-3%	-7%	-10%	0%	-10%	-19%
2A Houston	-19%	-16%	-14%	-5%	-4%	-5%	-3%	-7%	-8%	-12%	-1%	-10%	-20%
2B Phoenix	-23%	-14%	-13%	-5%	-4%	-10%	-4%	-7%	-11%	-15%	0%	-10%	-25%
3A Memphis	-16%	-18%	-13%	-6%	-9%	-4%	-4%	-12%	-12%	-15%	-5%	-13%	-23%
3B El Paso	-21%	-13%	-12%	-6%	-6%	-4%	-4%	-9%	-10%	-13%	-1%	-10%	-23%
3C San Francisco	-16%	-14%	-10%	-8%	-3%	-1%	-3%	-6%	-4%	-7%	3%	-6%	-15%
4A Baltimore	-11%	-22%	-13%	-7%	-13%	-2%	-4%	-16%	-15%	-19%	-7%	-13%	-25%
4B Albuquerque	-16%	-17%	-12%	-7%	-11%	-3%	-3%	-14%	-14%	-17%	-2%	-10%	-25%
4C Seattle	-9%	-22%	-11%	-8%	-11%	-1%	-4%	-14%	-11%	-15%	-7%	-13%	-21%
5A Chicago	-9%	-23%	-13%	-7%	-18%	-1%	-3%	-21%	-19%	-22%	-17%	-22%	-28%
5B Colorado Springs	-13%	-18%	-12%	-7%	-16%	-1%	-3%	-18%	-17%	-19%	-7%	-13%	-26%
6A Burlington	-7%	-25%	-13%	-7%	-20%	-1%	-3%	-23%	-21%	-24%	-14%	-19%	-28%
6B Helena	-8%	-23%	-13%	-7%	-20%	-1%	-3%	-22%	-21%	-23%	-12%	-18%	-29%
7A Duluth	-5%	-25%	-14%	-7%	-24%	0%	-3%	-26%	-24%	-26%	-18%	-22%	-30%
8A Fairbanks	-2%	-27%	-15%	-6%	-28%	0%	-2%	-29%	-28%	-30%	-32%	-34%	-32%
Avg % Savings	-13%	-19%	-13%	-6%	-13%	-3%	-3%	-15%	-15%	-18%	-8%	-15%	-25%

After reviewing the data with the COSs and cost estimators, packages 5, 8 and 11 were selected in addition to the baseline Low Energy Package 4 for full cost estimates. These selections were made based on possible issues with maintenance of newer technologies and a high first cost or lack of availability of systems to be supplied by three or more vendors.

As can be seen from Figure 5.1 below, the initial EEMs show good source energy improvement and the selected packages for closer evaluation are indicated (P5, P8, and P11). Even with all of these technologies applied the targets could not be achieved, and only when internal loads are reduced further do we start seeing further improvements. Another interesting result is that when source fuels are calculated, the savings from GSHPs (P11) are not as good as expected because most of the advantages are negated when the source fuels for electricity generation are considered. In other words, GSHPs inherently need electricity to operate, and a large percentage of the electricity generation in the United States is from fossil-fuel-based power plants.

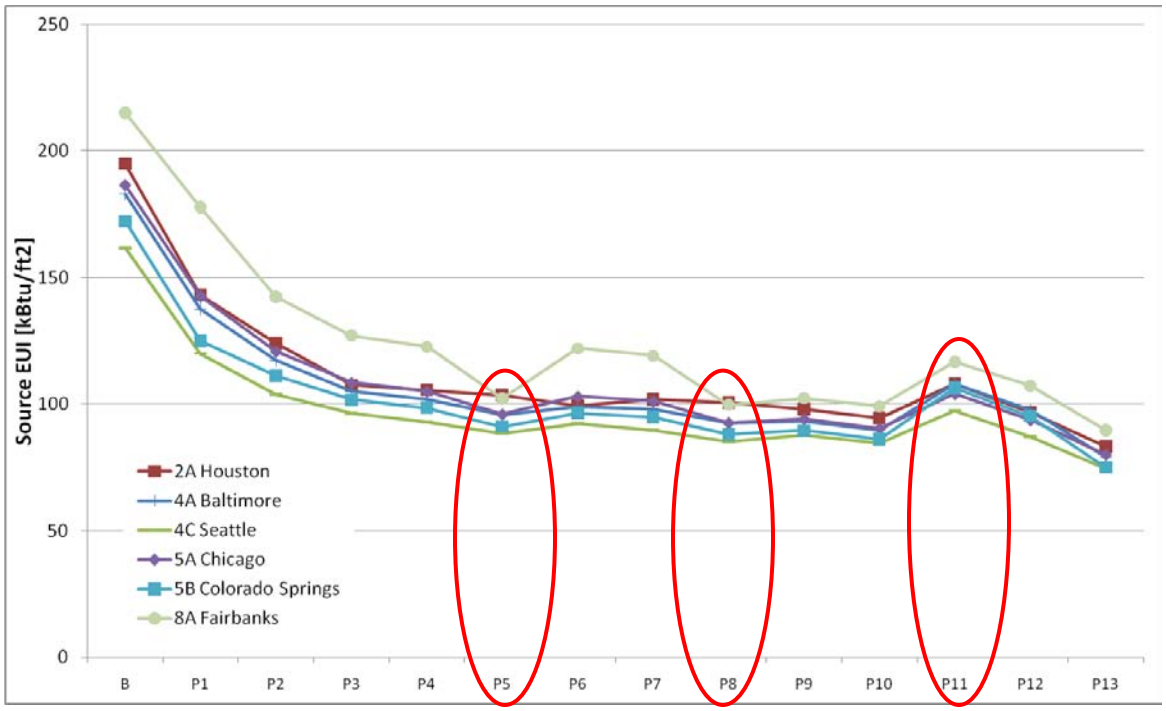

Figure 5.1 UEPH Source Energy Use Intensities by EEM Package (P5, P8, and P11, circled in red, show packages that were chosen for cost estimation in addition to baseline package P4)

In addition to the energy packages that were evaluated, 30 percent of the hot water demand was supplied with solar hot water heaters. Table 5.4 below shows the site energy savings results with the solar hot water added to the Low Energy Packages that were evaluated for the UEPH facility. For simplification purposes, P4, P5, P8, and P11 are renamed Low Energy Package 1–4 in the tables that follow.

Table 5.4 Description of Low Energy Packages for the UEPH

UEPH	Energy Efficiency Measures
Low Energy Package 1 (P1-P4)	• Passive house insulation, windows– applied to whole building. • Reduced infiltration rates from 0.4 cfm/ft^2 to 0.15 cfm/ft^2 • Reduced lighting power densities • High efficiency fixtures to reduce hot water demand includes: 0.5-gpm flow faucets, 1.5-gpm flow shower heads • Cool roofs in climates 1-5 and window shading • Increased vertical glazing size by 50%, increased skylight-to-floor area (SFA) fraction to 3% • Advanced HVAC system: o Dedicated outside air system (DOAS) for ventilation, o Improved chiller and boiler efficiencies, o All variable high-efficiency pumps and fans, o Pressurization and make-up air, o Condenser heat recovery for DOAS o Separate ventilation for living area and laundry facilities • Solar hot water system included • Top tier ENERGY STAR® appliances
Low Energy Package 2 (P5)	• Same as Low Energy Package 1 plus adding total energy recovery (ERV) unit at 80% effectiveness
Low Energy Package 3 (P8)	• Same as Low Energy Package 2 with ceiling radiant heating and cooling added (radiant mat is installed in the ceiling)
Low Energy Package 4 (P11)	• Same as Low Energy Package 2 except replace high-efficiency chiller and boiler with a ground-source heat pump system

Table 5.5 UEPH Cumulative Site Energy Savings of Each Low Energy Package with 30% Solar Domestic Hot Water Heating Added as Compared to the Baseline EUI

Site Energy Savings Compared to Baseline [%]	Low Energy Package 1	Low Energy Package 2	Low Energy Package 3	Low Energy Package 4
1A Miami	37%	49%	50%	48%
2A Houston	37%	50%	52%	49%
2B Phoenix	39%	51%	52%	49%
3A Memphis	37%	53%	54%	51%
3B El Paso	38%	51%	53%	48%
3C San Francisco	37%	48%	49%	44%
4A Baltimore	37%	56%	57%	52%
4B Albuquerque	38%	54%	56%	49%
4C Seattle	37%	53%	55%	51%
5A Chicago	36%	58%	60%	54%
5B Colorado Springs	37%	56%	58%	51%
6A Burlington	37%	60%	61%	56%
6B Helena	37%	59%	61%	55%
7A Duluth	36%	62%	63%	58%
8A Fairbanks	36%	64%	65%	66%

Based on the cost estimates that were completed and the energy savings that resulted from the modeling analysis, Low Energy Package 3 was selected as the lowest energy and most cost-effective package (see Section 5.5 for LCCA analysis results). Table 5.6 compares the Low Energy Package 3 site EUI to the CBECS 2003 targets for the Dormitory category. Four of the 15 climate zones reach or are within 5 percent of the CBECS targets (noted in red). When comparing the CBECS source energy targets to the low-energy model, the percentage difference is not as high as in the CBECS site EUI comparison.

Table 5.6 UEPH Site Energy Savings of Low Energy Package 3 Compared to the 2003 CBECS Baseline Category (Dormitory)

Site Energy Savings Compared to CBECS [kBtu/ft2]	2003 CBECS Site EUI (Dormitory)	65% Reduction - CBECS 2003 Target EUI [kBtu/ft2]	Low Energy Model EUI [kBtu/ft2]	% Difference of Low Energy from CBECS 2003
1A Miami	68	24	35	49%
2A Houston	69	24	33	51%
2B Phoenix	67	23	30	55%
3A Memphis	68	24	33	51%
3B El Paso	64	22	30	53%
3C San Francisco	58	20	30	49%
4A Baltimore	75	26	33	56%
4B Albuquerque	66	23	31	54%
4C Seattle	68	24	31	55%
5A Chicago	84	29	34	59%
5B Colorado Springs	73	26	32	57%
6A Burlington	97	34	34	64%
6B Helena	86	30	33	62%
7A Duluth	105	37	37	65%
8A Fairbanks	135	47	43	68%

Table 5.7 UEPH Source Energy Savings of Low Energy Package 3 Compared to the 2003 CBECS Baseline Category (Dormitory)

Source Energy Savings Compared to CBECS [kBtu/ft2]	2003 CBECS Source EUI (Dormitroy)	65% Reduction - CBECS 2003 Target EUI [kBtu/ft2]	Low Energy Model EUI [kBtu/ft2]	% Difference of Low Energy from CBECS 2003
1A Miami	191	67	106	44%
2A Houston	169	59	99	42%
2B Phoenix	168	59	91	46%
3A Memphis	161	56	93	42%
3B El Paso	143	50	86	39%
3C San Francisco	141	49	82	42%
4A Baltimore	164	58	90	45%
4B Albuquerque	155	54	85	45%
4C Seattle	148	52	82	44%
5A Chicago	170	59	90	47%
5B Colorado Springs	158	55	85	46%
6A Burlington	180	63	88	51%
6B Helena	166	58	85	49%
7A Duluth	185	65	89	52%
8A Fairbanks	217	76	96	56%

Note that the UEPH Low Energy Package 3 does not reduce fossil fuel-generated energy consumption in any climate zone sufficiently to meet the EISA 2007 fossil fuel-generated energy reduction goal of 65 percent. It is important to again note that the CBECS 2003 category that was chosen may not match well to the UEPH facility in terms of energy consumption data.

To investigate further how to reach the EISA 2007 targets, Figure 5.2 below plots the same results as Table 5.6, but also includes the breakdown of the components that make up the total building energy consumption. Although improvements have been made with the low-energy model toward meeting the EISA 2007 goals, this breakdown shows that without considering further internal load reduction, the EISA 2007 targets cannot be met. Even buildings with low internal energy loads can end up being dominated by internal loads when built or retrofitted to passive house requirements and using advanced "low-energy" systems to satisfy remaining heating and cooling needs. The remaining energy requirements will be dominated by electrical power needs for lighting, appliances, and internal processes, and by domestic hot water needs or the "mission" of the building.

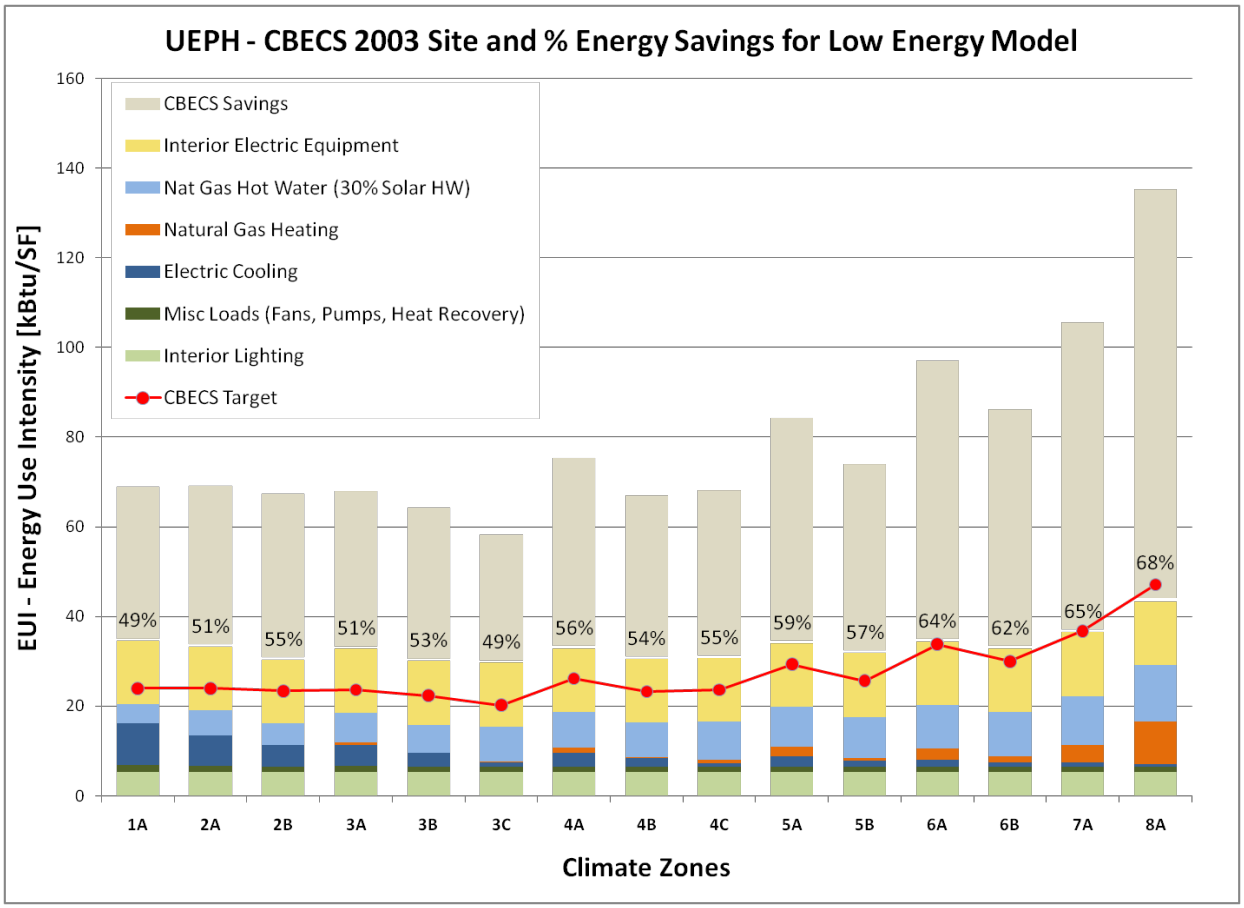

Figure 5.2 UEPH Percent Low Energy Package 3 with Comparison to EISA 2007 Targets (Site Energy)

Table 5.8 breaks down the site baseline building component energy for the UEPH by climate zone and shows that the interior lights, interior equipment/plug loads, and natural gas hot water make up from 50 percent to 86 percent of the load, varying by climate zone.

Table 5.8 Baseline UEPH (Site Energy)

Site Energy [kBtu/ft2]	Electric Cooling	Interior Lights	Interior Equipment	Electric Fans, Pumps	Natural Gas Heating	Natural Gas Hot Water	Total
1A Miami	22.9	11.2	22.4	3.2	0.1	9.1	68.8
2A Houston	17.0	11.2	22.4	2.2	3.2	12.1	68.9
2B Phoenix	15.5	11.2	22.4	2.4	1.3	10.4	63.8
3A Memphis	12.6	11.2	22.4	2.3	8.5	14.4	71.8
3B El Paso	9.4	11.2	22.4	2.2	4.2	13.6	63.5
3C San Francisco	3.5	11.2	22.4	2.1	2.4	16.9	58.6
4A Baltimore	8.5	11.2	22.4	2.2	14.9	17.2	76.9
4B Albuquerque	6.3	11.2	22.4	2.4	9.5	16.8	69.0
4C Seattle	3.1	11.2	22.4	2.1	11.3	18.4	68.8
5A Chicago	6.7	11.2	22.4	2.2	22.2	19.2	84.3
5B Colorado Springs	4.4	11.2	22.4	2.4	15.0	19.7	75.4
6A Burlington	4.7	11.2	22.4	2.1	26.7	21.0	88.4
6B Helena	3.4	11.2	22.4	2.3	22.9	21.2	83.8
7A Duluth	3.2	11.2	22.4	2.1	35.1	23.7	98.1
8A Fairbanks	2.0	11.2	22.4	2.2	57.0	27.1	122.1

Table 5.9 shows that even after the improved lighting design, reducing hot water consumption with low-flow shower heads and improving the interior equipment/plug loads by almost 50 percent , a significant percentage of interior equipment/plug load remains. With EISA 2007, total energy is now considered. This is unlike EPACT 2005, Section 109, where the plug loads were considered unregulated. Now they are a significant part of the challenge posed by EISA 2007 requirements.

Table 5.9 Energy Efficient UEPH (Site Energy)

Site Energy [kBtu/ft2]	Electric Cooling	Interior Lights	Interior Equipment	Electric Fans, Pumps	Natural Gas Heating	Natural Gas Hot Water	Total
1A Miami	9.3	5.4	14.2	1.5	0.0	4.2	34.6
2A Houston	6.7	5.4	14.2	1.4	0.1	5.6	33.3
2B Phoenix	4.8	5.4	14.2	1.2	0.0	4.8	30.4
3A Memphis	4.7	5.4	14.2	1.2	0.7	6.6	32.8
3B El Paso	3.0	5.4	14.2	1.1	0.1	6.3	30.1
3C San Francisco	1.1	5.4	14.2	1.0	0.2	7.8	29.7
4A Baltimore	3.1	5.4	14.2	1.2	1.0	8.0	32.8
4B Albuquerque	2.0	5.4	14.2	1.1	0.2	7.8	30.6
4C Seattle	0.9	5.4	14.2	1.1	0.7	8.5	30.7
5A Chicago	2.4	5.4	14.2	1.1	2.1	8.9	34.1
5B Colorado Springs	1.4	5.4	14.2	1.1	0.6	9.1	31.8
6A Burlington	1.6	5.4	14.2	1.1	2.4	9.7	34.4
6B Helena	1.1	5.4	14.2	1.1	1.4	9.8	32.9
7A Duluth	1.1	5.4	14.2	1.1	3.8	11.0	36.5
8A Fairbanks	0.6	5.4	14.2	1.1	9.5	12.5	43.3

Figure 5.3 further illustrates the point of how much the interior equipment/plug load percentage increases from the baseline building to the low-energy building in climate zone 4A.

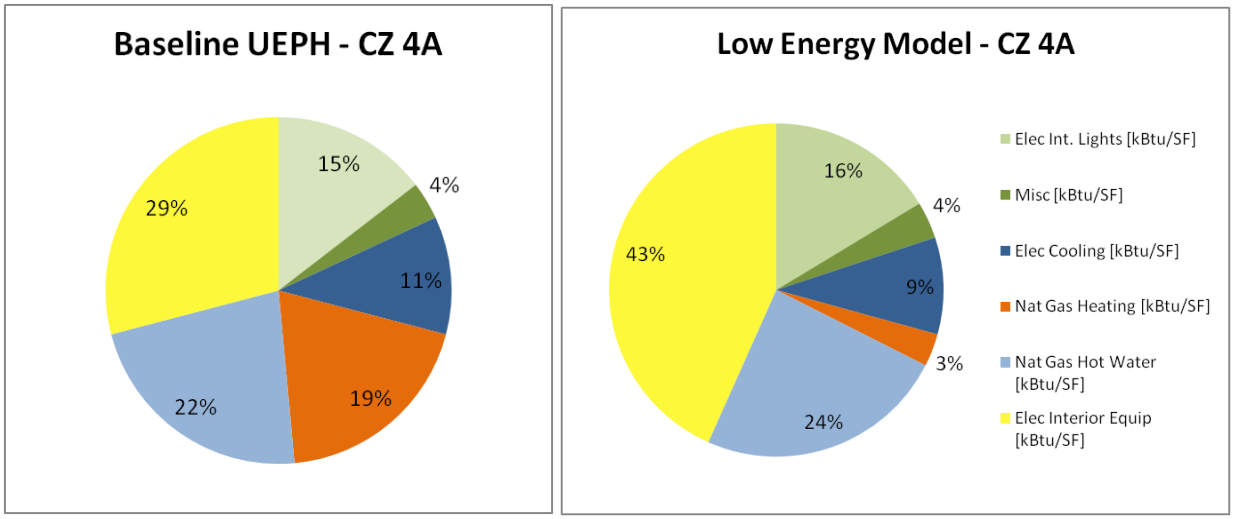

Figure 5.3 Percentage of Energy Loads – Baseline and Low-Energy Model for UEPH in Climate Zone 4A

5.1.2 TEMF

For the TEMF, the "Other Service" category was chosen from CBECS data. Annual energy use intensity for each climate zone was determined from the CBECS data and compared to the energy usage for the Army standard designed building. The EEMs considered for the TEMF were analyzed in a fashion similar to the UEPH. EEMs with the highest energy savings were chosen to be included in a Low Energy Package for each climate zone. Three iterations of Low Energy Packages followed, exploring the effects of adding TSCs to the south façade of the building, radiant floors in the repair bays and vehicle corridor, and a combination of both. Economizers were not modeled because the air handling units (AHUs) for the repair bays are dedicated to bringing 100 percent outside air and only minimally condition the air to 55 °F. A description of the four packages is found in Table 5.10 below.

Table 5.10 Description of Low Energy Packages for the TEMF

TEMF	Energy Efficiency Measures
Low Energy Package 1	• Increased daylighting and reduced lighting power density • Passive House insulation for climate zones 3A, 3B, 4A-8A • VAV fans, increased fan and HVAC efficiency, reduced ventilation in repair bays and vehicle corridor, transfer air from office to repair bays • Cool roofs for climate zones 1-5
Low Energy Package 2	• Low Energy Package 1 plus the installation of TSCs on south façade
Low Energy Package 3	• Low Energy Package 1 plus the installation of radiant floors in the repair bays and vehicle corridor
Low Energy Package 4	• Low Energy Package 1 plus the installation of both TSCs on the south façade and radiant floors in the repair bays and vehicle corridor

Results showing EUI and percent savings are presented in Table 5.11and Table 5.12 below. Baseline modeling assumptions were taken from the drawings for the Vehicle Maintenance Shop 7th Transportation Battalion PN-20807, FY10 for Fort Bragg, North Carolina.

Table 5.11 TEMF Site EUI for Each Low Energy Package

Site Energy [kBtu/ft2]	Baseline	Low Energy Package 1	Low Energy Package 2	Low Energy Package 3	Low Energy Package 4
1A Miami	27	15	15	16	16
2A Houston	33	20	19	20	19
2B Phoenix	31	19	19	20	19
3A Memphis	41	21	20	22	20
3B El Paso	36	19	19	19	19
3C San Francisco	32	18	18	17	16
4A Baltimore	55	25	23	25	23
4B Albuquerque	46	21	20	21	20
4C Seattle	51	23	21	23	22
5A Chicago	68	29	27	29	27
5B Colorado Springs	58	25	22	25	22
6A Burlington	78	33	30	33	30
6B Helena	74	31	28	30	28
7A Duluth	94	40	35	39	35
8A Fairbanks	138	63	59	59	56

Table 5.12 Site Energy Savings of Each Low Energy Package Compared to the TEMF Baseline EUI

Site Energy Savings Compared to Baseline [%]	Low Energy Package 1	Low Energy Package 2	Low Energy Package 3	Low Energy Package 4
1A Miami	43%	43%	38%	39%
2A Houston	39%	41%	40%	42%
2B Phoenix	39%	40%	37%	39%
3A Memphis	48%	51%	48%	51%
3B El Paso	46%	48%	46%	48%
3C San Francisco	43%	45%	47%	49%
4A Baltimore	55%	59%	55%	58%
4B Albuquerque	54%	58%	54%	57%
4C Seattle	55%	58%	55%	57%
5A Chicago	57%	61%	57%	60%
5B Colorado Springs	56%	62%	56%	61%
6A Burlington	58%	62%	58%	62%
6B Helena	59%	63%	59%	62%
7A Duluth	58%	63%	59%	63%
8A Fairbanks	55%	57%	57%	59%

The highlighted packages in Table 5.12 were chosen as recommended low-energy packages for each climate zone. The recommendations were based upon the level of energy savings and a rough assumption on cost for TSCs and radiant floors. Achieving the highest amount of energy savings was the goal for this project. However, for climate zones 4A through 7A, the decision to install radiant floors along with TSCs was made to increase occupant comfort in the repair bays and vehicle corridor, even though the option shows slightly lower energy savings when compared to Low Energy Package 2. It is also important to note that passive house insulation levels are not recommended for all climate zones. Climate zones 1A though 2B and 3C did not show significant savings from the specified passive house insulation levels, and thus the measure was excluded from the respective low-energy model packages. However, it is recommended that that a more detailed analysis investigating insulation levels, cost, and energy savings be conducted to fine-tune and optimize the level of insulation needed for each climate zone.

Table 5.13 compares the Low Energy Package site EUI to the CBECS 2003 targets for the Other Repair Service category. Fourteen out of the 15 climate zones meet the CBECS site targets (noted in red).

Table 5.13 TEMF Site Energy Savings of Low Energy Package Models to CBECS 2003 "Other Service" Data

Site Energy Savings Compared to CBECS [kBtu/ft2]	CBECS 2003 Site Energy EUI (Other Service)	65% Reduction - CBECS 2003 Target EUI [kBtu/ft2]	Low Energy Model EUI [kBtu/ft2]	% Difference of Low Energy from CBECS 2003
1A Miami	85	30	15	82%
2A Houston	84	29	19	77%
2B Phoenix	82	29	19	77%
3A Memphis	84	29	21	75%
3B El Paso	79	28	19	76%
3C San Francisco	76	27	16	79%
4A Baltimore	93	33	24	74%
4B Albuquerque	83	29	21	75%
4C Seattle	86	30	23	73%
5A Chicago	100	35	29	71%
5B Colorado Springs	90	32	24	73%
6A Burlington	111	39	33	70%
6B Helena	101	35	30	70%
7A Duluth	119	42	39	67%
8A Fairbanks	158	55	63	60%

The source EUI for the recommended Low Energy Packages per climate zone was compared to source energy data from CBECS 2003 for "Other Service" building types to determine compliance with the EISA 2007 fossil fuel reduction requirements. This comparison is shown in Table 5.13. All 15 climate zones reach or are within 5 percent of the CBECS targets (noted in red).

Table 5.14 TEMF Source Energy Savings of Low Energy Package Models to CBECS 2003 "Other Service" Data

Source Energy Savings Compared to CBECS [kBtu/ft2]	CBECS 2003 Source Energy EUI (Other Service)	65% Reduction - CBECS 2003 Target EUI [kBtu/ft2]	Low Energy Model EUI [kBtu/ft2]	% Difference of Low Energy from CBECS 2003
1A Miami	325	71	49	85%
2A Houston	198	65	54	73%
2B Phoenix	208	53	56	73%
3A Memphis	180	56	59	67%
3B El Paso	158	51	58	63%
3C San Francisco	160	48	46	71%
4A Baltimore	187	57	59	68%
4B Albuquerque	182	40	56	69%
4C Seattle	172	41	56	68%
5A Chicago	207	58	61	71%
5B Colorado Springs	201	56	57	72%
6A Burlington	226	66	63	72%
6B Helena	218	52	62	72%
7A Duluth	242	63	67	72%
8A Fairbanks	317	79	91	71%

5.1.3 COF

For the COF, the "Government Office" and "Other Public Assembly" categories were chosen from 2003 CBECS data. Government Office represented the administrative office space portion of the COF and Other Public Assembly represented the readiness bays. A blended or mixed CBECS EUI value was calculated assuming a 50-50 mix of the two building types.

The EEMs considered for the COF were analyzed individually, and the EEMs with the highest energy savings were chosen to be included in a low-energy "package" for each climate zone. This follows the same path as the UEPH and TEMF analyses. Reduced lighting power density, increased daylighting, control strategies for lighting and daylighting, and passive house insulation levels were recommended for each climate zone. High-efficiency HVAC equipment and VAV fans were also recommended for each climate zone, as well as "cool roof" construction for climate zones 1A through 3B.

For the readiness bays alone, energy recovery ventilators were recommended for climate zones 1A, 2A, 3A, and 3C to 4B. DOASs, energy recovery ventilators and fan coils were recommended for climate zones 2B and 3B, and indirect evaporative cooling was recommended for climate zones 4C to 8A. Lastly, an alternative construction design was also explored for the readiness bays, which reduced the volume of conditioned air in each module. Energy savings from this efficiency measure was significant, ranging between 16 percent and 34 percent for the readiness bays alone. However, a drastic change in the design of these modules may conflict with current Army regulations on building form and geometry, and it is recommended that this efficiency measure be examined in more depth.

The administration building followed the same HVAC efficiency measures as those considered for the Bde HQ study, because the buildings are similar in form and function. These efficiency measures include energy recovery ventilators for climate zones 1A to 4B, and indirect evaporative cooling for 4C to 8A. The Low Energy Packages considered in this study are summarized below in Table 5.815.

Table 5.15 Description of Low Energy Packages for the COF

COF	Energy Efficiency Measures
Low Energy Package 1	• **Readiness bays only:** o Increased daylighting, daylighting and occupancy controls, and reduced lighting power density o Passive House insulation for all climate zones o Cool roof for climate zones 1A-3B o VAV fans, increased fan and HVAC efficiency o ERV in climate zones 1A, 2A, 3A, 3C-4B o IDEC in climate zones 4C-8A, o DOAS, ERV, and fan coils in climate zones 2B and 3B • **Administration Building follows Bde HQ measures**
Low Energy Package 2	• **Whole building – Low Energy Package 1 with the following applied to the administration building:** o Increased daylighting, daylighting and occupancy controls, and reduced lighting power density o VAV fans, increased fan and HVAC efficiency o ERV in climate zones 1A-4B o IDEC in climate zones 4C-8A
Low Energy Package 3	• **Whole Building:** o Low Energy Package 2 with a reduced air volume alternate construction applied to the readiness bays

Three low-energy packages were modeled and compared to baseline building models for all 15 climate zones. Low Energy Package 1 includes EEMs for the readiness bays alone, and was compared to a baseline building model consisting of just the readiness bays. The approach to isolate the readiness bays was chosen so that design options for these modules could be examined and optimized without the influence of the administration building. Low Energy Packages 2 and 3 include EEMs for the entire building, including both the administration building and the readiness bays. Table 5.16 compares the Low Energy Packages with the baseline building models.

The baseline building envelope features were modeled as steel frame wall construction, roof insulation entirely above deck, and door and fenestration types from ASHRAE 90.1-2007. Recommended building insulation levels follow the passive house standard and are noted in Table 4.1. With passive house insulation values, infiltration rates were assumed to fall from 0.4 cfm/ft^2 to 0.15 cfm/ft^2 throughout the building. Results showing EUI and percent savings are presented in Tables 5.16 and Table 5.17 below.

Table 5.16 COF Site EUI for Each Low Energy Package

Site Energy [kBtu/ft2]	Baseline	Baseline - Readiness Bays Only	Low Energy Package 1 - Readiness Bays Only	Low Energy Package 2 - Whole Building	Low Energy Package 3 - Whole Building w/Alternate Construction
1A Miami	58	47	27	29	23
2A Houston	62	53	26	30	24
2B Phoenix	60	48	32	35	29
3A Memphis	72	60	26	30	25
3B El Paso	59	48	31	34	29
3C San Francisco	54	43	20	25	21
4A Baltimore	78	70	25	29	25
4B Albuquerque	67	57	21	26	21
4C Seattle	68	57	21	26	23
5A Chicago	94	83	24	29	25
5B Colorado Springs	79	69	20	25	21
6A Burlington	103	92	24	29	25
6B Helena	94	83	22	27	23
7A Duluth	117	108	24	30	26
8A Fairbanks	163	152	32	37	33

Table 5.17 COF Site Energy Savings of Each Low Energy Package Compared to the Baseline EUI

Site Energy Savings Compared to Baseline [%]	Low Energy Package 1 - Readiness Bays Only	Low Energy Package 2 - Whole Building	Low Energy Package 3 - Whole Building w/Alternate Construction Applied to Repair Bays
1A Miami	43%	50%	60%
2A Houston	51%	52%	61%
2B Phoenix	34%	42%	52%
3A Memphis	57%	58%	65%
3B El Paso	36%	42%	50%
3C San Francisco	53%	54%	61%
4A Baltimore	65%	62%	68%
4B Albuquerque	63%	62%	69%
4C Seattle	63%	62%	67%
5A Chicago	71%	69%	73%
5B Colorado Springs	70%	68%	73%
6A Burlington	74%	72%	76%
6B Helena	73%	71%	75%
7A Duluth	77%	75%	78%
8A Fairbanks	79%	77%	80%

The readiness bays were modeled separately from the whole building design (which includes the readiness bays and the administration building) because the administration building is similar in form and function to the Bde HQ, and studies have already been conducted to optimize the Bde HQ design. Tables 5.16 and 5.17 presents results for three packages. The change in construction to the readiness bays as modeled in EnergyPlus is shown in Figure 4.1. The results show that significant energy savings can be achieved by any of the three packages that were modeled.

In order to compare the fossil fuel energy consumption of the recommended low-energy COF with the CBECS 2003 building data, a new composite CBECS-equivalent value was necessary because the administration building and readiness bays have different EUIs. A blended or mixed CBECS EUI value was calculated assuming a 50-50 mix of the two building types. The new source EUIs were calculated by applying conversion factors (3.35 for electricity and 1.05 for gas) to each portion of site electricity and site gas of the whole building baseline model. Table 5.18 shows the site CBECs EUI values for each building type plus the new hybrid site and source values, as well as the breakdown of electricity and gas of the baseline whole building for each climate zone.

Table 5.18 COF Site and Source Whole Building CBECS Values

CBECS Values for Whole Building EUI Calculation [kBtu/ft2]	CBECS 2003 Site Energy EUI Government Office	CBECS 2003 Site Energy EUI Other Public Assembly	CBECS 2003 Site New Whole Building	Whole Building Site Energy		New Source Values for
				% Electricity	% Gas	
1A Miami	73	40	56	78%	22%	160
2A Houston	75	40	57	63%	37%	143
2B Phoenix	73	38	56	71%	29%	149
3A Memphis	71	39	55	51%	49%	122
3B El Paso	66	37	52	57%	43%	121
3C San Francisco	65	36	50	46%	54%	106
4A Baltimore	79	43	61	38%	62%	118
4B Albuquerque	68	39	53	45%	55%	111
4C Seattle	72	40	56	36%	64%	105
5A Chicago	85	47	66	34%	66%	121
5B Colorado Springs	73	42	57	37%	63%	109
6A Burlington	94	52	73	29%	71%	125
6B Helena	83	47	65	32%	68%	116
7A Duluth	98	56	77	24%	76%	123
8A Fairbanks	133	74	104	21%	79%	159

The source EUI for the lowest energy package (package 3) per climate zone was compared to the new blended CBECS EUIs. This comparison is shown in Table 5.19. None of the 15 climate zones reaches or is within 5 percent of the CBECS targets.

Table 5.19 COF Source Energy Savings of Low Energy Package Whole Building Models Compared to the Blended CBECS 2003 EUIs

Source Energy Savings Compared to CBECS [kBtu/ft2]	CBECS 2003 Source Energy EUI ((Whole Building - Government Office + Other Public	65% Reduction - CBECS 2003 Target EUI [kBtu/ft2]	Low Energy Model EUI [kBtu/ft2]	% Difference of Low Energy from CBECS 2003
1A Miami	160	56	74	54%
2A Houston	143	50	69	52%
2B Phoenix	149	52	80	46%
3A Memphis	122	43	69	44%
3B El Paso	121	42	72	41%
3C San Francisco	106	37	54	49%
4A Baltimore	118	41	64	46%
4B Albuquerque	111	39	56	50%
4C Seattle	105	37	51	51%
5A Chicago	121	42	62	49%
5B Colorado Springs	109	38	52	52%
6A Burlington	125	44	58	54%
6B Helena	116	41	54	54%
7A Duluth	123	43	57	54%
8A Fairbanks	159	55	64	60%

5.1.4 Bde HQ

For the Bde HQ, the "Government Office" category was chosen from the 2003 CBECS data. Annual site energy EUI for each climate zone was determined from the CBECS data and compared to the baseline EUI for the designed building. This theoretical study was designed to give guidance on the direction and limitations for this building type. It showed that the internal loads are very important to address and will limit the building designer's ability to meet the EISA 2007 requirements. The source of the fuels to produce the energy is also very important and ultimately will need a mix of efficient generation.

It is noteworthy to mention that predicted energy savings strongly depend upon the climate and building orientation, and will vary for specific building design. However, implementation of developed energy budgets and sets of technologies included in the prescriptive path, and allowing the designer to streamline and reduce the cost of facility design and construction process, will ensure that newly constructed facilities comply with the intent of EPACT 2005 and EISA 2007 without jeopardizing the facilities' functional quality.

Addition of the passive house insulation package and airtightness specifications reduces the loads on the HVAC systems and reduces the impact for the type of system selected. Therefore, the HVAC system can be selected using multiple criteria with energy efficiency gains along with ease of O&M and installation preference.

With this study, the targets are based on source fuels, not on site energy consumption. This changes the benefits of the different HVAC and plant technologies selected. When looking just at site energy, GSHPs can look like an attractive selection until you take into account the regional source fuels. When the calculation is made back to the source fuels, many of the gains of using GSHPs are negated and in some locations they use more source fuel.

The simulated results for the Bde HQ energy efficient designs, including the envelope, infiltration, lighting, equipment, and HVAC EEMs, are shown in the tables below with the cumulative percentage savings for each Low Energy Package. In Table 5.20, Low Energy Packages P1–P3 are applied cumulatively to the baseline building until Package P4, which is considered the standard high-performance or low-energy building (P1-P4). Then, Low Energy Packages P5–P13 are applied to P4 to compare the different HVAC alternatives in the same way as the UEPH. The results are shown for both site and source, where the source results are necessary for EISA 2007 compliance. The site results are shown for direct comparison to CBECS data.

Table 5.20 Site Bde HQ Results

Site Energy Totals with Plug Loads [kBtu/ft2]	2003 CBECS Government Office	CBECS Budget (65% Reduction)	Baseline Building	Low Energy Package 1												
			B	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
1A Miami	73	26	61	58	48	45	37	36	35	44	44	44	38	44	35	33
2A Houston	75	26	55	52	44	39	33	33	32	40	40	40	35	40	33	30
2B Phoenix	73	26	67	64	54	45	37	37	27	38	38	37	35	37	33	31
3A Memphis	71	25	54	52	46	37	32	31	31	38	38	38	34	37	32	29
3B El Paso	66	23	47	45	38	34	30	30	26	35	35	34	32	32	31	29
3C San Francisco	65	23	38	36	30	28	27	27	26	32	33	32	32	32	30	26
4A Baltimore	79	28	54	52	47	33	30	29	29	36	35	36	32	34	31	28
4B Albuquerque	68	24	50	48	42	32	29	29	26	33	33	33	31	30	31	28
4C Seattle	72	25	42	41	37	28	26	26	26	32	32	32	32	30	30	26
5A Chicago	85	30	59	57	53	34	30	29	30	36	35	36	32	33	31	28
5B Colorado Springs	73	26	50	49	44	31	28	28	26	33	32	33	30	29	30	28
6A Burlington	94	33	60	58	55	33	30	27	29	36	33	36	31	32	30	27
6B Helena	83	29	56	55	51	31	29	27	27	34	32	34	30	29	30	27
7A Duluth	98	34	67	65	63	34	31	28	31	36	33	36	31	31	31	27
8A Fairbanks	133	47	88	87	85	43	37	31	36	41	35	41	34	33	32	29

B	Baseline Energy Budget
P1	Lighting Load and Electric Power Load Density Reduction from 1.67 W/ft^2 to 0.835 W/ft^2 applied to B
P2	Reduced Electric Power Load Density from 1.7 W/ft^2 to 1.2 W/ft^2 in the Office Areas average for all spaces
P3	Passive Haus Specification; Increased Insulation, Advanced Windows and Air Tightness, reduce OA pressurization air due to air tightness
P4	Efficient VAV Sys: Increase Chiller and Boiler Efficiencies and all variable high efficiency pumps and fans.
P5	Energy Recovery [ERV] and VAV with P4
P6	Indirect evaporative pre-cooling (IDEC) and VAV with P4
P7	Dedicated Outdoor Air System (DOAS) with P4
P8	DOAS and ERV with P4
P9	DOAS and IDEC with P4
P10	DOAS, IDEC and radiant heating and cooling with V4
P11	DOAS, ERV and free cooling chiller with P4
P12	DOAS, ERV and Ground Source Heat Pump (GSHP) with P4
P13	GSHP, ERV and VAV with P4

Table 5.21 Site Bde HQ Cumulative Results

Bde HQ	Cumulative % Savings (Site)												
	P1-B	P2-P1	P3-P2	P4-P3	P5-P4	P6-P4	P7-P4	P8-P4	P9-P4	P10-P4	P11-P4	P12-P4	P13-P4
1A Miami	-5%	-21%	-26%	-38%	-40%	-42%	-27%	-27%	-28%	-38%	-27%	-43%	-46%
2A Houston	-4%	-19%	-29%	-39%	-40%	-42%	-26%	-26%	-28%	-35%	-28%	-40%	-45%
2B Phoenix	-4%	-18%	-33%	-44%	-45%	-59%	-43%	-43%	-45%	-48%	-45%	-50%	-54%
3A Memphis	-4%	-16%	-33%	-41%	-43%	-44%	-29%	-30%	-30%	-37%	-33%	-41%	-47%
3B El Paso	-5%	-20%	-28%	-36%	-37%	-44%	-26%	-26%	-27%	-31%	-31%	-33%	-39%
3C San Francisco	-5%	-23%	-26%	-30%	-28%	-33%	-16%	-14%	-16%	-18%	-17%	-21%	-31%
4A Baltimore	-3%	-13%	-38%	-44%	-46%	-46%	-33%	-35%	-33%	-40%	-38%	-42%	-48%
4B Albuquerque	-4%	-16%	-35%	-41%	-41%	-48%	-33%	-34%	-33%	-38%	-39%	-38%	-44%
4C Seattle	-3%	-13%	-35%	-38%	-39%	-39%	-24%	-25%	-24%	-24%	-29%	-30%	-39%
5A Chicago	-2%	-10%	-42%	-48%	-51%	-49%	-38%	-41%	-38%	-45%	-44%	-48%	-52%
5B Colorado Springs	-3%	-13%	-39%	-44%	-45%	-48%	-34%	-37%	-35%	-40%	-42%	-40%	-45%
6A Burlington	-2%	-8%	-45%	-50%	-54%	-51%	-40%	-44%	-40%	-48%	-47%	-49%	-54%
6B Helena	-2%	-9%	-44%	-49%	-51%	-52%	-39%	-43%	-40%	-46%	-48%	-46%	-51%
7A Duluth	-2%	-6%	-48%	-54%	-58%	-54%	-45%	-51%	-45%	-53%	-53%	-54%	-59%
8A Fairbanks	-1%	-3%	-51%	-58%	-64%	-59%	-53%	-60%	-53%	-61%	-62%	-64%	-67%
Avg % Savings	-3%	-14%	-37%	-44%	-46%	-47%	-34%	-36%	-34%	-40%	-39%	-43%	-48%

As can be seen from Table 5.21, the initial Low Energy Packages show good improvement and the selected packages for closer evaluation were P5, P6, and P13. Even with all of these EEMs applied to the individual building, the targets could not be achieved.

Table 5.22 Source Energy Use Intensities for Each EEM Package with Cumulative Percent Savings

Bde HQ	Cumulative % Savings (Source)												
	P1-B	P2-P1	P3-P2	P4-P3	P5-P4	P6-P4	P7-P4	P8-P4	P9-P4	P10-P4	P11-P4	P12-P4	P13-P4
1A Miami	-5%	-21%	-26%	-38%	-40%	-42%	-27%	-27%	-28%	-38%	-27%	-43%	-46%
2A Houston	-5%	-21%	-28%	-38%	-39%	-41%	-25%	-25%	-26%	-34%	-26%	-39%	-44%
2B Phoenix	-4%	-19%	-32%	-44%	-44%	-59%	-43%	-42%	-45%	-48%	-45%	-50%	-54%
3A Memphis	-4%	-20%	-29%	-38%	-39%	-41%	-26%	-25%	-27%	-33%	-28%	-37%	-43%
3B El Paso	-5%	-23%	-27%	-34%	-35%	-43%	-25%	-24%	-26%	-30%	-30%	-32%	-37%
3C San Francisco	-6%	-25%	-25%	-29%	-27%	-32%	-14%	-12%	-15%	-16%	-16%	-19%	-30%
4A Baltimore	-4%	-20%	-31%	-37%	-38%	-40%	-25%	-25%	-25%	-31%	-28%	-33%	-40%
4B Albuquerque	-5%	-22%	-30%	-37%	-36%	-45%	-28%	-29%	-29%	-32%	-34%	-33%	-39%
4C Seattle	-5%	-21%	-29%	-32%	-32%	-33%	-17%	-16%	-17%	-17%	-21%	-21%	-31%
5A Chicago	-4%	-19%	-33%	-39%	-40%	-40%	-27%	-27%	-27%	-33%	-30%	-34%	-40%
5B Colorado Springs	-5%	-21%	-31%	-36%	-36%	-42%	-26%	-27%	-26%	-30%	-33%	-30%	-36%
6A Burlington	-4%	-18%	-34%	-39%	-40%	-40%	-26%	-28%	-27%	-32%	-31%	-32%	-39%
6B Helena	-4%	-19%	-34%	-38%	-38%	-42%	-27%	-29%	-28%	-32%	-35%	-31%	-38%
7A Duluth	-4%	-16%	-37%	-41%	-43%	-41%	-29%	-31%	-30%	-35%	-35%	-33%	-40%
8A Fairbanks	-3%	-13%	-40%	-45%	-48%	-46%	-37%	-41%	-37%	-43%	-44%	-39%	-45%
Avg % Savings	-5%	-20%	-31%	-38%	-38%	-42%	-27%	-27%	-28%	-32%	-31%	-34%	-40%

An interesting result is that when source fuels are calculated for the EEMs, the savings from GSHPs are not good as expected because many of the advantages are not there when the source fuels for electricity generation are considered.

The Bde HQ is a mixed-use building composed of an office building portion and a data center. CBECS only has EUI values for an office building. The data center represents approximately 17.5 percent of the total area. CBECS only has EUI values for an office building. If an EUI existed in CBECS for a data center, that value would be have been used for that percentage of the building. In this case, the decision was made to make the other 82.5% of the building comply and then use the same EEM's for the data center portion assuming that it would be the best possible path for that part of the building as well. As a result, data center specific EEMs were not developed since the office portion represents the dominant portion of the building's area.

For a more direct comparison and to account for the data center portion of the Bde HQ building, the simulation results were broken out into a data center in addition to the administrative office section. The data center section is labeled NOC/BOC/SCIF. As can be seen in Table 5.23, the NOC/BOC/SCIF EUIs are much higher than the EUIs from the "Government Office" CBECS category. This presents an added challenge to meeting EISA 2007 targets.

Table 5.23 Source Results for NOC/BOC/SCIF

Source Energy Totals with Plug Loads [kBtu/ft2]	2003 CBECS Government Office	CBECS Budget (65% Reduction)	Baseline Building	Low Energy Package 1												
			B	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
1A Miami	203	85	553	546	546	530	470	471	463	497	499	495	421	499	491	490
2A Houston	198	85	510	504	504	493	445	449	438	489	491	488	415	478	474	458
2B Phoenix	193	84	603	594	594	572	497	514	411	472	475	471	411	463	478	470
3A Memphis	183	76	483	477	477	468	429	435	421	488	490	488	413	463	466	437
3B El Paso	160	74	471	465	465	462	426	433	394	464	467	464	403	440	462	439
3C San Francisco	163	73	441	435	435	440	410	448	400	448	451	447	400	446	451	424
4A Baltimore	188	78	449	444	444	440	410	417	403	478	479	478	407	441	459	421
4B Albuquerque	170	72	482	475	475	475	434	449	388	452	454	451	400	422	455	427
4C Seattle	168	73	404	399	399	403	387	397	382	447	449	447	395	427	449	401
5A Chicago	185	77	437	431	431	428	403	410	398	477	477	477	405	432	456	412
5B Colorado Springs	170	72	449	443	443	445	415	430	380	449	450	448	398	413	452	414
6A Burlington	194	81	420	414	414	413	393	400	388	466	465	466	400	419	452	404
6B Helena	178	74	429	423	423	425	401	416	373	452	452	452	398	409	450	402
7A Duluth	193	77	409	404	404	403	387	393	384	462	461	461	398	410	451	396
8A Fairbanks	228	91	407	402	402	406	389	399	376	449	447	449	394	398	446	390

The DOE officials developing the federal rules for compliance with EISA 2007 have not yet developed a procedure for determining data center compliance with the fossil fuel reduction requirements since there is no comparable facility in the CBECS database. For purposes of this study, the administrative portion of the Bde HQ will be compared with the "Government Office" data in CBECS for EISA compliance.Table 5.24 and Table 5.25 show the site and source results of combining the administrative office section of the Bde HQ and the NOC/BOC/SCIF section. The results for the combined or hybrid building are not as good as the office building alone because now the high internal loads due to the NOC/BOC/SCIF or data center are accounted for.

Table 5.24 Site Results for Combined Office and NOC/BOC/SCIF

Site Energy Totals with Plug Loads [kBtu/ft2]	2003 CBECS Government Office	CBECS Budget (65% Reduction)	Baseline Building	Low Energy Package 1													
			B	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
1A Miami	73	26	83	81	76	72	61	60	59	71	71	70	56	71	56	56
2A Houston	75	26	75	73	69	64	55	56	54	66	66	66	54	65	54	52
2B Phoenix	73	26	91	89	83	75	63	64	47	63	63	62	53	61	54	52
3A Memphis	71	25	72	71	67	59	53	53	51	64	63	64	53	61	52	49
3B El Paso	66	23	66	64	60	57	51	52	45	59	59	59	51	56	52	49
3C San Francisco	65	23	55	53	49	49	46	50	44	56	56	56	50	55	50	46
4A Baltimore	79	28	70	69	66	54	49	50	48	61	60	60	52	57	51	47
4B Albuquerque	68	24	68	66	63	56	51	52	43	57	56	57	50	52	51	47
4C Seattle	72	25	56	55	52	46	44	45	43	55	55	55	49	52	49	44
5A Chicago	85	30	73	72	70	54	49	49	48	60	59	60	52	55	51	46
5B Colorado Springs	73	26	66	64	61	52	48	49	43	56	55	56	50	51	51	46
6A Burlington	94	33	73	72	70	51	47	47	46	59	57	59	50	53	50	45
6B Helena	83	29	69	68	66	50	47	47	43	57	55	57	50	50	50	45
7A Duluth	98	34	78	77	75	51	47	46	47	58	56	58	50	51	50	45
8A Fairbanks	133	47	97	96	95	59	52	48	51	60	55	60	52	51	50	45

Table 5.25 Source Results for Combined Office and NOC/BOC/SCIF

Source Energy Totals with Plug Loads [kBtu/ft2]	2003 CBECS Government Office	CBECS Budget (65% Reduction)	Baseline Building	Low Energy Package 1													
			B	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
1A Miami	203	85	278	271	252	239	202	200	195	237	236	234	185	237	188	185
2A Houston	198	85	246	239	223	211	183	184	177	219	219	217	180	216	179	172
2B Phoenix	193	84	302	294	274	249	208	212	157	208	209	205	177	204	180	173
3A Memphis	183	76	230	224	209	196	174	176	167	210	210	209	177	203	174	163
3B El Paso	160	74	214	208	193	188	169	172	149	196	197	195	170	187	173	164
3C San Francisco	163	73	179	174	159	164	152	165	147	184	186	184	167	184	166	152
4A Baltimore	188	78	210	205	192	177	161	164	156	198	198	197	171	187	169	156
4B Albuquerque	170	72	214	209	194	185	167	173	143	186	186	186	167	174	170	156
4C Seattle	168	73	173	168	156	151	144	150	141	181	181	181	161	172	164	146
5A Chicago	185	77	208	203	190	171	158	160	154	194	193	193	169	181	167	153
5B Colorado Springs	170	72	198	192	179	170	157	162	140	182	182	182	164	167	168	151
6A Burlington	194	81	198	193	181	162	151	153	148	187	186	187	165	172	165	149
6B Helena	178	74	195	190	178	161	151	156	139	182	181	182	164	165	166	148
7A Duluth	193	77	197	193	182	157	148	149	146	184	181	183	163	166	165	147
8A Fairbanks	228	91	215	211	201	163	152	151	147	179	174	179	162	160	166	149

After reviewing the data with the COS for the Bde HQ and cost estimators, P5, P6, and P13 were selected in addition to the baseline Low Energy Package 4 for full cost estimates. Following the same methodology for the other buildings, these selections were made based on balancing good energy savings results with possible issues with maintenance of newer technologies and a high first cost or lack of availability of systems to be supplied by three or more vendors. For simplification purposes, P4, P5, P6, and P13 are renamed Low Energy Package 1–4 in the tables that follow.

Table 5.26 Description of Low Energy Packages for the Brigade Headquarters (Bde HQ)

Bde HQ	Energy Efficiency Measures
Low Energy Package 1 (P1-P4)	• Passive house insulation, windows– applied to whole building. Reduced infiltration rates from 0.4 cfm/ft^2 to 0.15 cfm/ft^2 Reduced lighting power densities • High efficiency fixtures to reduce hot water demand includes: 0.5-gpm flow faucets, 1.5-gpm flow shower heads Advanced HVAC system: o Dedicated outside air system (DOAS) for ventilation, o Improved chiller and boiler efficiencies, o All variable high-efficiency pumps and fans, o Pressurization and make-up air, o Condenser heat recovery for DOAS o Separate ventilation for living area and laundry facilities
Low Energy Package 2 (P5)	• Same as Low Energy Package 1 plus adding total energy recovery (ERV) unit at 80% effectiveness
Low Energy Package 3 (P6)	• Same as Low Energy Package 2 with indirect evaporative cooling (IDEC)
Low Energy Package 4 (P13)	• Same as Low Energy Package 2 except replace high-efficiency chiller and boiler with a ground-source heat pump system

The source EUI for the lowest energy package (lowest of the four packages) per climate zone was compared to the 2003 CBECS EUIs for "Government Office" category. None of the 15 climate zones reaches or is within 5 percent of the CBECS targets. Buildings with high internal energy loads are dominate by internal loads when built or retrofitted to passive house requirements. These buildings use advanced "low-energy" systems to satisfy remaining heating and cooling needs. This same phenomenon happens to low internal load buildings as well. Therefore, we see that both the administrative office portion and the NOC/BOC/SCIF portion end up being internal load dominated. The remaining energy requirements will be dominated by electrical power needs for lighting, appliances and internal processes, and by domestic hot water needs. Table 5.27 summarizes the improvements made towards EISA 2007 goals and shows that without considering further internal load reduction, the EISA 2007 targets cannot be met for the full building.

Table 5.27 Source Energy Savings of Low Energy Package Models to 2003 CBECS Government Office Data

Source Energy Savings Compared to CBECS [kBtu/ft2]	CBECS 2003 Source Energy EUI (Government Office)	65% Reduction - CBECS 2003 Target EUI [kBtu/ft2]	Low Energy Model EUI [kBtu/ft2]	% Difference of Low Energy from CBECS 2003
1A Miami	203	71	185	9%
2A Houston	198	69	172	13%
2B Phoenix	193	68	157	19%
3A Memphis	183	64	163	11%
3B El Paso	160	56	149	7%
3C San Francisco	163	57	147	10%
4A Baltimore	188	66	156	17%
4B Albuquerque	170	59	143	16%
4C Seattle	168	59	141	16%
5A Chicago	185	65	153	17%
5B Colorado Springs	170	59	140	18%
6A Burlington	194	68	148	24%
6B Helena	178	62	139	22%
7A Duluth	193	68	146	24%
8A Fairbanks	228	80	147	35%

The results are much better when removing the NOC/BOC/SCIF section from the Bde HQ building. Table 5.28 shows that even though EISA 2007 targets cannot be met even when the administrative office results are broken out the results are much closer to the 65 percent target.

Table 5.28 Bde HQ Office Source Energy Savings of Low Energy Package Models to 2003 CBECS Government Office Data

Source Energy Savings Compared to CBECS [kBtu/ft2]	CBECS 2003 Source Energy EUI (Government Office)	65% Reduction - CBECS 2003 Target EUI [kBtu/ft2]	Low Energy Model EUI [kBtu/ft2]	% Difference of Low Energy from CBECS 2003
1A Miami	203	71	108	47%
2A Houston	198	69	99	50%
2B Phoenix	193	68	90	53%
3A Memphis	183	64	95	48%
3B El Paso	160	56	86	47%
3C San Francisco	163	57	84	49%
4A Baltimore	188	66	91	52%
4B Albuquerque	170	59	83	51%
4C Seattle	168	59	82	51%
5A Chicago	185	65	91	51%
5B Colorado Springs	170	59	82	52%
6A Burlington	194	68	88	55%
6B Helena	178	62	83	54%
7A Duluth	193	68	86	55%
8A Fairbanks	228	80	90	61%

With EISA 2007, the total energy usage (building plus plug loads) of the building is now considered unlike EPACT 2005 where the plug loads were considered unregulated. Including plug loads in the energy usage calculations creates a significant energy usage that may be outside the control of the designers and constructors of the building. This is illustrated in the comparison of the combined office and NOC/BOC/SCIF and just the office section, which shows that the plug loads are the most significant and uncontrolled percentage of the total energy consumed. The building envelope and HVAC systems efficiency gains will reach a theoretical minimum with the largest percentage remaining in the building due to the “mission” of the building: lighting, equipment, and domestic hot water usage. The next steps will to look at understanding these loads and make further energy efficiency increases and reductions in these areas.

5.1.5 DFAC

For the DFAC, the “Fast Food” category was chosen from 2003 CBECS data. Annual energy use intensity for each climate zone was determined from the CBECS data and compared to the energy baseline for the designed building.

The EEMs considered for the DFAC were analyzed individually, and EEMs with the highest energy savings were chosen to be included in a Low Energy Package for each climate zone. Reduced lighting power density, daylighting, and control strategies for both lighting and daylighting were recommended for each climate zone, along with passive house insulation for climate zones 4A through 8A. Efficiency upgrades in the HVAC system were also recommended, as well as a number of EEMs associated with the kitchen equipment. A set of best-in-class, high-efficiency kitchen equipment upgrades were paired with exhaust hood design and control options to reduce cooking, fan, and HVAC energy. Demand control

ventilation (DCV) on the make-up air units (MAUs) were also explored, as well as an all-electric kitchen equipment option. Each Low Energy Package is summarized below in Table 5.29.

Table 5.29 Summary of Low Energy Packages for the DFAC

DFAC	EEMs
Low Energy Package 1	• Increased daylighting, daylighting and occupancy controls, and reduced lighting power density • Passive House insulation for climate zones 4A-8A • VAV fans, increased fan and HVAC efficiency, reduced exhaust hood ventilation • High efficiency kitchen equipment
Low Energy Package 2	• Package 1 with demand control ventilation on make-up air units
Low Energy Package 3	• Package 1 with all-electric, high-efficiency kitchen equipment
Low Energy Package 4	• Package 3 with demand control ventilation on make-up air units

Results showing EUI and percent savings as compared to the standard baseline design are presented in Table 5.30 and Table 5.31 below.

Table 5.30 DFAC Site Energy Use Intensity for Each Low Energy Package

Site Energy [kBtu/ft2]	Baseline	Low Energy Package 1	Low Energy Package 2	Low Energy Package 3	Low Energy Package 4
1A Miami	354	272	268	227	221
2A Houston	373	297	287	256	243
2B Phoenix	363	287	277	248	235
3A Memphis	394	322	307	286	267
3B El Paso	369	297	284	259	243
3C San Francisco	359	297	281	257	239
4A Baltimore	428	356	336	323	297
4B Albuquerque	396	327	309	292	270
4C Seattle	402	337	316	304	278
5A Chicago	468	391	365	362	329
5B Colorado Springs	430	355	333	319	294
6A Burlington	509	425	393	399	359
6B Helena	481	399	369	369	335
7A Duluth	566	472	433	451	403
8A Fairbanks	730	606	547	593	525

Table 5.31 DFAC Site Energy Savings of Each Low Energy Package Compared to the Baseline EUI

Site Energy Savings Compared to Baseline [%]	Baseline [kBtu/ft2]	Low Energy Package 1	Low Energy Package 2	Low Energy Package 3	Low Energy Package 4
1A Miami	354	23%	24%	36%	38%
2A Houston	373	21%	23%	31%	35%
2B Phoenix	363	21%	24%	32%	35%
3A Memphis	394	18%	22%	27%	32%
3B El Paso	369	19%	23%	30%	34%
3C San Francisco	359	17%	22%	28%	33%
4A Baltimore	428	17%	22%	24%	31%
4B Albuquerque	396	17%	22%	26%	32%
4C Seattle	402	16%	21%	24%	31%
5A Chicago	468	17%	22%	23%	30%
5B Colorado Springs	430	18%	23%	26%	32%
6A Burlington	509	17%	23%	22%	29%
6B Helena	481	17%	23%	23%	30%
7A Duluth	566	17%	23%	20%	29%
8A Fairbanks	730	17%	25%	19%	28%

The highlighted packages in Table 5.31 were chosen as recommended energy packages per climate zone. For each case, the highest level of energy savings was associated with the packages including all-electric kitchen equipment and aggressive exhaust flow rate reduction strategies. Because plug and process loads make up a significant portion of the total building energy use, it is important to consider high-efficiency kitchen designs for these facilities. The all-electric kitchen equipment design also positions the facility to have the option to operate using 100 percent renewable energy.

Table 5.32 and Table 5.33 compare Low Energy Packages 2 and 4 site and source EUIs to the CBECS 2003 EUI targets for the “Fast Food” category. All of the low-energy model values fail to reach or get within 5 percent of the site and source CBECS targets. This illustrates the problem with selecting “Fast Food” as a building category to compare to a DFAC. Even though there was a significant decrease in energy consumption for the low-energy model compared to the baseline building, when comparing the low-energy model values to the fast food facility, the source values do not come close to meeting the targets.

Table 5.32 DFAC Site Energy Savings of Low Energy Package Models to CBECS 2003 Fast Food Data

Site Energy Savings Compared to CBECS [kBtu/ft2]	CBECS 2003 Site Energy EUI (Fast Food)	65% Reduction - CBECS 2003 Target EUI	Low Energy Model Package 2	All Electric Low-Energy Model Package 4	Package 2: %Difference from CBECS 2003	Package 4: %Difference from CBECS 2003
1A Miami	377	132	268	221	29%	41%
2A Houston	387	135	287	243	26%	37%
2B Phoenix	380	133	277	235	27%	38%
3A Memphis	396	139	307	267	22%	33%
3B El Paso	381	133	284	243	26%	36%
3C San Francisco	370	130	281	239	24%	35%
4A Baltimore	430	151	336	297	22%	31%
4B Albuquerque	400	140	309	270	23%	32%
4C Seattle	406	142	316	278	22%	32%
5A Chicago	463	162	365	329	21%	29%
5B Colorado Springs	426	149	333	294	22%	31%
6A Burlington	503	176	393	359	22%	29%
6B Helena	467	163	369	335	21%	28%
7A Duluth	540	189	433	403	20%	25%
8A Fairbanks	669	234	547	525	18%	22%

Table 5.33 DFAC Source Energy Savings of Low Energy Package Models to CBECS 2003 Fast Food Data

Source Energy Savings Compared to CBECS [kBtu/ft2]	CBECS 2003 Source Energy EUI (Fast Food)	65% Reduction - CBECS 2003 Target EUI	Package 2: Low-Energy Model	Package 4: All Electric Low-Energy Model	Package 2: %Difference from CBECS 2003	Package 4: %Difference from CBECS 2003
1A Miami	1244	435	768	722	38%	42%
2A Houston	1212	424	752	721	38%	40%
2B Phoenix	1187	416	737	713	38%	40%
3A Memphis	1175	411	746	728	37%	38%
3B El Paso	1032	361	717	699	31%	32%
3C San Francisco	1161	406	677	669	42%	42%
4A Baltimore	1067	373	764	753	28%	29%
4B Albuquerque	1221	427	724	716	41%	41%
4C Seattle	1159	406	711	710	39%	39%
5A Chicago	1142	400	782	780	32%	32%
5B Colorado Springs	1256	440	754	748	40%	40%
6A Burlington	1188	416	800	805	33%	32%
6B Helena	1311	459	778	782	41%	40%
7A Duluth	1242	435	832	848	33%	32%
8A Fairbanks	1348	472	939	974	30%	28%

5.2 Square Footage Impact

Increased insulation levels on the exterior of the buildings to meet passive house requirements resulted in a direct impact on square footage. Most of the building types across the range of climate zones were shown to have an increase in gross square footage.

The tables below list increases in scope based on insulation being added to the exterior of the buildings.

- Note that the thickness of brick and the airspace is at least 0.35 ft. If the buildings that use brick were to replace the brick with an Exterior Insulation Finishing System rather than add to buildings material there would be no increase in scope for climate zones 1A through 6B.
- The UEPH does not have an overall building plan. It is difficult to establish the perimeter of the entire building, and layout may affect the scope. Depending on the enhanced HVAC package selected, the mechanical closets may not be required. This could reduce the scope by 9 ft2 per closet. For 112 soldiers there would be 56 closets freeing up 504 ft^2—that is as long as the closet space is not used for light tube space.
- 3C is not an error. This is the number derived from the climate zone information.

Table 5.34 UEPH Insulation Square Footage Impact

UEPH The UEPH is a three story building with each floor the same size. The perimeter of the building is 550 LF per floor. Perimeter of the upper floor is 1100 LF.					
Climate Zone	Continuous base building insulation of XPS in inches thick	Passive house continuous insulation of XPS in inches thick	Additional wall thickness in inches	Additional wall thickness in feet	Total increase of scope of ground floor and upper floors
1A	1.5	1.5	0.0	0.00	0
2A	1.5	3.0	1.5	0.13	206
2B	1.5	3.0	1.5	0.13	206
3A	1.5	4.0	2.5	0.21	344
3B	1.5	4.0	2.5	0.21	344
3C	1.5	2.0	0.5	0.04	69
4A	1.5	5.0	3.5	0.29	481
4B	2.5	5.0	2.5	0.21	344
4C	2.5	4.0	1.5	0.13	206
5A	2.5	6.0	3.5	0.29	481
5B	2.5	6.0	3.5	0.29	481
6A	4.0	8.0	4.0	0.33	550
6B	4.0	8.0	4.0	0.33	550
7A	4.0	10.0	6.0	0.50	825
8A	4.0	12.0	8.0	0.67	1100

Table 5.35 TEMF Insulation Square Footage Impact

TEMF The TEMF is a two story building. The majority of the scope is on the first floor. The ground floor has a perimeter of 830 LF. The second floor only covers a portion of the first floor. The second floor has 260 LF of exterior perimeter.					
Climate Zone	Continuous base building insulation of XPS in inches thick	Passive house continuous insulation of XPS in inches thick	Additional wall thickness in inches	Additional wall thickness in feet	Total increase of scope of ground floor and upper floors
1A	1.5	1.5	0.0	0.00	0
2A	1.5	3.0	1.5	0.13	136
2B	1.5	3.0	1.5	0.13	136
3A	1.5	4.0	2.5	0.21	227
3B	1.5	4.0	2.5	0.21	227
3C	1.5	2.0	0.5	0.04	45
4A	1.5	5.0	3.5	0.29	318
4B	2.5	5.0	2.5	0.21	227
4C	2.5	4.0	1.5	0.13	136
5A	2.5	6.0	3.5	0.29	318
5B	2.5	6.0	3.5	0.29	318
6A	4.0	8.0	4.0	0.33	363
6B	4.0	8.0	4.0	0.33	363
7A	4.0	10.0	6.0	0.50	545
8A	4.0	12.0	8.0	0.67	727

Table 5.36 COF Administrative Building A Insulation Square Footage Impact

COF Admin Building A The COF Admin is a two-story building. Each floor is the same size, perimeter per floor is 388 LF.					
Climate Zone	Continuous base building insulation of XPS in inches thick	Passive house continuous insulation of XPS in inches thick	Additional wall thickness in inches	Additional wall thickness in feet	Total increase of scope of ground floor and upper floors
1A	1.5	1.5	0.0	0.00	0
2A	1.5	3.0	1.5	0.13	97
2B	1.5	3.0	1.5	0.13	97
3A	1.5	4.0	2.5	0.21	162
3B	1.5	4.0	2.5	0.21	162
3C	1.5	2.0	0.5	0.04	32
4A	1.5	5.0	3.5	0.29	226
4B	2.5	5.0	2.5	0.21	162
4C	2.5	4.0	1.5	0.13	97
5A	2.5	6.0	3.5	0.29	226
5B	2.5	6.0	3.5	0.29	226
6A	4.0	8.0	4.0	0.33	259
6B	4.0	8.0	4.0	0.33	259
7A	4.0	10.0	6.0	0.50	388
8A	4.0	12.0	8.0	0.67	517

Table 5.37 COF Readiness Building B Insulation Square Footage Impact

COF Readiness Building B The COF readiness building is a partial two-story building. The majority of the scope is on the first floor. The ground floor has a perimeter of 918 LF. The second floor is a mezzanine and does not affect the perimeter.					
Climate Zone	Continuous base building insulation of XPS in inches thick	Passive house continuous insulation of XPS in inches thick	Additional wall thickness in inches	Additional wall thickness in feet	Total increase of scope of ground floor and upper floors
1A	1.5	1.5	0.0	0.00	0
2A	1.5	3.0	1.5	0.13	115
2B	1.5	3.0	1.5	0.13	115
3A	1.5	4.0	2.5	0.21	191
3B	1.5	4.0	2.5	0.21	191
3C	1.5	2.0	0.5	0.04	38
4A	1.5	5.0	3.5	0.29	268
4B	2.5	5.0	2.5	0.21	191
4C	2.5	4.0	1.5	0.13	115
5A	2.5	6.0	3.5	0.29	268
5B	2.5	6.0	3.5	0.29	268
6A	4.0	8.0	4.0	0.33	306
6B	4.0	8.0	4.0	0.33	306
7A	4.0	10.0	6.0	0.50	459
8A	4.0	12.0	8.0	0.67	612

Table 5.38 COF Readiness Building C Insulation Square Footage Impact

COF Readiness Building C The COF readiness building is a partial two-story building. The majority of the scope is on the first floor. The ground floor has a perimeter of 904 LF. The second floor is a mezzanine and does not affect the perimeter.					
Climate Zone	Continuous base building insulation of XPS in inches thick	Passive house continuous insulation of XPS in inches thick	Additional wall thickness in inches	Additional wall thickness in feet	Total increase of scope of ground floor and upper floors
1A	1.5	1.5	0.0	0.00	0
2A	1.5	3.0	1.5	0.13	113
2B	1.5	3.0	1.5	0.13	113
3A	1.5	4.0	2.5	0.21	188
3B	1.5	4.0	2.5	0.21	188
3C	1.5	2.0	0.5	0.04	38
4A	1.5	5.0	3.5	0.29	264
4B	2.5	5.0	2.5	0.21	188
4C	2.5	4.0	1.5	0.13	113
5A	2.5	6.0	3.5	0.29	264
5B	2.5	6.0	3.5	0.29	264
6A	4.0	8.0	4.0	0.33	301
6B	4.0	8.0	4.0	0.33	301
7A	4.0	10.0	6.0	0.50	452
8A	4.0	12.0	8.0	0.67	603

Table 5.39 Bde HQ Insulation Square Footage Impact

Bde HQ The BDE is a two story building. Each floor is the same size, perimeter per floor is 570 LF.					
Climate Zone	Continuous base building insulation of XPS in inches thick	Passive house continuous insulation of XPS in inches thick	Additional wall thickness in inches	Additional wall thickness in feet	Total increase of scope of ground floor and upper floors
1A	1.5	1.5	0.0	0.00	0
2A	1.5	3.0	1.5	0.13	143
2B	1.5	3.0	1.5	0.13	143
3A	1.5	4.0	2.5	0.21	238
3B	1.5	4.0	2.5	0.21	238
3C	1.5	2.0	0.5	0.04	48
4A	1.5	5.0	3.5	0.29	333
4B	2.5	5.0	2.5	0.21	238
4C	2.5	4.0	1.5	0.13	143
5A	2.5	6.0	3.5	0.29	333
5B	2.5	6.0	3.5	0.29	333
6A	4.0	8.0	4.0	0.33	380
6B	4.0	8.0	4.0	0.33	380
7A	4.0	10.0	6.0	0.50	570
8A	4.0	12.0	8.0	0.67	760

Table 5.40 DFAC Insulation Square Footage Impact

DFAC The DFAC is a single story building. The perimeter of the building is 550 LF per floor.					
Climate Zone	Continuous base building insulation of XPS in inches thick	Passive house continuous insulation of XPS in inches thick	Additional wall thickness in inches	Additional wall thickness in feet	Total increase of scope of ground floor and upper floors
1A	1.5	1.5	0.0	0.00	0
2A	1.5	3.0	1.5	0.13	118
2B	1.5	3.0	1.5	0.13	118
3A	1.5	4.0	2.5	0.21	197
3B	1.5	4.0	2.5	0.21	197
3C	1.5	2.0	0.5	0.04	39
4A	1.5	5.0	3.5	0.29	276
4B	2.5	5.0	2.5	0.21	197
4C	2.5	4.0	1.5	0.13	118
5A	2.5	6.0	3.5	0.29	276
5B	2.5	6.0	3.5	0.29	276
6A	4.0	8.0	4.0	0.33	316
6B	4.0	8.0	4.0	0.33	316
7A	4.0	10.0	6.0	0.50	474
8A	4.0	12.0	8.0	0.67	631

5.3 Water Savings

The UEPH peak washing machine use per floor is assumed to be four loads per hour or 80 gal/hr of 120 ºF hot water, which is approximately 53 gal/hr from a 140 ºF storage tank. Hot water usage from shower is at 105 ºF with from a 140 ºF storage tank and assumes 30 to 35 gal/person/day for hot water use, with a subset of 20 gal/person/day for shower with a 2.0-gpm shower head and 5 gal of miscellaneous use in the kitchen and bathroom. The efficient building assumes a 1.5-gpm shower head that reduces the shower hot water usage.

Flush fixtures include water closets and urinals. Three different design options were proposed. The first used low-flow water closets and non-water urinals; the second called for composting toilets and non-water urinals; the third called for dual-flush toilets and non-water urinals. Figure 5.4 summarizes the comparison between the baseline design and the three proposed water-savings options for the UEPH.

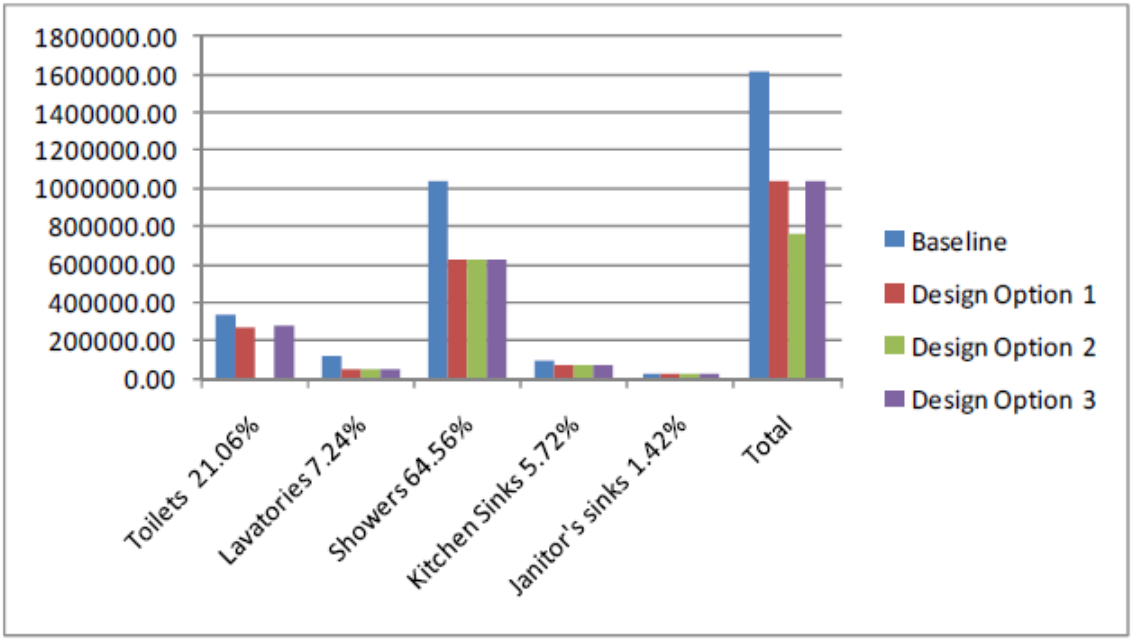

Figure 5.4 UEPH Water Consumption (Gallons)

The TEMF includes specialty equipment that contributes to the overall water consumption that was not accounted for in the water conservation analysis. For the COF, the toilets are the largest consumers of water. Water usage of toilets is dramatically reduced by using water-conserving fixtures. Like most office buildings, a Bde HQ consumes a minimal amount of domestic hot water. Hot water consumption was assumed to be 1.0 gal/person/day. The usage profile was taken from a typical office building schedule. The hot water supply temperature was set at 140 ºF with a mixed water temperature at the tap of 105ºF. The domestic water heating system in the baseline building models uses an 80 percent efficient boiler and the energy efficient models use a 95 percent efficient boiler. Figure 5.5 through Figure 5.7 summarize the comparison between the baseline design and the three proposed water savings options for the TEMF, COF, and Bde HQ.

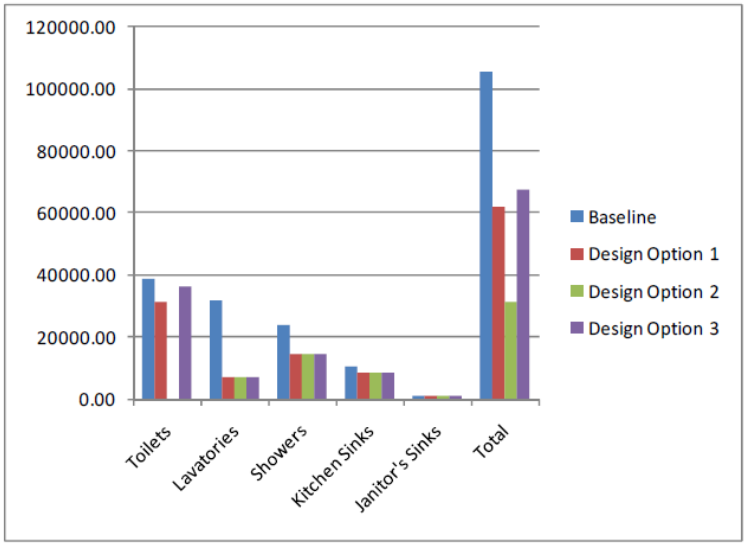

Figure 5.5 TEMF Water Consumption (Gallons)

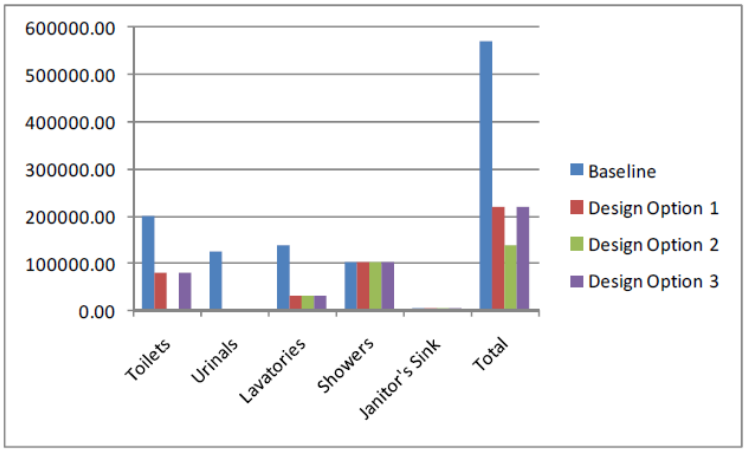

Figure 5.6 COF Water Consumption (Gallons)

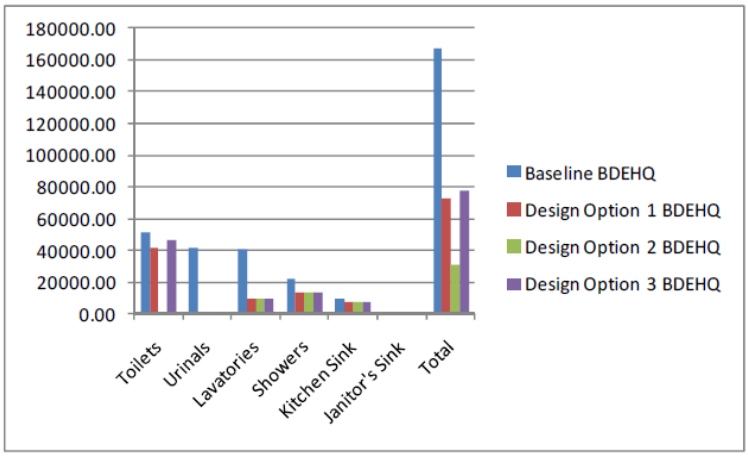

Figure 5.7 Bde HQ Water Consumption (Gallons)

Although kitchen equipment in the DFAC consumes the majority of the water, only flush and flow fixtures were addressed in the water-reduction calculations. It is assumed that with the high-efficiency equipment in the Low Energy Packages there will be water savings in addition to the savings that were calculated. Figure 5.8 below summarizes a comparison of the baseline design and three design options.

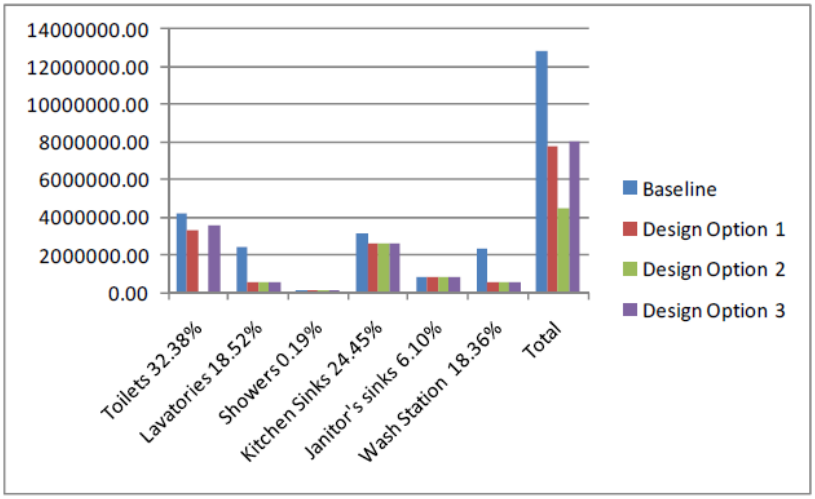

Figure 5.8 DFAC Water Consumption (Gallons)

The goals of 30 percent water reduction and 50 percent wastewater reduction were expected to be achieved based on the results of the study. Annual volume water savings for all five buildings are summarized in Table 5.41.

Table 5.41 Summary of Annual Water Consumption Volumes for UEPH, TEMF, COF, Bde HQ, and DFAC

UEPH	Gallons	Savings
Baseline		
Flush Fixtures	339,888	
Flow Fixtures	1,274,222	
Total	1,614,110	
Flush Fixtures		
Option 1	271,910	20.0%
Option 2	-	100.0%
Option 3	276,013	18.8%
Flow Fixtures	765,923	39.9%
Total Water Savings		
Option 1	1,037,834	35.7%
Option 2	765,923	52.5%
Option 3	1,041,936	35.4%

TEMF	Gallons	Savings
Baseline		
Flush Fixtures	72,044	
Flow Fixtures	72,285	
Total	144,329	
Flush Fixtures		
Option 1	31,027	56.9%
Option 2	-	100.0%
Option 3	36,214	49.7%
Flow Fixtures	36,448	49.6%
Total Water Savings		
Option 1	67,475	53.2%
Option 2	36,448	74.7%
Option 3	72,662	49.7%

COF	Gallons	Savings
Baseline		
Flush Fixtures	324,380	
Flow Fixtures	245,540	
Total	569,920	
Flush Fixtures		
Option 1	159,744	50.8%
Option 2	-	100.0%
Option 3	178,830	44.9%
Flow Fixtures	98,003	60.1%
Total Water Savings		
Option 1	257,747	54.8%
Option 2	98,003	82.8%
Option 3	276,833	51.4%

Bde HQ	Gallons	Savings
Baseline		
Flush Fixtures	93,800	
Flow Fixtures	72,406	
Total	166,206	
Flush Fixtures		
Option 1	41,440	55.8%
Option 2	-	100.0%
Option 3	46,550	50.4%
Flow Fixtures	31,259	56.8%
Total Water Savings		
Option 1	72,699	56.3%
Option 2	31,259	81.2%
Option 3	77,809	53.2%

DFAC	Gallons	Savings
Baseline		
Flush Fixtures	5,890,662	
Flow Fixtures	8,692,099	
Total	14,582,761	
Flush Fixtures		
Option 1	3,330,201	43.5%
Option 2	-	100.0%
Option 3	3,583,497	39.2%
Flow Fixtures	4,436,709	49.0%
Total Water Savings		
Option 1	7,766,910	46.7%
Option 2	4,436,709	69.6%
Option 3	8,020,206	45.0%

5.4 Summary of Cost Estimates

The estimates use a "unit cost for bill of quantities" approach and assigned a unit cost to each of the facility components. The estimates were made based on the following work breakdown structure:

- Substructure
- Interior Construction
- HVAC
- Equipment
- Superstructure
- Interior Finishes
- Fire Protection
- Special Construction

- Exterior Closure
- Conveying Systems
- Electric Power and Lighting
- Roofing
- Plumbing
- Electrical Systems

Quantities were available from the Adapt Build-level construction drawings. As a result, the construction components in question could be identified.

The estimates were tailored to their respective locations. Taxes, markups, and libraries were selected as appropriate. Ideally, this would be done for all the facilities in all the climate zones for multiple HVAC systems; however, doing all the estimates that way was not practical. The estimates were revised to reflect a non-specific location. Taxes, markups, and labor rates were removed or replaced with national averages. To adjust for location, a direct cost markup similar to an area cost factor was included for labor, equipment, material, and subcontractor bid costs. As a result, the estimates were reasonably close to the original standard design while allowing it to be quickly adjusted for use in other locations by applying an Area Cost Factor (ACF) in line with the Army Programming Accounting Execution System (PAX) newsletter system.

Each of the facilities was estimated using an ACF of 1.0. At this stage the estimated project is at a neutral location, based on construction design drawings incorporating the most recent standards criteria and requirement solutions, with enough detail to identify construction component quantities.

Project estimates were compared to estimates developed using a programmatic method. The Army Detailed Cost Estimating System (MII) file estimates adjusted for location by adjustments to the direct costs were returning results similar to programmed projects using the PAX newsletter system.

The nonspecific subcontractor markup would not be as accurate as a specific subcontractor markup, but the benefit of identifying individual subcontractors would be of no significant benefit to the overall subcontractor cost. Using the latest PAX area cost factor to mark up direct cost, mark up of material and labor is an acceptable method of estimating construction at different locations. Design cost was 4 percent in all cases.

The Energy Analysis package identified EEMs that required modifications to the construction components. In addition to the EEMs, sustainable practices are included. As a rule, the construction method or design was not altered by the estimator. Only in the case of the foundation of the UEPH did the COS identify a construction change from the standard. The COF also had, in addition to the true standard scenario, a second study completed where the volume of the readiness module was reduced by removing the mezzanine and replacing it with an increased single-level building footprint.

The building envelope is one of the significant cost impacts due to the quantity of additional material. The change of construction in the foundation of the UEPH is a significant factor in the UEPH results. Items that are not due to the EEM but are in the package because of sustainability make it difficult to draw the line in the cost comparisons based on what features make the buildings more energy efficient.

The insulation of the buildings required adjustments based on a comparison of the existing constructed value to the amount of insulation needed to meet passive house standards. In some cases, this is straightforward. For example, the current design indicates 6 in., while in a given climate zone the additional insulation might be 8 in. A recommendation would be to allow for an increase to the gross square footage of a building in order to allow for increased envelope insulation for improved energy conservation.

The insulating value requirement of the building's envelope is the reason for the cost of replacing double-pane with triple-pane windows. The lighting plan and the daylighting requirements share the cost of additional window area. As a result, attributing the cost of this item is difficult to separate out between the insulation, lighting reduction, and additional sustainability practices EEMs. The estimate results report this as a single item cost titled, "Increased Window Efficiency."

The EEM package identified the changes to the lighting plan in general terms. The estimator contacted vendors in developing the new lighting plan estimate.

At most, four packages per facility type were selected from the many available mechanical systems. The mechanical systems with the most likely benefit were selected to be estimated. Some equipment was resized based on the reduced loads. This information was calculated and provided in addition to the EEM package. A variety and combination of elements and systems were required. Items such as equipment sizes, higher efficiency components, energy recovery, indirect evaporative cooling, transpired solar collectors, radiant flooring, radiant ceiling, and ground source heat pump are items in the packages. The mechanical estimator contacted vendors for major component costs.

The construction drawings provided enough information to quantify plumbing items and the estimate provided enough detail to identify the plumbing fixtures and replacement with the higher efficiency fixtures. The delta between the fixtures was relatively easy to document and attribute to a sustainable cost.

Some items were not included in the original standard design and since they did not replace another system, their costs were added to the total baseline costs of the project. These added items include rainwater harvesting, enhanced commissioning, and measurement and verification.

Rainwater harvesting is not only new to the project, it is also under discussion as to whether it should be included in the building or supporting facilities costs in the programming document (DD1391). The system captures water from the roof, channels it to a tank, filters it, pumps it out, and distributes it into the building as a secondary plumbing system. In the estimates, the rainwater harvesting system is included in the building cost.

Enhanced commissioning is a new initial contract cost to the standard and continues 10 months beyond the buildings completion date. The enhanced commissioning cost was established by providing resources to each of the tasks identified in LEED 2009 for new construction.

M&V is a new initial contract cost to the standard and continues beyond the buildings completion date. The M&V estimate includes metering equipment, collection of the data on a regular basis throughout the year, evaluating the data, and revising the energy model using the collected data.

The cost estimates for the five building types are summarized in Tables 5.42 through 5.46 below.

Table 5.42 UEPH Cost Estimate Summary

UEPH	Climate Zone	Baseline Building Contract Cost	Low E Package 1				Low E Package 2			
			Revised Cost	Cost Increase	% Increase	Energy Savings	Revised Cost	Cost Increase	% Increase	Energy Savings
Fort Shafter	1	$18,209,585	$19,902,998	$1,693,413	9.30%	37%	$19,957,568	$1,747,983	9.60%	49%
Fort Hood	2A	$7,585,822	$8,393,139	$807,317	10.64%	37%	$8,416,563	$830,741	10.95%	50%
Fort Bliss	3B	$8,986,431	$9,889,334	$902,903	10.05%	38%	$9,917,134	$930,703	10.36%	51%
Fort Campbell	4A	$8,597,669	$9,514,315	$916,646	10.66%	37%	$9,540,056	$942,387	10.96%	56%
Fort Lewis	4C	$10,242,658	$11,262,589	$1,019,931	9.96%	37%	$11,293,220	$1,050,562	10.26%	53%
Fort Wainwright	8	$18,080,550	$20,982,214	$2,901,664	16.05%	36%	$21,103,771	$3,023,221	16.72%	64%
	Climate Zone		Low E Package 3				Low E Package 4			
			Revised Cost	Cost Increase	% Increase	Energy Savings	Revised Cost	Cost Increase	% Increase	Energy Savings
Fort Shafter	1		$19,062,512	$852,927	4.68%	50%	$22,100,105	$3,890,520	21.37%	48%
Fort Hood	2A		$8,031,414	$445,592	5.87%	52%	$9,333,535	$1,747,713	23.04%	49%
Fort Bliss	3B		$9,382,468	$396,037	4.41%	53%	$11,009,837	$2,023,406	22.52%	48%
Fort Campbell	4A		$9,044,995	$447,326	5.20%	57%	$10,551,818	$1,954,149	22.73%	52%
Fort Lewis	4C		$10,704,097	$461,439	4.51%	55%	$12,497,217	$2,254,559	22.01%	51%
Fort Wainwright	8		$20,087,958	$2,007,408	11.10%	65%	$23,159,854	$5,079,304	28.09%	66%

Table 5.43TEMF Cost Estimate Summary

TEMF	Climate Zone	Baseline Building Contract Cost	Low E Package 1				Low E Package 2			
			Revised Cost	Cost Increase	% Increase	Energy Savings	Revised Cost	Cost Increase	% Increase	Energy Savings
Fort Bliss	3B	$7,529,077	$8,027,764	$498,687	6.62%	46%	$8,120,106	$591,029	7.85%	48%
Fort Campbell	4A	$6,969,882	$7,470,428	$500,546	7.18%	55%	$7,555,930	$586,048	8.41%	59%
Fort Lewis	4C	$8,302,808	$8,888,652	$585,844	7.06%	55%	$8,990,399	$687,591	8.28%	58%
Fort Carson	5B	$7,610,110	$8,210,887	$600,777	7.89%	56%	$8,304,084	$693,974	9.12%	62%
			Low E Package 3				Low E Package 4			
			Revised Cost	Cost Increase	% Increase	Energy Savings	Revised Cost	Cost Increase	% Increase	Energy Savings
Fort Bliss	3B		$8,119,395	$590,318	7.84%	46%	$8,211,736	$682,659	9.07%	48%
Fort Campbell	4A		$7,555,271	$585,389	8.40%	55%	$7,640,773	$670,891	9.63%	58%
Fort Lewis	4C		$8,989,615	$686,807	8.27%	55%	$9,091,362	$788,554	9.50%	57%
Fort Carson	5B		$8,303,366	$693,256	9.11%	56%	$8,396,562	$786,452	10.33%	61%

Table 5.44 Bde HQ Cost Estimate Summary

Bde HQ	Climate Zone	Baseline Building Contract Cost	Low E Package 1				Low E Package 2			
			Revised Cost	Cost Increase	% Increase	Energy Savings	Revised Cost	Cost Increase	% Increase	Energy Savings
Fort Campbell	4A	$8,535,728	$8,965,589	$429,861	5.0%	44%	$9,410,513	$874,785	10.2%	46%
Fort Lewis	4C	$10,122,092	$10,609,301	$487,209	4.8%	38%	$11,138,760	$1,016,668	10.0%	39%
Fort Drum	6A	$9,894,934	$10,575,485	$680,551	6.9%	50%	$11,087,147	$1,192,213	12.0%	54%
Fort Wainwright	8	$18,362,721	$20,142,153	$1,779,432	9.7%	58%	$21,094,290	$2,731,569	14.9%	64%
			Low E Package 3				Low E Package 4			
			Revised Cost	Cost Increase	% Increase	Energy Savings	Revised Cost	Cost Increase	% Increase	Energy Savings
Fort Campbell	4A		$9,646,657	$1,110,929	13.0%	46%	$9,781,123	$1,245,395	14.6%	48%
Fort Lewis	4C		$11,419,771	$1,297,679	12.8%	39%	$11,592,301	$1,470,209	14.5%	39%
Fort Drum	6A		$11,358,713	$1,463,779	14.8%	51%	$11,516,438	$1,621,504	16.4%	54%
Fort Wainwright	8		$21,599,637	$3,236,916	17.6%	59%	$21,868,796	$3,506,075	19.1%	67%

Table 5.45 COF Administrative Building Cost Estimate Summary

COF			Low E Package 1				Low E Package 3			
Admin A + Readiness B + Readiness C	Climate Zone	Baseline Building Contract Cost	Revised Cost	Cost Increase	% Increase	Energy Savings	Revised Cost	Cost Increase	% Increase	Energy Savings
Fort Shafter	1	$30,909,084	$33,334,464	$2,425,380	7.8%	43%	$33,295,314	$2,386,230	7.7%	60%
Fort Campbell	4A	$14,631,260	NA	NA	NA	65%	$16,254,649	$1,623,389	11.1%	68%
Fort Lewis	4C	$17,309,882	NA	NA	NA	63%	$19,335,410	$2,025,528	11.7%	67%
Fort Carson	5B	$15,923,121	$18,159,680	$2,236,559	14.0%	70%	$18,198,947	$2,275,826	14.3%	73%
Fort Drum	6A	$16,995,154	NA	NA	NA	74%	$19,688,509	$2,693,355	15.8%	76%
Fort Richardson	7A	$26,632,969	$31,493,361	$4,860,392	18.2%	77%	$31,886,041	$5,253,072	19.7%	78%

Table 5.46 DFAC Cost Estimate Summary

DFAC	Climate Zone	Baseline Building Contract Cost	Low E Package 2				Low E Package 4			
			Revised Cost	Cost Increase	% Increase	Energy Savings	Revised Cost	Cost Increase	% Increase	Energy Savings
Fort Wainwright	8	$9,749,134	$10,179,126	$429,992	4.4%	25%	$9,944,342	$195,208	2.0%	28%

5.5 Life-Cycle Cost Analysis

The installations that were selected for this analysis were based on the locations where the majority of projects were located in the FY13 program list. Energy and water use were taken directly from the energy models and investment costs were taken from cost estimates. Energy savings were based on the low-energy model compared to the baseline building model.

Life-cycle cost analysis was performed for UEPH (Fort Bliss and Fort Campbell) and TEMF (Fort Carson and Fort Campbell). The analysis met the requirements of 10 CFR 436 by using the BLCC program developed by NIST.

Assumptions for the analysis included the following:

- A 40-year life cycle was used.
- All capital investment amounts and energy savings were based on the cost estimates and energy modeling results from this study.
- Current Dollar Analysis with a 4 percent nominal discount rate (provided by the BLCC software) for operations, maintenance, and repair (OM&R) and utility costs. Initial Capital Investment was held constant with the provided cost estimate.
- The BLCC program used the DOE escalation factor for utility costs.
- For water consumption, we assumed constant usage throughout seasons. Water usage split 50/50 between summer and winter.
- Residual factor: 0 percent
- Cost adjustment factor: 0.97 percent
- Annual rate of increase annual OM&R: 4 percent
- We assumed an even distribution of total project cost between a 2-year period (April 2011 – April 2013) for cost phasing of initial costs.
- Routine Annually Recurring OM&R Costs: Assumed $100,000 per year. One percent of the Total Project Cost did not provide a constant when comparing energy savings versus total project cost.
- We assumed that the building systems maintenance is generally the same for all packages on a level-of-effort basis. This was one of the decision factors in selecting Low Energy Packages.
- For the UEPH, non-recurring facility maintenance was not taken into account in the analysis.
- For the TEMF, windows (skylight) were the only system identified to not have a useful life for the entire analysis period. Cost equals material plus installation ($62,120.02).

An assumption to keep O&M constant for the baseline building and Low Energy Packages was made for two reasons. First, good historical operations and maintenance data were not available for any of the buildings studied. Second, part of the technology selection process was to pick the energy systems that would not severely affect the current O&M staff at the installations. Utility rate information for specific installations that was used in the LCCA was provided by the Huntsville COS and is listed in Table 5.47. This cost is lower than would be the case in other parts of the country.

Table 5.47 Utility Rate Information for Army Installations

		Rate ($)/Unit			Annual Demand Charge (%)
Climate Zone	Installation	Electricity (Mbtu)	Gas (Mbtu)	Water (gal)	Electricity
3B	Fort Bliss	14.43	6.38	0.006	0.52
4A	Fort Campbell	19.66	6.98	0.0023	0.5
4C	Fort Lewis	14.65	8.14	0.0021	0.1
5B	Fort Carson	14.36	6.26	0.003	0

The LCCA results show the dependency on building type and location. Not all buildings will have the same payback period because they have different EUIs and vary in how much electricity versus gas is consumed. Building locations will also factor into the LCCA because energy savings differ for each climate zone. In addition, utility rates play a big part because some locations have a much lower utility rate based on how the energy is generated in each particular region. The LCCA results (Table 5.48 through Table 5.51) show that three of the four buildings that were analyzed had various Low Energy Package options with net present values (NPVs) that were less than the baseline building alternative NPV. The TEMF at Fort Carson (climate zone 5B) was the only building where the NPV was not less than the baseline alternative. One reason for this is that the cost of the passive house insulation ($249,350) was about a third of the overall cost increase for the four low-energy alternatives. Design teams are encouraged to analyze each building in each climate zone to fine-tune the EEMs and find the right balance between energy savings and cost effectiveness.

Table 5.48 Fort Bliss Net Present Value of Life-Cycle Costs – UEPH

UEPH - Net Present Value of Life Cycle Costs					
Fort Bliss (El Paso)	**Baseline**	**Low Energy Package 1**	**Low Energy Package 2**	**Low Energy Package 3**	**Low Energy Package 4**
Investment cost	$ 9,117,135	$ 9,746,942	$ 9,774,742	$ 9,240,076	$ 10,867,445
Operations and Maintenance	$ 3,800,000	$ 3,800,000	$ 3,800,000	$ 3,800,000	$ 3,800,000
Utility costs	$ 1,578,166	$ 912,336	$ 886,539	$ 860,763	$ 943,413
Replacement costs	$ -	$ -	$ -	$ -	$ -
Total NPV LCC:	$ 14,495,301	$ 14,459,278	$ 14,461,281	$ 13,900,839	$ 15,610,858
LCC Savings:	$ -	$ 36,023	$ 34,020	$ 594,462	$ (1,115,557)
Simple Payback Period (Years)		18.72	18.82	3.39	54.58

Table 5.49 Fort Campbell Net Present Value of Life-Cycle Costs – UEPH

UEPH - Net Present Value of Life Cycle Costs					
Fort Campbell (Baltimore)	**Baseline**	**Low Energy Package 1**	**Low Energy Package 2**	**Low Energy Package 3**	**Low Energy Package 4**
Investment cost	$ 8,718,690	$ 9,361,512	$ 9,387,253	$ 8,852,191	$ 10,399,015
Operations and Maintenance	$ 3,800,000	$ 3,800,000	$ 3,800,000	$ 3,800,000	$ 3,800,000
Utility costs	$ 1,952,823	$ 1,075,392	$ 1,015,216	$ 1,003,991	$ 1,139,731
Replacement costs	$ -	$ -	$ -	$ -	$ -
Total NPV LCC:	$ 14,471,513	$ 14,236,904	$ 14,202,469	$ 13,656,182	$ 15,338,746
LCC Savings:	$ -	$ 234,609	$ 269,044	$ 815,331	$ (867,233)
Simple Payback Period (Years)		14.50	14.11	2.78	40.90

Table 5.50 Fort Carson Net Present Value of Life-Cycle Costs – TEMF

TEMF - Net Present Value of Life Cycle Costs					
Fort Carson (Colorado Springs)	**Baseline**	**Low Energy Package 1**	**Low Energy Package 2**	**Low Energy Package 3**	**Low Energy Package 4**
Investment cost	$ 7,743,244	$ 8,101,952	$ 8,195,149	$ 8,194,431	$ 8,287,627
Operations and Maintenance	$ 3,799,309	$ 3,799,309	$ 3,799,309	$ 3,799,309	$ 3,799,309
Utility costs	$ 451,916	$ 220,010	$ 199,072	$ 213,293	$ 196,999
Replacement costs	$ 62,106	$ 62,106	$ 62,106	$ 62,106	$ 62,106
Total NPV LCC:	$ 12,056,575	$ 12,183,377	$ 12,255,636	$ 12,269,139	$ 12,346,041
LCC Savings:	$ -	$ (126,802)	$ (199,061)	$ (212,564)	$ (289,466)
Simple Payback Period (Years)	-	30.61	35.37	37.42	42.27

Table 5.51 Fort Campbell Net Present Value of Life-Cycle Costs – TEMF

TEMF - Net Present Value of Life Cycle Costs					
Fort Campbell (Baltimore)	**Baseline**	**Low Energy Package 1**	**Low Energy Package 2**	**Low Energy Package 3**	**Low Energy Package 4**
Investment cost	$ 7,073,200	$ 7,353,554	$ 7,439,056	$ 7,438,397	$ 7,523,899
Operations and Maintenance	$ 3,800,000	$ 3,800,000	$ 3,800,000	$ 3,800,000	$ 3,800,000
Utility costs	$ 812,503	$ 442,204	$ 419,401	$ 419,595	$ 406,448
Replacement costs	$ 62,120	$ 62,120	$ 62,120	$ 62,120	$ 62,120
Total NPV LCC:	$ 11,747,823	$ 11,657,878	$ 11,720,577	$ 11,720,112	$ 11,792,467
LCC Savings:	$ -	$ 89,945	$ 27,246	$ 27,711	$ (44,644)
Simple Payback Period (Years)	-	14.98	18.42	18.40	21.97

5.6 Progress Toward Other Mandates

ERDC-CERL staff conducted an analysis to ensure that all five building types would be able to achieve LEED Silver certification. LEED scorecards were completed and an analysis of credits was conducted to determine which credits should be pursued.

5.6.1 ASHRAE 189.1

This was not a study of ASHRAE 189.1 and the recent Army policy requiring compliance with ASHRAE 189.1 was not in effect when this study began. Therefore, this is not a comprehensive analysis, rather it is intended to "red flag" sections of ASHRAE 189.1 that may need further evaluation during the design of these buildings; e.g., some of the sections of ASHRAE 189.1 can only be evaluated based on the building site. However, in terms of ASHRAE 189.1, there is a high level of confidence from this study that using the measures described above the five building types would meet or exceed the ASHRAE 90.1-2007 energy goal of a 30 percent reduction in energy use. It is important to note that there are examples where this study exceeded the prescriptive values found in ASHRAE 189.1, such as improved insulation levels, a lower air infiltration rate, greater HVAC equipment efficiencies, and lighting concepts and strategies that exceeded the minimum requirements of the ASHRAE standard.

In terms of formatting, as is true in the "Mapping to LEED" tool described in Section 5.6.3, in general, a full circle indicates compliance with ASHRAE 189.1 requirements; a half circle indicates some but not all ASHRAE 189.1 requirements are met, and an empty circle indicates that 1) the relevant information to determine if the design specs complied could not be found, or 2) there is a loose association with the ASHRAE 189.1 requirements. Running notes are found in the second, more detailed tab of the Excel spreadsheet.

5.6.2 TechNotes

"TechNotes" were developed to provide summary technology information for DoD designers, cost engineers, and installation personnel. Each TechNote includes a description of the technology or design strategy, potential specific products, a summary of the requirements the strategy could affect, supplemental specification language or resources, and a case study emphasizing the technology.

Case in point, the topic of roofing material choices that meet both design goals and environmental and energy goals has been a design challenge in recent years. The "Heat Island Roof" TechNote includes information regarding roofing materials and colors that may assist installation and design teams with that decision. The 'Heat Island Roof' TechNote also provides an example of the expected content for the TechNotes. TechNotes can be found at the following web link:
http://mrsi.usace.army.mil/cos/TechNotes/Forms/AllItems.aspx

Additional TechNotes organized by general categories are posted for the following topics:

- HVAC
  - Desiccant HVAC
  - Overhead Radiant Heating
  - Radiant Floor Heating – Commercial
  - Radiant Floor Heating and Cooling – Residential
  - Ground Source Heat Pumps
- Renewables
  - Solar Collector Wall
  - Solar Hot Water
- Water
  - Dual Flush Toilets
  - High Efficiency Toilets
  - Low-Flow Showerheads
  - Ultra Low Flow Faucets
- Lighting
  - LED – Parking Lot
  - Light Pollution Reduction
- Daylighting
  - Dimming Photosensor
  - Light Shelf
  - Light Tubes
  - Sunlight Tracking

- Miscellaneous
  - Appliances
  - Enhanced Commissioning
  - Heat Island – Roof
  - Permeable Pavement
  - Reflective Paints

Another 20 TechNotes will be added to this page once their initial technical review has been completed. O&M TechNotes for O&M staff and one-page summary TechNotes for building occupants will also be developed. Additional feedback on the technical content and/or requests for additional topics for new TechNotes should be sent to Daniel.Carpio@usace.army.mil.

5.6.3 Mapping to LEED

The research team reviewed current mandates, policies, and standards (MPS) and compared them to LEED 2009 in an effort to illustrate potentially attainable levels of LEED certification from meeting current requirements. The following documents were evaluated in comparison to LEED 2009:

- Energy Policy Act of 2005 (EPACT)
- Energy Independence and Security Act of 2007 (EISA)
- Executive Order (EO) 13423
- EO 13514
- High Performance and Sustainable Buildings Guiding Principles (HPSB GP) Final (dated 12/1/08)
- Army Memorandum: Sustainable Design and Development Policy Update (SDD Policy, dated 10/27/10)
- Other policies and mandates, including Unified Facilities Criteria (UFC), Unified Facilities Guide Specifications (UFGS), and U.S. Codes of Federal Regulations (CFRs)
- Army Engineering and Construction Bulletins (ECBs)
- ASHRAE 189.1.

The requirements listed in each document were compared to the relevant LEED credit to determine whether meeting the requirements would result in achieving points under LEED. If the MPS requirements were equal to or more stringent than the requirements to achieve the LEED points, and complying with the MPS would result in achieving the LEED points, a black circle was placed next to the corresponding LEED credit.

If the MPS requirements were patterned after the requirements to achieve LEED points, but are either less stringent or dependent on specific site or building systems, and complying with the MPS may or may not result in achieving the LEED points, a half circle was placed next to the corresponding LEED credit. For example, the MPS may require 70 percent of regularly occupied spaces to have lighting controls, but providing lighting controls to 90 percent of building occupants is required to achieve LEED points.

If the MPS requirements were loosely related or had a general relationship to the requirements to achieve LEED points, but either could not achieve the LEED points by complying with the MPS or it was unclear whether complying with the MPS would result in achieving the LEED points, a white or empty circle was placed next to the corresponding LEED credit. Best practices that are encouraged but not required by the MPS also fall under this category.

If the MPS did not include any requirements that related to a LEED credit, the space next to the corresponding LEED credit was left blank.

6.0 Recommendations for Implementation

This section discusses three major areas: cost estimating, barriers, and recommendations. The impact of the modeling results for new energy and sustainability features on the original baseline/standard design buildings became clear during cost estimating. During the course of the study, a number of barriers or constraints had to be overcome. A list of recommendations is provided as a summary of lessons learned.

6.1 Costs

The cost increases for the recommended Low Energy Packages for the five building types ranged from 2 percent to 10 percent with an average cost increase of 6 to 8 percent. This study performed a life-cycle cost for two buildings (baseline building plus four Low Energy Packages) in three climate zones. Three of the four building combinations had multiple Low Energy Packages that were life-cycle cost effective. The one building (four Low Energy Packages) that was not life-cycle cost effective was due to the increased cost for additional insulation without a proportionate increase in energy savings. Adding renewables to individual buildings to bring them above the 65 percent energy reduction target would be cost prohibitive. In terms of renewables, the cost is over six times higher than the current investment in EEMs in today's dollars. Renewables should be considered as a centralized resource either for clusters of buildings or as completely offsite, e.g., large, ground-based solar arrays. Energy costs vary by season and region and the DoD should take advantage of cost effective renewable energy technology during peak demand periods, avoiding the most expensive fossil fuel based resources and their associated environmental externalities.

As an example of this approach, numerous innovations in solar thermal technologies in recent years have resulted in cost-effective large-scale systems including integrated solar supported heating networks. Such systems may be cost-effective for clusters of Army buildings containing, for example, barracks, dining facilities, gyms, child-development centers, and swimming pools. Similar opportunities exist on large hospital campuses, family housing complexes, etc.

The Central Solar Water Heating Systems – Design Guide (draft available from ERDC/CERL) is the first attempt to develop recommendations for optimal and reliable configurations of solar water heating systems in different climates along with design specifications, planning principles, and guidelines for such systems serving building clusters with significant usage of domestic hot water (DHW) operating in combination with central heating systems. Designers of new Army construction projects should first consider implementing larger centralized solar water heating systems in accordance with the Design Guide referenced above before designing a small individual building solar water heating system to meet the Sustainable Design Policy and EISA 2007 requirements discussed above.

6.2 Barriers

The final savings determination was difficult because there is no clearly defined baseline for these Army building types within CBECS. In other words, these buildings do not have equivalent categories within CBECS. Assumptions and compromises had to be made in terms of category selection and EUI figures used.

There was also initial confusion about the different energy baselines found in ASHRAE standards (modeled building energy) and EISA 2007 (measured building and plug load energy). This created an "apples to oranges" scenario that cannot be easily resolved.

Because of the uncertain baseline, the focus became one of creating the most efficient building within the constraints of the analysis rather than trying to create an exact match with what were basically arbitrary CBECS targets. Modeling and calculations were done, however, to provide results in terms of EISA 2007 and CBECS requirements.

The study was able to show the energy effectiveness of selected bundles of energy efficient technologies. However, the study was not able to show the cost-effectiveness of individual measures, nor was it able to optimize the designs for the highest energy performance at the lowest costs. This typically is done early in the design phase.

The issue of how to address the impact of plug loads was also a barrier. As can be seen from the building energy reduction results, the increased cost only takes the buildings up to a certain point in terms of energy efficiency unless and until plug loads are reduced. In other words, the buildings are as energy efficient as possible while remaining life-cycle cost-effective and would meet the 65 percent energy reduction target in a number of climate zones and for the building types if proportionately high plug loads are not considered. Because controlling the plug loads was not within the scope of the project, all the study could do was highlight the impact on energy usage.

Among other challenges are limited or no availability of some advanced technologies on the US market (e.g., triple-pane windows that meet AT/FP blast-resistance requirements) and the need to adopt advanced design, construction and QC practices (e.g., for well insulated and air tight building envelopes) required to construct energy efficient buildings. Other challenges included a lengthy and difficult contracting process between USACE and the DOE Laboratories (a Memorandum of Understanding is now in place that makes this process easier), unavailability of new technologies with three U.S. manufacturers (e.g., triple-pane windows that meet AT/FP blast-resistance requirements), and ASHRAE 189.1 becoming an Army requirement during the course of the study.

6.3 Recommendations

To implement the results of this study, a number of efforts are needed. These include the following:

- Tools, protocols, and guidance –
  - Develop tools that will help COSs, Army Installations staff, general contractors, A&Es, trades, and occupants to understand what needs to be done to design, implement, operate, maintain, and properly use the technologies and packages that were analyzed and recommended in this study. These would need to include tools such as additional TechNotes, guide specifications, UFCs, and training materials.
  - Develop protocols that will ensure performance targets are met for individual projects that are building type and site specific
  - In cooperation with the COSs, develop guidance about how to achieve a truly integrated design regardless of building type.

- Technical assistance –
  - Provide technical assistance as needed to the COSs to determine what changes need to be made to the standard designs to achieve maximum, life-cycle cost-effective energy efficient buildings
  - Review mission and quality of life requirements that affect high plug loads for some building types, implement changes, as appropriate.
  - Work with master planners to redesign the location of several types of buildings and multiple usages for a single building or connected complex of buildings, e.g., barracks, to take maximum advantage of shared resources. Evaluate energy savings for various options and institute changes.
- Additional research –
  - Complete the cost optimization for each of the energy efficiency packages.
  - Ensure compliance with ASHRAE 189.1 and the results of this study.
  - Conduct a study of other technologies in combination with current practices in some climate zones for the five building types that could produce similar energy savings to those found in this study.
  - Evaluate these study results in terms of major renovations that will be conducted within the next 5 years of specific types of buildings in specific climate zones, e.g., VOLAR barracks.
  - Coordinate work with DOE commercial building projects and research.
- Procurement –
  - Procure only top-tier ENERGY STAR® appliances and equipment or appliances and equipment that can be shown to be in the top 10 percent in terms of energy efficiency where an ENERGY STAR labeling program is unavailable.
  - Develop industry partnerships for specific technologies and products to ensure availability and lower cost over time.

The analysis showed that significant energy savings are possible for all climates. However, it is very difficult to reach the EISA 2007 target for the 2015 goal of 65 percent fossil fuel reduction with building-specific efficiency measures alone. The extent of energy savings achieved is site- and facility-specific. Additional savings may be achievable, but the current study shows the energy savings picture as follows:

- 25 to 35 percent energy savings: The building yields the maximum energy savings for the lowest cost
- 35 to 60 percent energy savings: Each increment of energy saved comes at an increasingly higher cost (plug load reduction, small scale renewable energy, building orientation, site specific design)
- Above 60 percent: May be cost prohibitive without looking beyond the building (significant plug load reduction, clustering, renewable energy, cogeneration, etc.)
- Some facility types in certain regions will never achieve the 65 percent energy target through energy efficiency measures alone

At the start of this study, the EISA 2007 target for a 65 percent energy reduction by 2015 was analyzed in terms of site energy (not based on the source of energy used). However during the study in 2010, a new rule interpreting EISA 2007 and the energy targets was released by DOE (see References

section for citation) that shifts the energy analysis from site energy to source energy, which is based on the reduction of fossil fuels at the point of energy production. The source energy reduction requirement is generally more difficult to achieve than site energy reduction requirements..

This resulted in fewer building types meeting the targets for all climate zones and also results in installation of all-electric appliances and equipment to minimize retrofitting from gas or oil to electric at a later date to meet even more stringent requirements. In other words, in this study, the buildings reduced energy usage at the site to meet source energy reduction targets.

In addition, CBECS building categories and their related EUIs are not directly comparable to these five Army building types in most cases. This also negatively affected the ability of the buildings to meet CBECS source energy targets.

With regards to ASHRAE 189.1, there is a high level of confidence from this study that the five building types would meet or exceed the goal of ASHRAE 189.1 to achieve a 30 percent reduction in energy use compared to an ASHRAE 90.1-2007 building including plug loads.

7.0 Summary of Findings

Fully integrated design is a requirement and not an option with high-efficiency buildings. All subject matter experts, including the commissioning agent and O&M staff, need to be involved from the earliest stages of the project. If this is not done, much time is wasted passing the design back and forth for changes and systems, particularly HVAC systems, are not designed to their maximum efficiency to work with exterior insulation levels, roofing materials, etc.

Enhanced commissioning is a particularly important part of integrated design to ensure that design, installation, and startup of systems are done correctly and M&V is important to verify modeling results. Many of the mechanical systems will only operate properly within a narrow set of parameters. Once operating outside of those parameters for extended periods of time, systems will either not function efficiently or fail to function at all.

Cost optimization needs to be completed for all energy models that were a part of this study and should ideally be completed at the early stages of a project. It is important to complete cost optimization early so that the highest energy efficiencies can be determined.

There is no single, “silver bullet” answer for these buildings. Climate zone, building site conditions, and other factors play major roles in building performance. When buildings are designed to be minimally energy efficient, it is relatively easy to use a “one size fits all,” prescriptive approach because the results in terms of energy efficiency are not a factor. With these buildings, the burden is on the designers to take a performance-based rule set and apply it to an individual building by defining strategies that result in achieving overall energy reduction targets.

While this study focused on passive house approaches and technologies, these should not be the prescribed path for the design team to take when it comes to incorporating measures into standard designs. For example, in climate zone 1A, passive house insulation levels may be slightly relaxed but stringent air tightness and DOAS system shall be applied to ensure moisture/humidity control. Climate zone 5A may achieve much better results. Another example, it may not be optimal to design triple-pane windows on all four walls of a building if further study and modeling reveal that it is not appropriate on the north side of the building or if a taller building or landscaping shades one or more sides of the building and two-pane, low-e windows can be used with little or no impact on energy performance. In this example, it would be beneficial to also take a look at the window U-value to maintain an acceptable occupant thermal comfort and not just the solar heat gain.

In the future, to meet ever more stringent energy targets on the path to net zero energy, buildings will need to be:

- Grouped together and connected to central energy plants with co-and tri-generation to take advantage of larger, fewer, and more energy efficient technologies. This will allow for the sharing of resources between buildings, e.g., waste heat in a cogeneration facility, taking advantage of differences in building schedules and occupancies, utilization of waste heat generated by co-generation and using larger solar panel fields in Solar Water Heating Systems.

- Combined into one building for multiple life/work purposes (e.g., UEPH on the upper floors, DFAC on the main floor of a barracks complex, and a COF either on the first floor or in the basement of the barracks complex).
- Evaluated using additional criteria, e.g, some buildings or locations are optimal for minimizing energy demands and should be the preferred ones for upgrades. For example those located below a hill outside of the prevailing wind have much less exposure to the elements and could have a better orientation for renewable technologies like roof top solar.
- Evaluated to determine if full use is being made of the thermal mass of the structure.

Reducing the plug loads to a level that would achieve the targeted EISA-2007 fossil fuel energy reduction goal by 2015 would require a reevaluation of mission and quality of life requirements for some standard designs. For example:

- UEPH – Prescribe the types of electronic equipment that soldiers can put in their modules; e.g., LED TVs only of a maximum size—no plasma TVs, LED computer screens only, limit kitchen appliances to a microwave, centralized laundry facilities—no in-module facilities, two person modules versus one person.
- Bde HQ – Procure only LED computer screens; limit the number per person; procure only top-tier ENERGY STAR ® central processing units, laptops, and related/support equipment; mandate and enforce a low maximum wattage usage per person.
- DFAC – Change the menu to eliminate or minimize the need for high-energy-usage kitchen appliances and equipment. Extend the meal periods over a longer period of time to reduce the peak demand loads currently needed by kitchen appliances and equipment.

When it is determined that technologies need further development/improvement, the Army should work with industry directly to make the changes so improved or new products can be brought to market by leveraging the buying power of all of the armed services.

In addition, lessons learned from operators of large portfolios of buildings with similar use to the DOD could offer some very practical and cost effective insights into the payback of various options within specific regions. Many large real estate firms that have taken over BRAC and other facilities and transformed them into profitable and energy efficient installations should be consulted and site visits conducted to see how this “reuse” has progressed and why landowners elected to invest in different building improvements to achieve their financial and other ownership objectives to determine if the private sector done better than existing DOD installations in making progress toward similar goals in the last 5-10 years.

O&M staff must be properly trained on new systems and technologies or high-efficiency buildings will quickly become less efficient or worse than buildings constructed in the past. Occupant behavior needs to change. Whether it is turning off lights when not in use, properly using operable windows or not blocking HVAC vents, occupants determine the ultimate efficiency of a building. Changing these behavior patterns through education and training is essential to the long-term goal of having a net zero installation. Education also needs to be provided to USACE COSs, Army Installations staff, general contractors, A&Es, and trades on new features, technologies, systems and approaches.

This study's results need to be integrated into ASHRAE 189.1 requirements. Meeting EISA 2007 energy targets is important, but other requirements also now need to be met. This study was already in progress when ASHRAE 189.1 became an Army requirement. More work is needed to ensure compliance.

8.0 References

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Appendix A:

UEPH

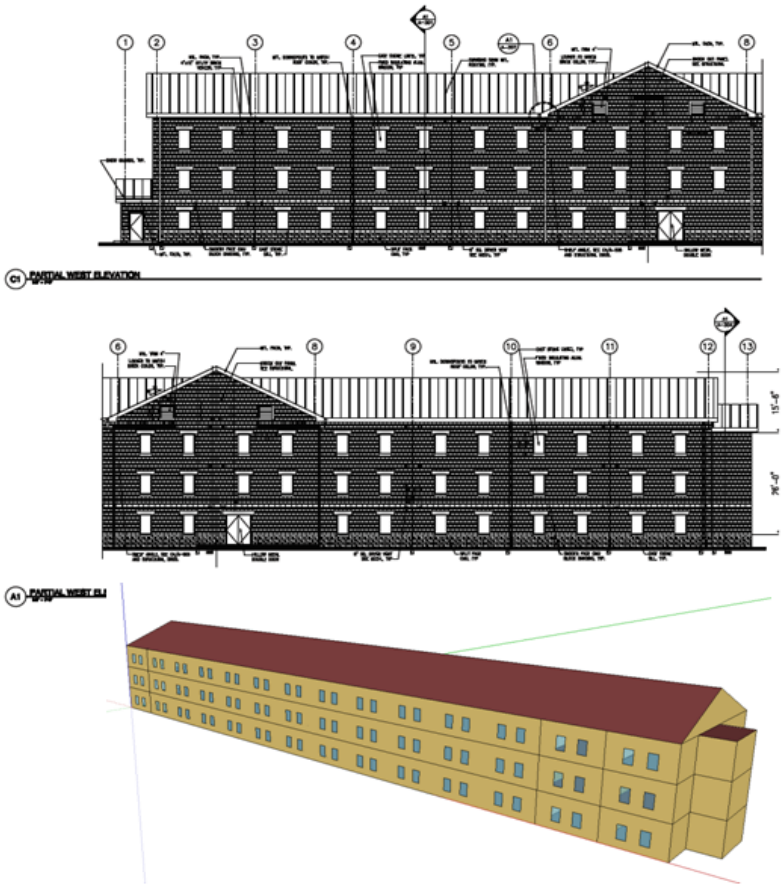


Figure A.1 Section views and rendering of UEPH configuration

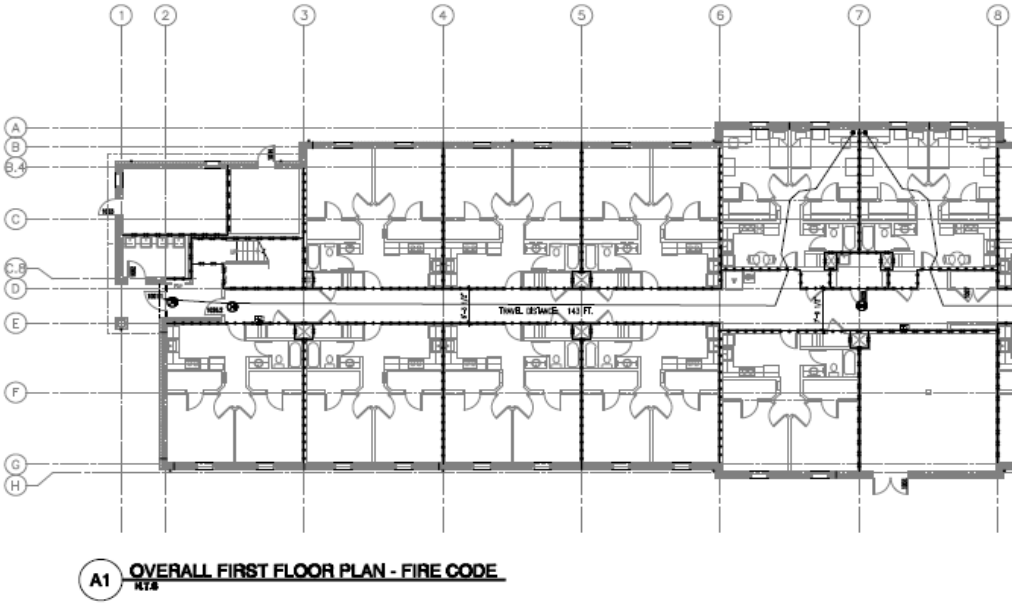


Figure A.2 Plan view of baseline UEPH configuration

Parameter	Baseline	Low Energy (V10)
Envelope – Roof	Army WBDG compliant	Passive Haus (see attached) Cool Roof in CZ 1-5
Envelope-Walls, floors	Army WBDG compliant	Passive Haus (see attached)
Envelope - Windows	Army WBDG compliant	Passive Haus (see attached)
Envelope - airtightness	.25 cfm/sq ft envelope area	.15 cfm/sq ft envelope area High traffic entry vestibule
Lighting		Lighting Power Densities recommended by AtellierTen Advanced controls
HVAC DOAS 65 cfm/room	Standard DOAS plus soldier room fan coil units DOAS cooling cap: 2A 425 KBtu/h 4A 417 KBtu/h 7A 375 Kbtu/h DOAS heating cap: 2A 257 Kbtu/h 4A 324 Kbtu/h 7A 406 Kbtu/h	Advanced DOAS plus radiant heating and cooling in soldier rooms DOAS cooling cap: 2A 304 KBtu/h 4A 297 Kbtu/h 7A 271 Kbtu/h DOAS heating cap: 2A 185 Kbtu/h 4A 234 Kbtu/h 7A 293 Kbtu/h DOAS has ERV, 0.8 effectiveness

Table A.1a UEPH Baseline and low energy component values

Parameter	Baseline	Low Energy (V10)
HVAC (continued)	Fan Coils Cooling: 2A 10667Btu/h 4A 8074 Btu/h 7A 6559 Btu/h Fan Coils Heating: 2A 6215 Btu/h 4A 6215 Btu/h 7A 7830 Btu/h	Radiant Cooling: 2A 5803 Btu/h 4A 5211 Btu/h 7A 4137 Btu/h Radiant Heating: 2A 4330 Btu/h 4A 4927 Btu/h 7A 5728 Btu/h
Chiller	Stnd Effic 2A 89.4 tons 4A 81.4 tons 7A 58.6 tons	High Effic 2A 59.6 tons 4A 53.9 tons 7A 40.3 tons
Boiler	Stnd Effic 2A 913 Kbtu/h 4A 1,234 Kbtu/h 7A 1,741 Kbtu/h	High Effic 2A 635 Kbtu/h Condensing 4A 775 Kbtu/h 7A 1,025 Kbtu/h

Table A.1b (Continued) UEPH Baseline and low energy component values

Building Component	Model	Efficient Building Model
Area	54,771 ft^2 (5,088 m^2)	Same as baseline
Floors	3	Same as baseline
Orientation	Long axis running east and west	Same as baseline
Window to wall ratio	15% WWR on north and south facades	Same as baseline
Window type	Standard 90.1-2004	See Table 2
Wall construction	Steel frame	Same as baseline
Wall insulation	Standard 90.1-2004	See Table 2
Roof construction	Sloped roof and attic with insulation at the roof level	Same as baseline
Roof insulation	Standard 90.1-2004 equal to the "insulation entirely above deck"	See Table 2
Infiltration	0.25 cfm/ft^2 @ 0.3 in w.g.	0.15 cfm/ft^2 @ 0.3 in w.g.
Lighting	Rooms - 1.1 W/ft^2 (10.8 W/m^2) Corridors: 0.5 W/ft^2 (6.5 W/m^2) See Table Lighting Design	Rooms – 0.6 W/ft^2 (10.8 W/m^2) Corridors: 0.5 W/ft^2 (6.5 W/m^2) See Table Lighting Design
Plug loads	1.67 W/ft^2 plus refrigerator and range	0.835 W/ft^2 plus refrigerator and range
Temp set points	70°F heating; 75°F cooling, no set back	Same as baseline
HVAC	DOAS (2.87 COP), natural gas boiler hot water system (0.80 Et), 4-pipe Fan Coil Units (FCU's) for zone temperature control.	**Sys Base:** DOAS (4.4 COP), natural gas boiler hot water system (0.95 Et), 4-pipe FCUs for zone temperature control. **System options**: Central exhaust used for HRV and ERV (80% effectiveness), Radiant heating and cooling in ceilings for zone temperature control Ground Source Heat Pumps (GSHP)
DHW	Natural gas boiler (0.8 E_t)	Natural gas boiler (0.95 E_t)

Table A.2 Baseline and Energy Efficient Inputs for Energy Modeling - UEPH

	Design Criteria			Control Strategies				Technologies				Approach				
				Levels	Automatic Interface											
Space	Target Illuminance at Task [fc] (Design Goal)	Target Lighting Power Density [W/ft^2] (Project Design Goal)	Allowable Lighting Power Density [W/ft^2] (ASHRAE/IESNA Std 90.1-2004/2007)	Switching - (blank) Multi-Level - M Full Dimming - D	V - Vacancy [Manual ON / Auto OFF] O - Occupancy [Auto ON / Auto OFF]	Daylight (e.g. Photosensors)	Schedule (e.g. Astronomical time-clock)	Linear Fluorescent	Compact Fluorescent	Ceramic Metal Halide	Light Emitting Diodes	Overhead General Lighting	Overhead Ambient Lighting	Task Lighting	Wallwash / Perimeter Lighting	Adjustable Accent Lighting
Corridor	10	0.50	0.5		O			✓				•			•	
Living Quarters	5 - 30	0.60	1.1		V		🕑	✓	✓		✓	•	•	•		
Mechanical / Electrical	30	0.70	1.5		V			✓				•				
Restroom / Shower	20	0.80	0.9		V			✓	✓		✓	•			•	
Stair	10	0.50	0.6	M	O			✓				•				
Storage (General)	10	0.50	0.8		V			✓				•				•

Table A.3 Atelier Ten Lighting Design Guide Recommendations - UEPH

Space	Lighting	Controls
Corridor		Occupancy sensors to reduce load to 25%-50% when vacancy is detected. Multi-Level ballasts may be appropriate in many cases
Living Quarters		Vacancy sensors in bathroom, kitchen, and each bedroom. Low-load night lights in bath vanity areas; Sensors also switch off selected plug loads.
Mechanical / Electrical	Locate luminaires relative to working areas and equipment	Dual-technology vacancy sensors with long time out
Restroom / Shower	Lighting over sink and toilet wall will often be enough for entire restroom	Dual-technology vacancy sensor
Stair	Locate luminaires to provide 10 fc at landings	Use bi-level luminaire with integrated occupancy sensor
Storage (General)	Locate and specify luminaires to light vertical surfaces	

Table A.4 Atelier Ten Lighting Design Guide Notes – UEPH

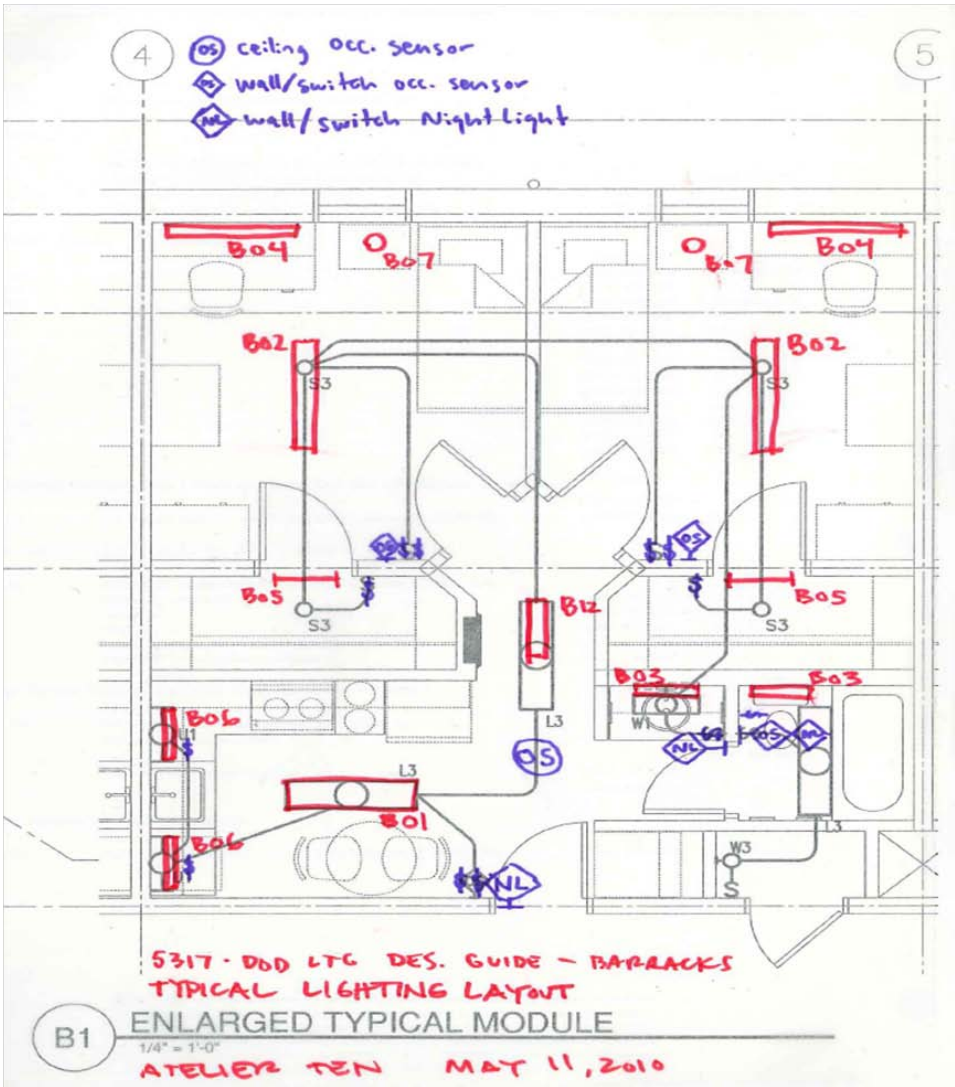


Figure A.3 Atelier Ten Lighting Design for UEPH Living Unit

Hr	Occupancy			Lighting			Plug Loads			Service Hot Water		
	Wk	Sat	Sun	Wk	Sat	Sun	Wk	Sat	Sun	Wk	Sat	Sun
1	0.80	0.75	0.75	0.10	0.10	0.10	0.30	0.30	0.30	0.00	0.00	0.00
2	0.80	0.75	0.75	0.10	0.10	0.10	0.30	0.30	0.30	0.00	0.00	0.00
3	0.80	0.75	0.75	0.10	0.10	0.10	0.30	0.30	0.30	0.00	0.00	0.00
4	0.80	0.75	0.75	0.10	0.10	0.10	0.30	0.30	0.30	0.00	0.00	0.00
5	0.80	0.75	0.75	0.20	0.20	0.20	0.30	0.30	0.30	0.00	0.00	0.00
6	0.80	0.75	0.75	0.40	0.30	0.30	0.30	0.30	0.30	0.10	0.10	0.10
7	0.70	0.65	0.75	0.50	0.50	0.50	0.30	0.30	0.30	0.20	0.20	0.20
8	0.60	0.60	0.70	0.70	0.50	0.70	0.50	0.35	0.30	0.10	0.10	0.10
9	0.50	0.50	1.00	0.20	0.20	0.20	0.50	0.40	0.50	0.00	0.00	0.00
10	0.25	0.25	0.00	0.20	0.20	0.20	0.30	0.40	0.50	0.00	0.00	0.00
11	0.20	0.20	0.20	0.20	0.20	0.20	0.30	0.30	0.50	0.00	0.00	0.00
12	0.20	0.20	0.20	0.20	0.20	0.20	0.30	0.30	0.50	0.00	0.00	0.00
13	0.20	0.20	0.20	0.20	0.20	0.20	0.30	0.30	0.50	0.00	0.00	0.00
14	0.20	0.20	0.20	0.20	0.20	0.20	0.30	0.30	0.50	0.00	0.00	0.00
15	0.20	0.20	0.20	0.10	0.20	0.20	0.30	0.30	0.50	0.00	0.00	0.00
16	0.20	0.20	0.20	0.10	0.20	0.20	0.30	0.30	0.50	0.00	0.00	0.00
17	0.20	0.20	0.20	0.20	0.20	0.20	0.30	0.30	0.50	0.00	0.00	0.00
18	0.20	0.20	0.20	0.50	0.50	0.50	0.30	0.30	0.50	0.10	0.10	0.10
19	0.30	0.30	0.30	0.70	0.50	0.50	0.50	0.50	0.50	0.10	0.10	0.10
20	0.50	0.50	0.50	0.70	0.50	0.50	0.60	0.50	0.40	0.10	0.10	0.10
21	0.50	0.50	0.50	0.70	0.50	0.50	0.70	0.50	0.40	0.00	0.00	0.00
22	0.70	0.50	0.50	0.50	0.50	0.50	0.70	0.50	0.40	0.00	0.00	0.00
23	0.70	0.50	0.50	0.40	0.40	0.40	0.50	0.50	0.40	0.00	0.00	0.00
24	0.80	0.75	0.75	0.20	0.20	0.20	0.30	0.50	0.30	0.00	0.00	0.00
Peak	2 occ/unit			0.6 W/ft^2			0.835 W/ft^2			1.5 gpm/shower		

Table A.5 UEPH occupancy, lighting, plug load and service hot water schedule

B	Baseline Energy Budget
P1	Lighting Load and Electric Power Load Density Reduction from 1.67 W/ft^2 to 0.835 W/ft^2 applied to B
P2	Passiv haus insulation specification; increased insulation and air tightness, reduce OA pressurization air to 65CFM due to air tightness with P1-B
P3	Increase chiller and boiler efficiencies and all variable high efficiency pumps and fans with P2-B
P4	Reduce hot water with 1.5gpm shower heads with P3-B
P5	Energy recovery ventilation (ERV) with P4
P6	Indirect evaporative pre-cooling with P4
P7	Radiant heating and cooling with P4
P8	ERV and radiant with P4
P9	ERV and indirect evaporative pre-cooling with P4
P10	ERV, indirect evaporative pre-cooling and radiant heating and cooling with P4
P11	Ground source heat pump (GSHP) and ERV with P4
P12	Reduction in equiment loads (0.5W/ft2) with premium equipment in soldiers rooms; added to P11
P13	Reduction in equiment loads (0.5W/ft2) with premium equipment in soldiers rooms, Added to P10

Site Energy Totals with Plug Loads [kBtu/ft2]	2003 CBECS Other Lodging	CBECS Site Budget	Baseline Building	Low Energy Package 1												
			B	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
1A Miami	68	24	69	52	46	39	37	37	35	36	36	35	34	37	34	30
2A Houston	69	24	69	56	47	40	38	37	36	37	36	35	34	38	35	31
2B Phoenix	67	23	64	49	42	37	35	34	32	34	32	31	30	35	31	26
3A Memphis	68	24	72	61	50	43	41	37	39	39	36	36	34	38	35	31
3B El Paso	64	22	63	50	44	38	36	34	35	35	33	33	31	36	33	28
3C San Francisco	58	20	59	49	42	38	35	34	35	34	33	34	33	36	33	30
4A Baltimore	75	26	77	68	53	46	43	38	42	42	36	37	35	40	38	33
4B Albuquerque	66	23	69	58	48	42	40	35	38	38	34	34	33	39	35	30
4C Seattle	68	24	69	63	49	43	40	36	40	39	34	36	34	37	35	32
5A Chicago	84	29	84	77	59	51	48	39	47	46	38	39	37	40	37	35
5B Colorado Springs	73	26	75	65	54	47	44	37	43	42	36	36	35	41	38	32
6A Burlington	97	34	88	82	62	54	50	40	50	48	39	39	38	43	40	36
6B Helena	86	30	84	77	59	51	48	38	47	46	37	38	37	42	39	34
7A Duluth	105	37	98	93	70	60	56	42	55	54	41	42	41	45	43	39
8A Fairbanks	135	47	122	119	87	74	69	50	69	67	49	50	49	47	45	47

UEPH	Incremental % Savings (Site)												
	P1-B	P2-P1	P3-P2	P4-P3	P5-P4	P6-P4	P7-P4	P8-P4	P9-P4	P10-P4	P11-P4	P12-P4	P13-P4
1A Miami	-25%	-11%	-15%	-4%	-1%	-7%	-3%	-3%	-7%	-10%	0%	-10%	-19%
2A Houston	-19%	-16%	-14%	-5%	-4%	-5%	-3%	-7%	-8%	-12%	-1%	-10%	-20%
2B Phoenix	-23%	-14%	-13%	-5%	-4%	-10%	-4%	-7%	-11%	-15%	0%	-10%	-25%
3A Memphis	-16%	-18%	-13%	-6%	-9%	-4%	-4%	-12%	-12%	-15%	-5%	-13%	-23%
3B El Paso	-21%	-13%	-12%	-6%	-6%	-4%	-4%	-9%	-10%	-13%	-1%	-10%	-23%
3C San Francisco	-16%	-14%	-10%	-8%	-3%	-1%	-3%	-6%	-4%	-7%	3%	-6%	-15%
4A Baltimore	-11%	-22%	-13%	-7%	-13%	-2%	-4%	-16%	-15%	-19%	-7%	-13%	-25%
4B Albuquerque	-16%	-17%	-12%	-7%	-11%	-3%	-3%	-14%	-14%	-17%	-2%	-10%	-25%
4C Seattle	-9%	-22%	-11%	-8%	-11%	-1%	-4%	-14%	-11%	-15%	-7%	-13%	-21%
5A Chicago	-9%	-23%	-13%	-7%	-18%	-1%	-3%	-21%	-19%	-22%	-17%	-22%	-28%
5B Colorado Springs	-13%	-18%	-12%	-7%	-16%	-1%	-3%	-18%	-17%	-19%	-7%	-13%	-26%
6A Burlington	-7%	-25%	-13%	-7%	-20%	-1%	-3%	-23%	-21%	-24%	-14%	-19%	-28%
6B Helena	-8%	-23%	-13%	-7%	-20%	-1%	-3%	-22%	-21%	-23%	-12%	-18%	-29%
7A Duluth	-5%	-25%	-14%	-7%	-24%	0%	-3%	-26%	-24%	-26%	-18%	-22%	-30%
8A Fairbanks	-2%	-27%	-15%	-6%	-28%	0%	-2%	-29%	-28%	-30%	-32%	-34%	-32%
Avg % Savings	-13%	-19%	-13%	-6%	-13%	-3%	-3%	-15%	-15%	-18%	-8%	-15%	-25%

Table A.6 UEPH site baseline and low energy EUIs and incremental % savings for EEM packages

Site Energy Totals with Plug Loads [kBtu/ft2]	2003 CBECS Other Lodging	CBECS Site Budget	Baseline Building	Low Energy Package 1												
			B	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
1A Miami	68	24	69	52	46	39	37	37	35	36	36	35	34	37	34	30
2A Houston	69	24	69	56	47	40	38	37	36	37	36	35	34	38	35	31
2B Phoenix	67	23	64	49	42	37	35	34	32	34	32	31	30	35	31	26
3A Memphis	68	24	72	61	50	43	41	37	39	39	36	36	34	38	35	31
3B El Paso	64	22	63	50	44	38	36	34	35	35	33	33	31	36	33	28
3C San Francisco	58	20	59	49	42	38	35	34	35	34	33	34	33	36	33	30
4A Baltimore	75	26	77	68	53	46	43	38	42	42	36	37	35	40	38	33
4B Albuquerque	66	23	69	58	48	42	40	35	38	38	34	34	33	39	35	30
4C Seattle	68	24	69	63	49	43	40	36	40	39	34	36	34	37	35	32
5A Chicago	84	29	84	77	59	51	48	39	47	46	38	39	37	40	37	35
5B Colorado Springs	73	26	75	65	54	47	44	37	43	42	36	36	35	41	38	32
6A Burlington	97	34	88	82	62	54	50	40	50	48	39	39	38	43	40	36
6B Helena	86	30	84	77	59	51	48	38	47	46	37	38	37	42	39	34
7A Duluth	105	37	98	93	70	60	56	42	55	54	41	42	41	45	43	39
8A Fairbanks	135	47	122	119	87	74	69	50	69	67	49	50	49	47	45	47

UEPH	Incremental % Savings (Source)												
	P1-B	P2-P1	P3-P2	P4-P3	P5-P4	P6-P4	P7-P4	P8-P4	P9-P4	P10-P4	P11-P4	P12-P4	P13-P4
1A Miami	-28%	-12%	-15%	-1%	-1%	-8%	-3%	-3%	-7%	-11%	0%	-11%	-21%
2A Houston	-27%	-13%	-13%	-2%	-2%	-6%	-4%	-5%	-7%	-10%	2%	-8%	-21%
2B Phoenix	-29%	-13%	-12%	-1%	-3%	-11%	-5%	-7%	-12%	-16%	1%	-11%	-28%
3A Memphis	-26%	-13%	-12%	-2%	-4%	-5%	-4%	-7%	-8%	-12%	3%	-8%	-22%
3B El Paso	-31%	-9%	-10%	-2%	-3%	-6%	-4%	-7%	-8%	-12%	5%	-7%	-24%
3C San Francisco	-30%	-9%	-7%	-3%	-1%	-1%	-3%	-4%	-2%	-5%	8%	-4%	-17%
4A Baltimore	-25%	-15%	-10%	-3%	-6%	-3%	-4%	-9%	-9%	-12%	6%	-4%	-23%
4B Albuquerque	-29%	-11%	-9%	-3%	-5%	-4%	-4%	-9%	-8%	-12%	8%	-4%	-24%
4C Seattle	-26%	-13%	-7%	-3%	-5%	-1%	-4%	-8%	-6%	-9%	5%	-6%	-20%
5A Chicago	-24%	-15%	-10%	-3%	-9%	-2%	-4%	-12%	-10%	-14%	-1%	-11%	-24%
5B Colorado Springs	-27%	-11%	-9%	-3%	-8%	-2%	-4%	-11%	-9%	-13%	8%	-3%	-24%
6A Burlington	-22%	-16%	-10%	-3%	-10%	-1%	-4%	-13%	-11%	-14%	6%	-4%	-24%
6B Helena	-24%	-15%	-9%	-3%	-10%	-2%	-3%	-13%	-11%	-14%	6%	-5%	-25%
7A Duluth	-21%	-17%	-10%	-4%	-13%	-1%	-3%	-15%	-13%	-16%	6%	-3%	-25%
8A Fairbanks	-17%	-20%	-11%	-4%	-17%	-1%	-3%	-19%	-17%	-19%	-5%	-13%	-27%
Avg % Savings	-26%	-14%	-10%	-3%	-6%	-3%	-4%	-9%	-9%	-13%	4%	-7%	-23%

Table A.7 UEPH source baseline and low energy EUIs and incremental % savings for EEM packages

UEPH - Fort Campbell	Low Energy Package 1	Low Energy Package 2	Low Energy Package 3	Low Energy Package 4
Baseline Building	$ 8,597,669	$ 8,597,669	$ 8,597,669	$ 8,597,669
HVAC Components	$ (30,121)	$ (4,380)	$ (654,620)	$ (278,469)
Overhead Radiant Heating	$ -	$ -	$ 155,179	$ -
Ground Source Heat Pump	$ -	$ -	$ -	$ 1,285,851
Solar Hot Water	$ 86,402	$ 86,402	$ 86,402	$ 86,402
Advanced Lighting Systems	$ 81,877	$ 81,877	$ 81,877	$ 81,877
Increased Building Envelope	$ 233,309	$ 233,309	$ 233,309	$ 233,309
Increased Air Tightness	$ 730	$ 730	$ 730	$ 730
Increased Window Efficiency	$ 45,386	$ 45,386	$ 45,386	$ 45,386
Entrance Vestibules	$ 41,829	$ 41,829	$ 41,829	$ 41,829
Dual Flush Toilets	$ 33,063	$ 33,063	$ 33,063	$ 33,063
1.5gpm Flow Showerheads	$ 10,898	$ 10,898	$ 10,898	$ 10,898
0.5gpm Flow Faucets	$ 21,278	$ 21,278	$ 21,278	$ 21,278
Light Tube	$ 101,116	$ 101,116	$ 101,116	$ 101,116
Skylight	$ 9,644	$ 9,644	$ 9,644	$ 9,644
Cool Roof	$ 7,411	$ 7,411	$ 7,411	$ 7,411
Enhanced Commissioning	$ 57,298	$ 57,298	$ 57,298	$ 57,298
Measurement & Verification	$ 63,723	$ 63,723	$ 63,723	$ 63,723
Rainwater Harvesting	$ 152,803	$ 152,803	$ 152,803	$ 152,803
Add-on Cost	$ 916,646	$ 942,387	$ 447,326	$ 1,954,149
Revised Cost	$ 9,514,315	$ 9,540,056	$ 9,044,995	$ 10,551,818
Pecent Increase	10.66%	10.96%	5.20%	22.73%
Notes	(1) These costs are shown in contract costs			
	(2) Baseline builds to meet LEED Silver			

Table A.8 Cost breakdown for UEPH – Fort Campbell

UEPH - Fort Bliss	Low Energy Package 1	Low Energy Package 2	Low Energy Package 3	Low Energy Package 4
Baseline Building	$ 8,986,431	$ 8,986,431	$ 8,986,431	$ 8,986,431
HVAC Components	$ (32,530)	$ (4,730)	$ (706,989)	$ (300,746)
Overhead Radiant Heating	$ -	$ -	$ 167,593	$ -
Ground Source Heat Pump	$ -	$ -	$ -	$ 1,388,719
Solar Hot Water	$ 93,314	$ 93,314	$ 93,314	$ 93,314
Advanced Lighting Systems	$ 88,427	$ 88,427	$ 88,427	$ 88,427
Increased Building Envelope	$ 187,530	$ 187,530	$ 187,530	$ 187,530
Increased Air Tightness	$ 789	$ 789	$ 789	$ 789
Increased Window Efficiency	$ 49,017	$ 49,017	$ 49,017	$ 49,017
Entrance Vestibules	$ 45,176	$ 45,176	$ 45,176	$ 45,176
Dual Flush Toilets	$ 35,708	$ 35,708	$ 35,708	$ 35,708
1.5gpm Flow Showerheads	$ 11,770	$ 11,770	$ 11,770	$ 11,770
0.5gpm Flow Faucets	$ 22,980	$ 22,980	$ 22,980	$ 22,980
Light Tube	$ 109,206	$ 109,206	$ 109,206	$ 109,206
Skylight	$ 10,416	$ 10,416	$ 10,416	$ 10,416
Cool Roof	$ 8,004	$ 8,004	$ 8,004	$ 8,004
Enhanced Commissioning	$ 61,882	$ 61,882	$ 61,882	$ 61,882
Measurement & Verification	$ 68,822	$ 68,822	$ 68,822	$ 68,822
Rainwater Harvesting	$ 142,392	$ 142,392	$ 142,392	$ 142,392
Add-on Cost	$ 902,903	$ 930,703	$ 396,037	$ 2,023,406
Revised Cost	$ 9,889,334	$ 9,917,134	$ 9,382,468	$ 11,009,837
Pecent Increase	10.05%	10.36%	4.41%	22.52%
Notes	(1) These costs are shown in contract costs			
	(2) Baseline builds to meet LEED Silver			

Table A.9 Cost breakdown for UEPH – Fort Bliss

UEPH - Fort Lewis	Low Energy Package 1	Low Energy Package 2	Low Energy Package 3	Low Energy Package 4
Baseline Building	$ 10,242,658	$ 10,242,658	$ 10,242,658	$ 10,242,658
HVAC Components	$ (35,843)	$ (5,211)	$ (778,997)	$ (331,376)
Overhead Radiant Heating	$ -	$ -	$ 184,663	$ -
Ground Source Heat Pump	$ -	$ -	$ -	$ 1,530,162
Solar Hot Water	$ 102,818	$ 102,818	$ 102,818	$ 102,818
Advanced Lighting Systems	$ 97,434	$ 97,434	$ 97,434	$ 97,434
Increased Building Envelope	$ 206,755	$ 206,755	$ 206,755	$ 206,755
Increased Air Tightness	$ 870	$ 870	$ 870	$ 870
Increased Window Efficiency	$ 54,009	$ 54,009	$ 54,009	$ 54,009
Entrance Vestibules	$ 49,777	$ 49,777	$ 49,777	$ 49,777
Dual Flush Toilets	$ 39,346	$ 39,346	$ 39,346	$ 39,346
1.5gpm Flow Showerheads	$ 12,968	$ 12,968	$ 12,968	$ 12,968
0.5gpm Flow Faucets	$ 25,321	$ 25,321	$ 25,321	$ 25,321
Light Tube	$ 120,328	$ 120,328	$ 120,328	$ 120,328
Skylight	$ 11,477	$ 11,477	$ 11,477	$ 11,477
Cool Roof	$ 8,819	$ 8,819	$ 8,819	$ 8,819
Enhanced Commissioning	$ 68,185	$ 68,185	$ 68,185	$ 68,185
Measurement & Verification	$ 75,830	$ 75,830	$ 75,830	$ 75,830
Rainwater Harvesting	$ 181,836	$ 181,836	$ 181,836	$ 181,836
Add-on Cost	$ 1,019,930	$ 1,050,562	$ 461,439	$ 2,254,559
Revised Cost	$ 11,262,588	$ 11,293,220	$ 10,704,097	$ 12,497,217
Pecent Increase	9.96%	10.26%	4.51%	22.01%
Notes	(1) These costs are shown in contract costs			
	(2) Baseline builds to meet LEED Silver			

Table A.10 Cost breakdown for UEPH – Fort Lewis

UEPH - Fort Shafter	Low Energy Package 1	Low Energy Package 2	Low Energy Package 3	Low Energy Package 4
Baseline Building	$ 18,209,585	$ 18,209,585	$ 18,209,585	$ 18,209,585
HVAC Components	$ 54,333	$ 108,904	$ (1,115,131)	$ (174,562)
Overhead Radiant Heating	$ -	$ -	$ 328,979	$ -
Ground Source Heat Pump	$ -	$ -	$ -	$ 2,426,003
Solar Hot Water	$ 183,172	$ 183,172	$ 183,172	$ 183,172
Advanced Lighting Systems	$ 173,579	$ 173,579	$ 173,579	$ 173,579
Increased Building Envelope	$ 130,451	$ 130,451	$ 130,451	$ 130,451
Increased Air Tightness	$ 1,431	$ 1,431	$ 1,431	$ 1,431
Increased Window Efficiency	$ 96,218	$ 96,218	$ 96,218	$ 96,218
Entrance Vestibules	$ 88,679	$ 88,679	$ 88,679	$ 88,679
Dual Flush Toilets	$ 70,095	$ 70,095	$ 70,095	$ 70,095
1.5gpm Flow Showerheads	$ 23,105	$ 23,105	$ 23,105	$ 23,105
0.5gpm Flow Faucets	$ 45,109	$ 45,109	$ 45,109	$ 45,109
Light Tube	$ 214,367	$ 214,367	$ 214,367	$ 214,367
Skylight	$ 20,446	$ 20,446	$ 20,446	$ 20,446
Cool Roof	$ 11,919	$ 11,919	$ 11,919	$ 11,919
Enhanced Commissioning	$ 121,472	$ 121,472	$ 121,472	$ 121,472
Measurement & Verification	$ 135,093	$ 135,093	$ 135,093	$ 135,093
Rainwater Harvesting	$ 323,943	$ 323,943	$ 323,943	$ 323,943
Add-on Cost	$ 1,693,412	$ 1,747,983	$ 852,927	$ 3,890,520
Revised Cost	$ 19,902,997	$ 19,957,568	$ 19,062,512	$ 22,100,105
Pecent Increase	9.30%	9.60%	4.68%	21.37%
Notes	(1) These costs are shown in contract costs			
	(2) Baseline builds to meet LEED Silver			

Table A.11 Cost breakdown for UEPH – Fort Shafter

UEPH - Fort Hood	Low Energy Package 1	Low Energy Package 2	Low Energy Package 3	Low Energy Package 4
Baseline Building	$ 7,585,822	$ 7,585,822	$ 7,585,822	$ 7,585,822
HVAC Components	$ 26,846	$ 50,270	$ (476,092)	$ (202,882)
Overhead Radiant Heating	$ -	$ -	$ 141,213	$ -
Ground Source Heat Pump	$ -	$ -	$ -	$ 1,170,124
Solar Hot Water	$ 78,626	$ 78,626	$ 78,626	$ 78,626
Advanced Lighting Systems	$ 74,507	$ 74,507	$ 74,507	$ 74,507
Increased Building Envelope	$ 131,222	$ 131,222	$ 131,222	$ 131,222
Increased Air Tightness	$ 665	$ 665	$ 665	$ 665
Increased Window Efficiency	$ 41,302	$ 41,302	$ 41,302	$ 41,302
Entrance Vestibules	$ 38,065	$ 38,065	$ 38,065	$ 38,065
Dual Flush Toilets	$ 30,088	$ 30,088	$ 30,088	$ 30,088
1.5gpm Flow Showerheads	$ 9,917	$ 9,917	$ 9,917	$ 9,917
0.5gpm Flow Faucets	$ 19,363	$ 19,363	$ 19,363	$ 19,363
Light Tube	$ 92,016	$ 92,016	$ 92,016	$ 92,016
Skylight	$ 8,776	$ 8,776	$ 8,776	$ 8,776
Cool Roof	$ 6,744	$ 6,744	$ 6,744	$ 6,744
Enhanced Commissioning	$ 52,141	$ 52,141	$ 52,141	$ 52,141
Measurement & Verification	$ 57,988	$ 57,988	$ 57,988	$ 57,988
Rainwater Harvesting	$ 139,051	$ 139,051	$ 139,051	$ 139,051
Add-on Cost	$ 807,317	$ 830,741	$ 445,592	$ 1,747,713
Revised Cost	$ 8,393,139	$ 8,416,563	$ 8,031,414	$ 9,333,535
Pecent Increase	10.64%	10.95%	5.87%	23.04%
Notes	(1) These costs are shown in contract costs			
	(2) Baseline builds to meet LEED Silver			

Table A.12 Cost breakdown for UEPH – Fort Hood

UEPH - Fort Wainwright	Low Energy Package 1	Low Energy Package 2	Low Energy Package 3	Low Energy Package 4
Baseline Building	$ 18,080,550	$ 18,080,550	$ 18,080,550	$ 18,080,550
HVAC Components	$ 130,043	$ 251,600	$ (1,096,295)	$ (444,037)
Overhead Radiant Heating	$ -	$ -	$ 332,082	$ -
Ground Source Heat Pump	$ -	$ -	$ -	$ 2,751,720
Solar Hot Water	$ 184,900	$ 184,900	$ 184,900	$ 184,900
Advanced Lighting Systems	$ 175,216	$ 175,216	$ 175,216	$ 175,216
Increased Building Envelope	$ 1,289,666	$ 1,289,666	$ 1,289,666	$ 1,289,666
Increased Air Tightness	$ 1,563	$ 1,563	$ 1,563	$ 1,563
Increased Window Efficiency	$ 97,126	$ 97,126	$ 97,126	$ 97,126
Entrance Vestibules	$ 89,516	$ 89,516	$ 89,516	$ 89,516
Dual Flush Toilets	$ 70,757	$ 70,757	$ 70,757	$ 70,757
1.5gpm Flow Showerheads	$ 23,322	$ 23,322	$ 23,322	$ 23,322
0.5gpm Flow Faucets	$ 45,535	$ 45,535	$ 45,535	$ 45,535
Light Tube	$ 216,389	$ 216,389	$ 216,389	$ 216,389
Skylight	$ 20,639	$ 20,639	$ 20,639	$ 20,639
Cool Roof	$ 15,860	$ 15,860	$ 15,860	$ 15,860
Enhanced Commissioning	$ 122,618	$ 122,618	$ 122,618	$ 122,618
Measurement & Verification	$ 136,367	$ 136,367	$ 136,367	$ 136,367
Rainwater Harvesting	$ 282,147	$ 282,147	$ 282,147	$ 282,147
Add-on Cost	$ 2,901,664	$ 3,023,221	$ 2,007,408	$ 5,079,304
Revised Cost	$ 20,982,214	$ 21,103,771	$ 20,087,958	$ 23,159,854
Pecent Increase	16.05%	16.72%	11.10%	28.09%
Notes	(1) These costs are shown in contract costs			
	(2) Baseline builds to meet LEED Silver			

Table A.13 Cost breakdown for UEPH – Fort Wainwright

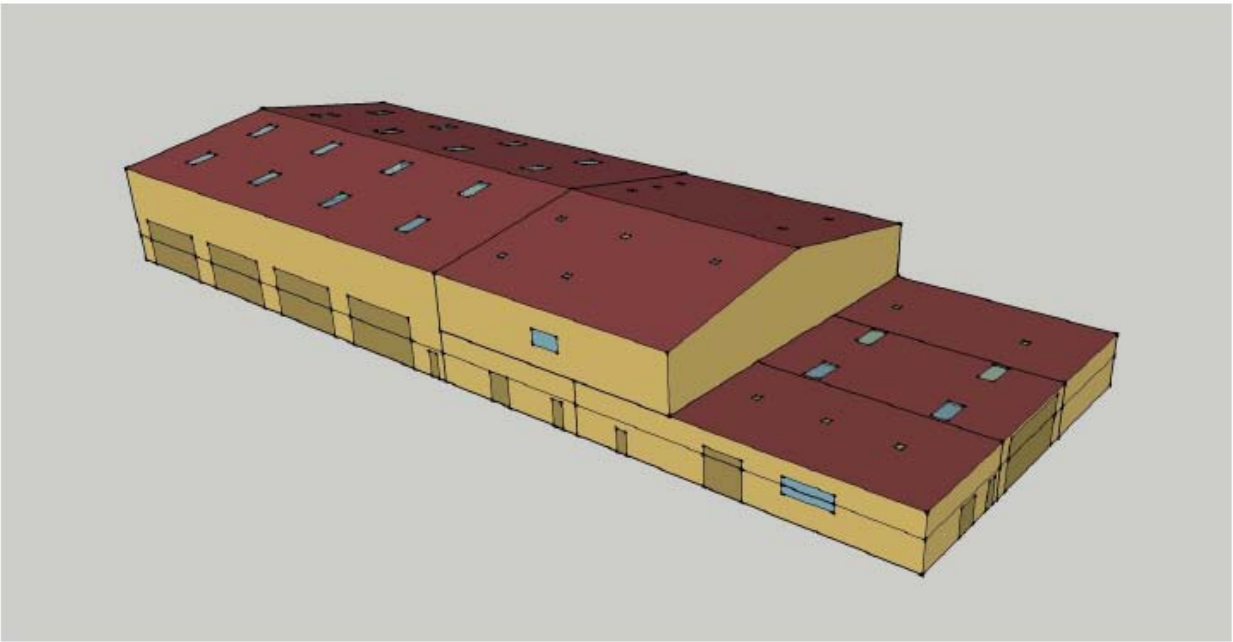
All new Army facilities have been required to increasingly reduce site energy consumption in response to EPACT 2005, then ECB 2010-14, then the Army Sustainable Design and Development Policy Update (Environmental and Energy Performance, October 27, 2010). As the results below show, the UEPH standard Army design including the Low Energy Package 3 EEMs, easily meets all the current site energy reduction mandates for new Army facilities.

Climate Zone	ASHRAE 90.1-2004 EUI (kBTU/sq ft-yr)	ASHRAE 90.1-2007 EUI (kBTU/sq ft-yr)	EPACT 2005 Target EUI + plug loads (kBTU/sq ft-yr)	ASHRAE 189.1 Target EUI (kBTU/sq ft-yr)	ECB 2010-14 Target EUI + plug loads (kBTU/sq ft-yr)	Low Energy Package 3 Site EUI including plug loads (kBTU/sq ft-yr)
1A	102	98	78	78	67	36
2A	102	98	78	78	67	37
2B	65	62	52	49	45	34
3A	91	87	70	69	60	39
3B	63	60	50	48	44	35
3C	67	64	53	51	47	34
4A	95	91	73	72	63	42
4B	68	65	54	52	47	38
4C	80	76	62	61	54	39
5A	97	93	74	74	64	46
5B	75	72	58	57	51	42
6A	103	98	78	78	67	48
6B	88	84	68	67	59	46
7A	111	106	84	84	72	54
8A	143	137	106	109	90	67

Table A.14 UEPH Site Energy EUIs of Low Energy Package 3 Compared to the required site energy reduction targets

Appendix B:

TEMF



Baseline*: Vehicle Maintenance Shop 7th Transportation Battalion PN-20807, FY-2010
Fort Bragg, NC

Figure B.1 Rendering of TEMF baseline building

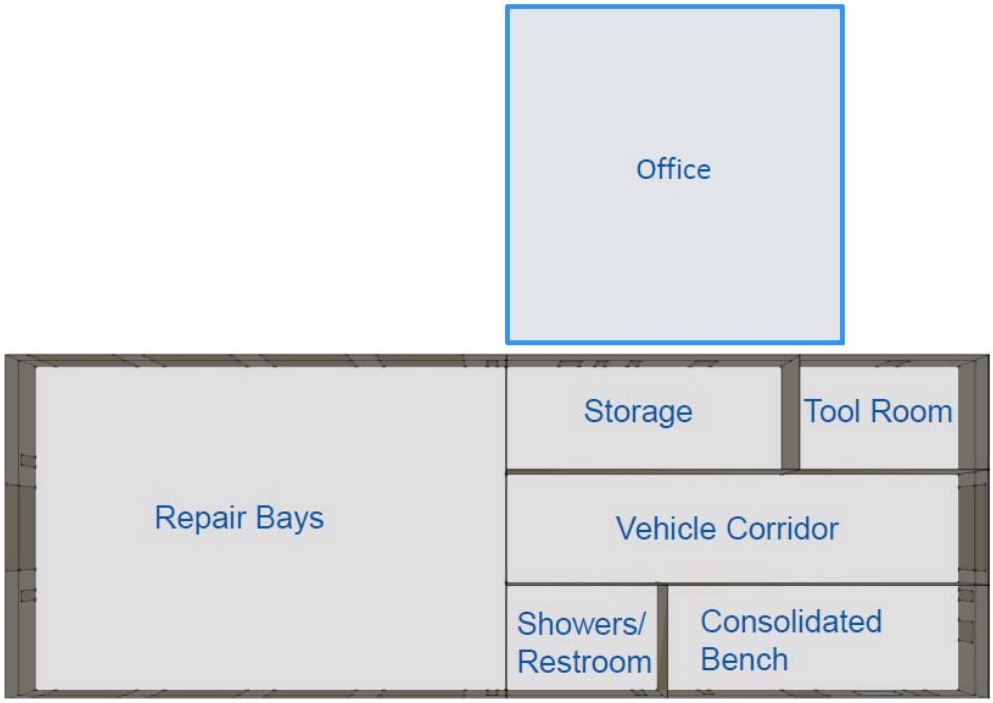


Figure B.2 Floor plan of TEMF baseline building

Parameter	Baseline*	Low Energy
Envelope	ASHRAE 90.1-2007 compliant envelope constructions	Passiv Haus insulation, Passiv Haus rated windows– applied to whole building. Reduced infiltration rates from 0.4 cfm/ft2 to 0.15 cfm/ft2except for Repair Bays and Vehicle Corridor
Lighting	Lighting Power Densities calculated from drawings	Lighting Power Densities recommended by Atellier Ten
Daylighting	No daylighting controls	Increased vertical glazing size by 50%, increased Skylight to Floor Area (SFA) fraction to 3% over admin/office and consolidated bench areas, added clerestory windows to north side of repair bays, added daylighting controls with 500 lux setpoint
HVAC Efficiency	-Standard efficiency CV fans - Cooling coil efficiencies: 3.31-3.55 (COP) - Unit heaters in Repair Bays and Vehicle Corridor	Increased fan efficiency (recommendations from Al Woody): AHU's serving the admin area, workshops, and repair bays have an efficiency of n=70%; Larger exhaust fans n=80%; Sidewall, roof and general exhaust fans n=40%. Cooling coil efficiencies increased to 3.68 (COP)
Repair Bay and Vehicle Corridor Ventilation Reduction	1.5 cfm/ft2	Reduced fan operation from 1.5 cfm/ft2 to 0.12 cfm/ft2 except for an assumed two hours during the day. Values based off of Appendix B in Standard 62.1-2007 – IAQ Procedure for shipping/receiving areas
Transpired Solar Collectors	None	Added to south façade
Radiant Floors	None	Added to the repair bay and vehicle corridor areas
Ground Source Heat Pump	None	Water-to-Air Ground Source Heat Pump

Table B.1 Baseline and energy efficient inputs for energy modeling – TEMF

Fan Efficiency

Zone	Baseline	Recommendation				Fan Type*	
		Large AHU	Large EF	Small AHUs	General EF	Supply	Exhaust
Repair Bay	0.45	0.70	0.80			Centrifugal forward curve	Backward inclined blade centrifugal
Vehicle Corridor	0.45	0.70	0.80			Centrifugal forward curve	Backward inclined blade centrifugal
Mechanical	0.45			0.7	0.4		Centrifugal forward curve
Showers	0.45			0.7	0.4		Centrifugal forward curve
Consolidated Bench	0.45			0.7		Centrifugal forward curve	Centrifugal forward curve
Office	0.45			0.7		Centrifugal forward curve	Centrifugal forward curve
ToolRoom	0.45			0.7		Centrifugal forward curve	Centrifugal forward curve

* Basline uses constant volume fans, recommendation is variable volume fans

Table B.2 Fan efficiency values for TEMF

Glazing Table					
Baseline					
	Vertical Glazing Area (ft^2)				Horizontal Glazing Area (ft^2)
Zone	North	East	South	West	Exposed Roof Area
Repair Bay	0	0	0	0	256
Vehicle Corridor	0	0	0	0	128
Mechanical	0	0	0	0	0
Showers	0	0	0	0	0
Consolidated Bench	0	0	48	0	7.2
Office	80	0	32	0	24
ToolRoom	0	0	0	0	5
Low Energy					
	Vertical Glazing Area				Horizontal Glazing Area
Zone	North	East	South	West	Exposed Roof Area
Repair Bay	288	0	0	0	512
Vehicle Corridor	0	0	0	0	128
Mechanical	0	0	0	0	0
Showers	0	0	0	0	0
Consolidated Bench	0	0	96	0	48
Office	160	96	64	0	192
ToolRoom	0	0	0	0	5

Table B.3 Glazing values for baseline TEMF

Lighting Power Density Levels				
	Baseline		Recommendation	
Zone	(W/ft^2)	(W/m^2)	(W/ft^2)	(W/m^2)
Repair Bay	1.20	12.917	0.85	9.146
Vehicle Corridor	0.90	9.688	0.75	8.07
Mechanical	0.70	7.535	0.70	7.532
Showers	0.70	7.535	0.80	8.608
Consolidated Bench	0.80	8.611	0.55	5.918
Office	0.55	5.92	0.70	7.532
ToolRoom	0.70	7.535	0.65	6.994

Table B.4 Lighting Power Density values for TEMF

	Design Criteria			Control Strategies				Technologies				Approach				
				Levels	Automatic Interface											
Space	Target Illuminance at Task [fc] (Design Goal)	Target Lighting Power Density [W/ft²] (Project Design Goal)	Allowable Lighting Power Density [W/ft²] (ASHRAE/IESNA Std 90.1-2004/2007)	Switching - (blank) Multi-Level - M Full Dimming - D	V - Vacancy [Manual ON / Auto OFF] O - Occupancy [Auto ON / Auto OFF]	Daylight (e.g. Photosensors)	Schedule (e.g. Astronomical time-clock)	Linear Fluorescent	Compact Fluorescent	Ceramic Metal Halide	Light Emitting Diodes	Overhead General Lighting	Overhead Ambient Lighting	Task Lighting	Wallwash / Perimeter Lighting	Adjustable Accent Lighting
Classroom / Training	40	0.75	1.4	M	V	☼		✓				•			•	
Conference Room	40	0.80	1.3	M/D	V			✓				•			•	
Consolidated Bench Repair	50	0.55	1.9		V			✓			✓	•		•		
Corridor	10	0.50	0.5		O			✓				•			•	
Maintenance Pit	15	0.70	1.9					✓			✓			•		
Mechanical / Electrical	30	0.70	1.5		V			✓				•				
Office (Open)	40	0.70	1.1	M/D	V	☼	⏲	✓		✓	✓		•	•	•	•
Repair Bay	50	0.85	1.9		V	☼	⏲	✓				•				
Restroom / Shower	20	0.80	0.9		V			✓	✓		✓	•			•	
Stair	10	0.50	0.6	M	O			✓				•				
Storage (General)	10	0.50	0.8		V			✓				•				•
Storage / Vaults (Occupied)	40	0.65	1.9		V			✓			✓	•				
Telecom / SIPRNET	50	1.20	1.5		V			✓				•				
Vehicle Corridor	50	0.75	0.7		V		⏲	✓				•				

Table B.5 Atelier Ten Lighting Design Guide Recommendations Table - TEMF

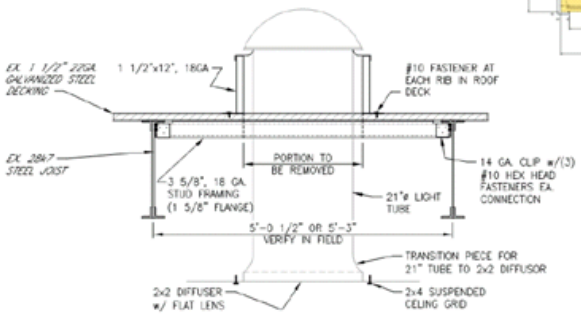
Space	Lighting	Controls
Classroom / Training	Light teaching wall; minimize glare	Provide zoning and circuiting for lecture mode and AV mode, control teaching wall luminaires independent of general lighting
Conference Room	Provide light on people's faces if video conferencing, glare control	Multi-scene preset scene controller may be appropriate in some cases; Use multi-level or dimming ballasts where appropriate
Consolidated Bench Repair	Locate luminaires relative to working areas and critical equipment	
Corridor		Occupancy sensors to reduce load to 25%-50% when vacancy is detected. Multi-Level ballasts may be appropriate in many cases
Maintenance Pit	Provide portable hazardous location task light	Local manual controls only
Mechanical / Electrical	Locate luminaires relative to working areas and equipment	Dual-technology vacancy sensors with long time out
Office (Open)	Use task/ambient scheme with furniture or ceiling mounted ambient lighting and furniture mounted task lighting	
Repair Bay	Luminaire mounting locations limited by overhead obstructions; optimize daylight; wire-guard and shielding recommended; Use narrow distribution	Luminaires wired for one-third/two-third/full output; luminaires and vacancy sensors zoned an controlled by repair bay
Restroom / Shower	Lighting over sink and toilet wall will often be enough for entire restroom	Dual-technology vacancy sensor
Stair	Locate luminaires to provide 10fc at landings	Use bi-level luminaire with integrated occupancy sensor
Storage (General)	Locate and specify luminaires to light vertical surfaces	
Storage / Vaults (Occupied)	Provide lighing on desks and work areas as well as vertical surfaces	
Telecom / SIPRNET	Lighting should be designed to provide 50 fc, LPDs will may be higher for very small telecom rooms and lower for larger rooms.	
Vehicle Corridor	Use medium/wide distribution luminaire	Luminaires wired for one-third/full output; luminaires switched to one-third when vacancy is detected

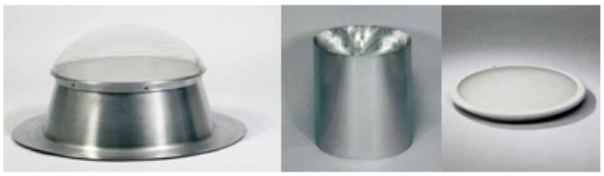
Table B.6 Atelier Ten Lighting Design Guide Notes - TEMF

Skylight Design Recommendations

•Standard skylights should be able to provide sufficient daylight to the upper-level offices and the lower-level storage area and small workshops.

•Tubular skylight can be used in the repair bays and maintenance area, if the larger skylights are not applicable (or not cost-effective) because of the high racks or the high-bay roof structure.





Reference: http://carlislesyntec.com/mka.cfm?id=520

Figure B.3 TEMF daylighting recommendations

TEMF Climate Zone 1A				
	Item	***Component***	***Baseline***	***Recommendation*** Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-15 ci
		Metal Building	R-19	
		Attic and Other	R-30	
	Walls	Mass	NR	R-13
		Steel Framed	R-13	
		Metal Building	R-13	
	Floors Over Unconditioned Space	Mass	NR	NR
		Steel Joist	NR	NR
		Wood Framed and Other	NR	NR
	Slab-on-Grade	Unheated	NR	NR
	Doors	Swinging	U-0.7	U-0.7
		Non-Swinging	U-1.45	U-1.45
	Infiltration	Areas that are mechanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10% See Glazing Table	Increased window area by 50% in Admin and Consolidated Bench spaces. Added 3x24' clerestory windows above north facing Repair Bay doors. See Glazing Table
		Thermal transmittance	U-1.22	U-0.26
		Solar heat gain coefficient (SHGC)	0.25	0.25
	Skylights	Percent Roof Area	4% Repair Bays, 0.34% Admin, 6.56% Vehicle Corridor, 0.36% Tool Room, 0.36% Consolidated Bench See Glazing Table	4% in Repair Bays, 3% of roof area for the rest of the building See Glazing Table
		Thermal transmittance	U-1.98	U-1.36
		SHGC	0.36	0.19
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Air Conditioner	See Fan Efficiency Table	See Fan Efficiency Table
		Make Up Air Unit Fans	PSZ-AC 12.1 EER	PSZ-AC 12.5 EER
		Gas Boiler	Natural Draft Condensing 90%	Natural Draft Condensing 90%
		Hydronic Radiant Floor Heat	None	None
		ERV	Shower Area	Shower Area
		Economizer	NR	None
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	NR	Repair Bays and Vehicle Corridor
		Transpired Solar Collectors	None	None

Table B.7 Recommended prescriptive values for low energy model – TEMF CZ 1A

TEMF Climate Zone 2A, 3B				
	Item	***Component***	***Baseline***	***Recommendation*** Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-15 ci
		Metal Building	R-19	
		Attic and Other	R-30	
	Walls	Mass	NR	R-13
		Steel Framed	R-13	
		Metal Building	R-13	
	Floors Over Unconditioned Space	Mass	R-4.2 ci	R-4.2 ci
		Steel Joist	R-19	R-19
		Wood Framed and Other	R-19	R-19
	Slab-on-Grade	Unheated	NR	NR
	Doors	Swinging	U-0.7	U-0.7
		Non-Swinging	U-1.45	U-1.45
	Infiltration	Areas that are mechanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10% See Glazing Table	Increased window area by 50% in Admin and Consolidated Bench spaces. Added 3x24' clerestory windows above north facing Repair Bay doors. See Glazing Table
		Thermal transmittance	U-1.22	U-0.26
		Solar heat gain coefficient (SHGC)	0.25	0.25
	Skylights	Percent Roof Area	4% Repair Bays, 0.34% Admin, 6.56% Vehicle Corridor, 0.36% Tool Room, 0.36% Consolidated Bench See Glazing Table	4% in Repair Bays, 3% of roof area for the rest of the building See Glazing Table
		Thermal transmittance	U-1.98	U-1.36
		SHGC	0.36	0.19
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Air Conditioner	See Fan Efficiency Table	See Fan Efficiency Table
		Make Up Air Unit Fans	PSZ-AC 12.1 EER	PSZ-AC 12.5 EER
		Gas Boiler	Natural Draft Condensing 90%	Natural Draft Condensing 90%
		Hydronic Radiant Floor Heat	None	None
		ERV	Shower Area	Shower Area
		Economizer	NR	None
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	NR	Repair Bays and Vehicle Corridor
		Transpired Solar Collectors	None	1,950 ft2 on South Façade of Repair Bay

Table B.8 Recommended prescriptive values for low energy model – TEMF CZ 2A, 2B

	TEMF Climate Zone 3A, 3B, 3C			
	Item	***Component***	***Baseline***	***Recommendation*** Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-35 (R-15 ci for 3C)
		Metal Building	R-19	
		Attic and Other	R-30	
	Walls	Mass	R-5.7 ci	R-24 (R-13 for 3C)
		Steel Framed	R-13	
		Metal Building	R-13	
	Floors Over Unconditioned Space	Mass	R-6.3 ci	R-10.4 ci (R-6.3 ci for 3C)
		Steel Joist	R-19	R-30 (R-19 for 3C)
		Wood Framed and Other	R-19	R-30 (R-19 for 3C)
	Slab-on-Grade	Unheated	NR	R-14 (NR for 3C)
	Doors	Swinging	U-0.7	U-0.7
		Non-Swinging	U-1.45	U-0.5
	Infiltration	Areas that are mechanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10% See Glazing Table	Increased window area by 50% in Admin and Consolidated Bench spaces. Added 3x24' clerestory windows above north facing Repair Bay doors. See Glazing Table
		Thermal transmittance	U-0.57 (U-1.22 for 3C)	U-0.26
		Solar heat gain coefficient (SHGC)	0.39 (0.61 for 3C)	0.39
	Skylights	Percent Roof Area	4% Repair Bays, 0.34% Admin, 6.56% Vehicle Corridor, 0.36% Tool Room, 0.36% Consolidated Bench See Glazing Table	4% in Repair Bays, 3% of roof area for the rest of the building See Glazing Table
		Thermal transmittance	U-1.98	U-0.69
		SHGC	0.36	0.16
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Air Conditioner	See Fan Efficiency Table	See Fan Efficiency Table
		Make Up Air Unit Fans	PSZ-AC 12.1 EER	PSZ-AC 12.5 EER
		Gas Boiler	Natural Draft Condensing 90%	Natural Draft Condensing 90%
		Hydronic Radiant Floor Heat	None	None (Yes- 3C)
		ERV	Shower Area	Shower Area
		Economizer	NR	None
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	NR	Repair Bays and Vehicle Corridor
		Transpired Solar Collectors	None	1,950 ft2 on South Façade of Repair Bay

Table B.9 Recommended prescriptive values for low energy model – TEMF CZ 3A, 3B, 3C

	TEMF Climate Zone 4A, 4B, 4C			
	Item	***Component***	***Baseline***	***Recommendation***
				Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-47 (R-35 for 4C)
		Metal Building	R-19	
		Attic and Other	R-30	
	Walls	Mass	R-5.7 ci	R-31 (R-24 for 4C)
		Steel Framed	R-13	
		Metal Building	R-13	
	Floors Over Unconditioned Space	Mass	R-6.3 ci	R-12.5 ci
		Steel Joist	R-19	R-30
		Wood Framed and Other	R-19	R-30
	Slab-on-Grade	Unheated	NR	R-19 (R-14 for 4C)
	Doors	Swinging	U-0.7	U-0.5
		Non-Swinging	U-1.45	U-0.5
	Infiltration	Areas that are mechanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10% See Glazing Table	Increased window area by 50% in Admin and Consolidated Bench spaces. Added 3x24' clerestory windows above north facing Repair Bay doors. See Glazing Table
		Thermal transmittance	U-0.57	U-0.18
		Solar heat gain coefficient (SHGC)	0.39	0.39
	Skylights	Percent Roof Area	4% Repair Bays, 0.34% Admin, 6.56% Vehicle Corridor, 0.36% Tool Room, 0.36% Consolidated Bench See Glazing Table	4% in Repair Bays, 3% of roof area for the rest of the building See Glazing Table
		Thermal transmittance	U-1.98	U-0.69
		SHGC	0.36	0.32
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Air Conditioner	See Fan Efficiency Table	See Fan Efficiency Table
		Make Up Air Unit Fans	PSZ-AC 12.1 EER	PSZ-AC 12.5 EER
		Gas Boiler	Natural Draft Condensing 90%	Natural Draft Condensing 90%
		Hydronic Radiant Floor Heat	None	None
		ERV	Shower Area	Shower Area
		Economizer	NR	None
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	NR	Repair Bays and Vehicle Corridor
		Transpired Solar Collectors	None	1,950 ft2 on South Façade of Repair Bay

Table B.10 Recommended prescriptive values for low energy model – TEMF CZ 4A, 4B, 4C

	TEMF Climate Zone 5A, 5B			
	Item	***Component***	***Baseline***	***Recommendation***
				Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-57
		Metal Building	R-19	
		Attic and Other	R-30	
	Walls	Mass	R-7.6 ci	R-38
		Steel Framed	R-13 + R-3.8 ci	
		Metal Building	R-13	
	Floors Over Unconditioned Space	Mass	R-8.3 ci	R-12.5 ci
		Steel Joist	R-19	R-30
		Wood Framed and Other	R-30	R-30
	Slab-on-Grade	Unheated	NR	R-23
	Doors	Swinging	U-0.7	U-0.5
		Non-Swinging	U-1.45	U-0.5
	Infiltration	Areas that are mechanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10% See Glazing Table	Increased window area by 50% in Admin and Consolidated Bench spaces. Added 3x24' clerestory windows above north facing Repair Bay doors. See Glazing Table
		Thermal transmittance	U-0.57	U-0.18
		Solar heat gain coefficient (SHGC)	0.49	0.49
	Skylights	Percent Roof Area	4% Repair Bays, 0.34% Admin, 6.56% Vehicle Corridor, 0.36% Tool Room, 0.36% Consolidated Bench See Glazing Table	4% in Repair Bays, 3% of roof area for the rest of the building See Glazing Table
		Thermal transmittance	U-1.98	U-0.69
		SHGC	0.36	0.36
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Air Conditioner	See Fan Efficiency Table	See Fan Efficiency Table
		Make Up Air Unit Fans	PSZ-AC 12.1 EER	PSZ-AC 12.5 EER
		Gas Boiler	Natural Draft Condensing 90%	Natural Draft Condensing 90%
		Hydronic Radiant Floor Heat	None	None
		ERV	Shower Area	Shower Area
		Economizer	NR	None
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	NR	Repair Bays and Vehicle Corridor
		Transpired Solar Collectors	None	1,950 ft2 on South Façade of Repair Bay

Table B.11 Recommended prescriptive values for low energy model – TEMF CZ 5A, 5B

	TEMF Climate Zone 6A, 6B			
	Item	***Component***	***Baseline***	***Recommendation***
				Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-71
		Metal Building	R-19	
		Attic and Other	R-38	
	Walls	Mass	R-9.5 ci	R-47
		Steel Framed	R-13 + R-3.8 ci	
		Metal Building	R-13	
	Floors Over Unconditioned Space	Mass	R-8.3 ci	R-12.5 ci
		Steel Joist	R-30	R-30
		Wood Framed and Other	R-30	R-30
	Slab-on-Grade	Unheated	NR	R-28
	Doors	Swinging	U-0.7	U-0.5
		Non-Swinging	U-1.45	U-0.5
	Infiltration	Areas that are mechanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10% See Glazing Table	Increased window area by 50% in Admin and Consolidated Bench spaces. Added 3x24' clerestory windows above north facing Repair Bay doors. See Glazing Table
		Thermal transmittance	U-0.57	U-0.18
		Solar heat gain coefficient (SHGC)	0.49	0.49
	Skylights	Percent Roof Area	4% Repair Bays, 0.34% Admin, 6.56% Vehicle Corridor, 0.36% Tool Room, 0.36% Consolidated Bench See Glazing Table	4% in Repair Bays, 3% of roof area for the rest of the building See Glazing Table
		Thermal transmittance	U-1.98	U-0.69
		SHGC	0.36	0.46
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Air Conditioner	See Fan Efficiency Table	See Fan Efficiency Table
		Make Up Air Unit Fans	PSZ-AC 12.1 EER	PSZ-AC 12.5 EER
		Gas Boiler	Natural Draft Condensing 90%	Natural Draft Condensing 90%
		Hydronic Radiant Floor Heat	None	None
		ERV	Shower Area	Shower Area
		Economizer	NR	None
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	NR	Repair Bays and Vehicle Corridor
		Transpired Solar Collectors	None	1,950 ft2 on South Façade of Repair Bay

Table B.12 Recommended prescriptive values for low energy model – TEMF CZ 6A, 6B

	TEMF Climate Zone 7			
	Item	***Component***	***Baseline***	***Recommendation***
				Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-94
		Metal Building	R-19	
		Attic and Other	R-38	
	Walls	Mass	R-11.4 ci	R-63
		Steel Framed	R-13 + R-7.5 ci	
		Metal Building	R-13 + R-13	
	Floors Over Unconditioned Space	Mass	R-8.3 ci	R-14.6 ci
		Steel Joist	R-30	R-38
		Wood Framed and Other	R-30	R-30
	Slab-on-Grade	Unheated	NR	R-38
	Doors	Swinging	U-0.7	U-0.5
		Non-Swinging	U-1.45	U-0.5
	Infiltration	Areas that are mechanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10% See Glazing Table	Increased window area by 50% in Admin and Consolidated Bench spaces. Added 3x24' clerestory windows above north facing Repair Bay doors. See Glazing Table
		Thermal transmittance	U-0.57	U-0.18
		Solar heat gain coefficient (SHGC)	0.49	0.49
	Skylights	Percent Roof Area	4% Repair Bays, 0.34% Admin, 6.56% Vehicle Corridor, 0.36% Tool Room, 0.36% Consolidated Bench See Glazing Table	4% in Repair Bays, 3% of roof area for the rest of the building See Glazing Table
		Thermal transmittance	U-1.98	U-0.69
		SHGC	0.36	0.64
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Air Conditioner	See Fan Efficiency Table	See Fan Efficiency Table
		Make Up Air Unit Fans	PSZ-AC 12.1 EER	PSZ-AC 12.5 EER
		Gas Boiler	Natural Draft Condensing 90%	Natural Draft Condensing 90%
		Hydronic Radiant Floor Heat	None	Yes
		ERV	Shower Area	Shower Area
		Economizer	NR	None
		Ground Source Heat Pump (GSHP)	None	Yes
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	NR	Repair Bays and Vehicle Corridor
		Transpired Solar Collectors	None	1,950 ft2 on South Façade of Repair Bay

Table B.13 Recommended prescriptive values for low energy model – TEMF CZ 7

	TEMF Climate Zone 8			
	Item	***Component***	***Baseline***	***Recommendation*** Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-20 ci	R-106
		Metal Building	R-13 + R-19	
		Attic and Other	R-38	
	Walls	Mass	R-13.3 ci	R-71
		Steel Framed	R-13 + R-7.5 ci	
		Metal Building	R-13 + R-13	
	Floors Over Unconditioned Space	Mass	R-12.5 ci	R-14.6 ci
		Steel Joist	R-30	R-38
		Wood Framed and Other	R-30	R-30
	Slab-on-Grade	Unheated	R-10 for 24 in.	R-37
	Doors	Swinging	U-0.7	U-0.5
		Non-Swinging	U-1.45	U-0.5
	Infiltration	Areas that are mechanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10% See Glazing Table	Increased window area by 50% in Admin and Consolidated Bench spaces. Added 3x24' clerestory windows above north facing Repair Bay doors. See Glazing Table
		Thermal transmittance	U-0.46	U-0.18
		Solar heat gain coefficient (SHGC)	NR	0.49
	Skylights	Percent Roof Area	4% Repair Bays, 0.34% Admin, 6.56% Vehicle Corridor, 0.36% Tool Room, 0.36% Consolidated Bench See Glazing Table	4% in Repair Bays, 3% of roof area for the rest of the building See Glazing Table
		Thermal transmittance	U-1.98	U-0.58
		SHGC	0.36	0.64
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Air Conditioner	See Fan Efficiency Table	See Fan Efficiency Table
		Make Up Air Unit Fans	PSZ-AC 12.1 EER	PSZ-AC 12.5 EER
		Gas Boiler	Natural Draft Condensing 90%	Natural Draft Condensing 90%
		Hydronic Radiant Floor Heat	None	Yes
		ERV	Shower Area	Shower Area
		Economizer	NR	None
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	NR	Repair Bays and Vehicle Corridor
		Transpired Solar Collectors	None	1,950 ft2 on South Façade of Repair Bay

Table B.14 Recommended prescriptive values for low energy model – TEMF CZ 8

Site EUI For Each EEM

1. Lighting Power Density (LPD) reduction (Atelier Ten)
2. Increased daylighting and LPD reduction
3. Passiv Haus insulation and windows, reduced infiltration except for Repair Bays and Vehicle Corridor
4. Passiv Haus insulation, reduced LPD and infiltration rates, increased daylighting
5. Passiv Haus insulation, reduced LPD and infiltration rates, no skylights
6. Increased fan and HVAC efficiency, VAV fans
7. Reduced ventilation in repair bays and vehicle corridor to 0.12 cfm/ft2 except for two hours /day at 1.5 cfm/ft2
8. Reduced ventilation in repair bays and vehicle corridor, plus transfer air from office to repair bays
9. Transpired solar collector added to south facing façade
10. Radiant floors added to repair bay and vehicle corridor
11. Ground source heat pump
12. LowE_1: Uses lowest energy strategies (highlighted strategies out of 1-8)
13. LowE_2: Uses highlighted strategies (out of 1-8) plus TSCs
14. LowE_3: Uses highlighted strategies (out of 1-9) plus radiant floors
15. LowE_4: Uses highlighted strategies (out of 1-8) plus TSC and radiant floors (see highlighted option)

	EEMs:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Site Energy [kBtu/ft2]	Baseline	LPD	Dyltg and LPD	Passiv Haus	Passiv Haus, LPD, Dyltg	Passiv Haus, LPD, No Skylights	HVAC efficiency	Reduced Ventilation	Reduced Ventilation and Transfer Air	Transpired Solar Collectors	Radiant Floors	Ground Source Heat Pump	LowE_1: Best of 1-8	LowE_2: Best of 1-8, TSC	LowE_3: Best of 1-8, Rad Flrs	LowE_4: Best of 1-8, TSC, Rad Flrs
1A Miami	27	25	22	27	25	25	23	22	22	26	27	31	15	15	16	16
2A Houston	33	31	28	30	28	29	28	25	25	31	30	38	20	19	20	19
2B Phoenix	31	30	27	30	28	28	27	25	25	30	29	37	19	19	20	19
3A Memphis	41	40	37	36	34	35	35	30	30	37	36	47	22	21	22	21
3B El Paso	36	35	31	32	30	30	30	27	27	33	31	42	20	19	20	19
3C San Francisco	32	31	28	30	27	28	27	24	24	30	30	37	18	18	17	16
4A Baltimore	55	54	51	47	44	46	46	38	37	48	47	62	26	24	26	24
4B Albuquerque	46	45	42	39	36	38	38	33	32	40	38	55	22	20	22	21
4C Seattle	51	50	47	45	42	44	40	33	32	45	44	54	24	22	24	23
5A Chicago	68	67	64	58	55	57	56	44	44	59	58	75	31	29	31	29
5B Colorado Springs	58	57	54	49	46	48	49	39	39	49	48	70	27	24	27	24
6A Burlington	78	77	75	66	62	65	67	52	51	69	71	89	36	33	35	33
6B Helena	74	73	71	62	59	61	63	49	48	65	65	84	33	30	33	30
7A Duluth	94	94	92	80	76	79	84	62	61	84	84	106	43	39	42	39
8A Fairbanks	138	137	137	117	115	116	131	93	91	128	130	167	69	65	65	63

Table B.15 Site EUI for each EEM package - TEMF

Site Energy Savings For Each EEM

1. Lighting Power Density (LPD) reduction (Atelier Ten)
2. Increased daylighting and LPD reduction
3. Passiv Haus insulation and windows, reduced infiltration except for Repair Bays and Vehicle Corridor
4. Passiv Haus insulation, reduced LPD and infiltration rates, increased daylighting
5. Passiv Haus insulation, reduced LPD and infiltration rates, no skylights
6. Increased fan and HVAC efficiency, VAV fans
7. Reduced ventilation in repair bays and vehicle corridor to 0.12 cfm/ft2 except for two hours /day at 1.5 cfm/ft2
8. Reduced ventilation in repair bays and vehicle corridor, plus transfer air from office to repair bays
9. Transpired solar collector added to south facing façade
10. Radiant floors added to repair bay and vehicle corridor
11. Ground source heat pump
12. LowE_1: Uses lowest energy strategies (highlighted strategies out of 1-8)
13. LowE_2: Uses highlighted strategies (out of 1-8) plus TSCs
14. LowE_3: Uses highlighted strategies (out of 1-9) plus radiant floors
15. LowE_4: Uses highlighted strategies (out of 1-8) plus TSC and radiant floors (see highlighted option)

	EEMs:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Site Energy Savings Compared to Baseline	Baseline	LPD	Dyltg and LPD	Passiv Haus	Passiv Haus, LPD, Dyltg	Passiv Haus, LPD, No Skylights	HVAC efficiency	Reduced Ventilation	Reduced Ventilation and Transfer Air	Transpired Solar Collectors	Radiant Floors	Ground Source Heat Pump	LowE_1: Best of 1-8	LowE_2: Best of 1-8, TSC	LowE_3: Best of 1-8, Rad Flrs	LowE_4: Best of 1-8, TSC, Rad Flrs
1A Miami	-	4%	19%	-2%	7%	4%	13%	18%	18%	1%	-1%	-16%	43%	43%	38%	39%
2A Houston	-	4%	13%	7%	14%	12%	13%	23%	23%	5%	9%	-18%	39%	41%	40%	42%
2B Phoenix	-	4%	13%	6%	12%	11%	15%	21%	21%	4%	7%	-16%	39%	40%	37%	39%
3A Memphis	-	3%	10%	12%	18%	16%	15%	27%	28%	10%	14%	-15%	46%	49%	46%	49%
3B El Paso	-	3%	12%	11%	18%	15%	16%	25%	25%	8%	13%	-18%	45%	46%	44%	46%
3C San Francisco	-	4%	15%	8%	15%	13%	16%	27%	28%	8%	9%	-13%	43%	45%	47%	49%
4A Baltimore	-	2%	7%	15%	20%	17%	17%	32%	32%	13%	15%	-12%	53%	56%	52%	56%
4B Albuquerque	-	2%	9%	15%	21%	18%	17%	29%	30%	14%	17%	-20%	52%	56%	52%	55%
4C Seattle	-	2%	7%	11%	17%	14%	22%	36%	36%	11%	14%	-6%	54%	56%	53%	55%
5A Chicago	-	2%	5%	14%	19%	16%	18%	35%	35%	13%	14%	-10%	54%	58%	54%	57%
5B Colorado Springs	-	2%	7%	15%	20%	17%	15%	32%	33%	15%	17%	-22%	54%	59%	54%	59%
6A Burlington	-	1%	4%	16%	20%	17%	14%	33%	34%	11%	10%	-14%	54%	58%	55%	58%
6B Helena	-	1%	4%	16%	20%	18%	15%	34%	35%	13%	12%	-13%	56%	59%	56%	59%
7A Duluth	-	1%	3%	16%	19%	17%	11%	34%	35%	11%	11%	-12%	54%	59%	55%	59%
8A Fairbanks	-	1%	1%	15%	17%	16%	5%	33%	34%	7%	6%	-21%	50%	53%	53%	55%

Table B.16 Site energy savings (%) for each EEM package – TEMF

Comparison to ASHRAE 189.1 – TEMF (Site) Climate Zone 2A

EUI [kBtu/ft2]	*CBECS 2003*	*Baseline*	*Standard 189.1 Prescriptive Option*	*EISA 2007 – Low Energy Model*	*EISA2007 w/Reduced Ventilation*
Interior Lighting		7.38	5.73	2.43	2.43
Interior Equipment		7.56	7.22	7.56	7.56
Fans		9.33	8.48	6.84	3.20
Pumps		0.01	0.01	0.01	0.01
Water Systems (gas)		0.35	0.35	0.35	0.35
Cooling (elec)		1.76	1.29	2.08	2.10
Heating (gas)		6.23	3.99	4.20	3.29
Total Energy	**84**	**32.61**	**27.06**	**23.47**	**18.92**
30 kW PV System	-	-	**-4.17**	-	-
Total Energy w/ 30kW PV System	**84**	**32.61 (61%)**	**22.89 (72%)**	**23.47 (72%)**	**18.92 (77%)**
Subtotal % Savings Compared to Baseline		**-**	**30%**	**28%**	**42%**
Building Cost		**$6,305,655**	**$7,278,833**	**$6,911,767**	**$6,911,767**
Cost Increase (%)		**-**	**$973,228 (+15.4%)**	**$606,112 (+9.6%)**	**$606,112 (+9.6%)**

Total Energy without PV System (% Savings CBECS)	**84**	**32.61 (61%)**	**27.06 (68%)**	**23.47 (72%)**	**18.92 (77%)**
Building Cost		**$6,305,655**	**$6,494,825**	**$6,911,767**	**$6,911,767**
Cost Increase (%)		**-**	**$189,170(+3%)**	**$699,601 (+9.6%)**	**$699,601 (+9.6%)**

Table B.17 Cost and energy comparison of ASHRAE 189.1 to baseline and low energy model – CZ 2A

TEMF - Fort Campbell	Low Energy Package 1	Low Energy Package 2	Low Energy Package 3	Low Energy Package 4
Baseline Building	$ 6,969,882	$ 6,969,882	$ 6,969,882	$ 6,969,882
HVACE Components	$ (67,518)	$ (67,518)	$ (97,709)	$ (97,709)
Increased Fan & HVAC Efficiency VAV Fans	$ 85,685	$ 85,685	$ 85,685	$ 85,685
Reduced Ventilation in Repair Bays & Vehicle Corridor plus Transfer Air from Office to Repair Bays	$ 6,212	$ 6,212	$ 6,212	$ 6,212
Floor Radiant Heating	$ -	$ -	$ 115,034	$ 115,034
Solar Collector Wall	$ -	$ 85,502	$ -	$ 85,502
Advanced Lighting Systems	$ 6,771	$ 6,771	$ 6,771	$ 6,771
Increased Building Envelope Efficiency	$ 176,059	$ 176,059	$ 176,059	$ 176,059
Increased Window Efficiency	$ 16,882	$ 16,882	$ 16,882	$ 16,882
Dual Flush Toilets	$ 2,437	$ 2,437	$ 2,437	$ 2,437
Waterless Urinals	$ (1,074)	$ (1,074)	$ (1,074)	$ (1,074)
0.5gpm Flow Faucets	$ 6,399	$ 6,399	$ 6,399	$ 6,399
1.5gpm Flow Showerheads	$ 467	$ 467	$ 467	$ 467
Light Tubes	$ 16,560	$ 16,560	$ 16,560	$ 16,560
Skylights	$ 20,372	$ 20,372	$ 20,372	$ 20,372
Transluscent Sandwich Panels	$ 11,102	$ 11,102	$ 11,102	$ 11,102
Enhanced Commissioning	$ 56,002	$ 56,002	$ 56,002	$ 56,002
Measurement & Verification	$ 64,249	$ 64,249	$ 64,249	$ 64,249
Rainwater Harvesting	$ 99,941	$ 99,941	$ 99,941	$ 99,941
Add-on Cost	$ 500,546	$ 586,048	$ 585,389	$ 670,891
Revised Cost	$ 7,470,428	$ 7,555,930	$ 7,555,271	$ 7,640,773
Pecent Increase	7.18%	8.41%	8.40%	9.63%
Notes	(1) These costs are shown in contract costs			
	(2) Building Envelope includes foundation insulation, wall panels, wall insulation, roof insulation, door insulation, all vapor barrier			
	(3) The total cost of the HVAC package is the sum of the HVAC package and the floor radiant heating and solar wall collector			

Table B.18 Cost breakdown for TEMF – Fort Campbell

TEMF - Fort Bliss	Low Energy Package 1	Low Energy Package 2	Low Energy Package 3	Low Energy Package 4
Baseline Building	$ 7,529,077	$ 7,529,077	$ 7,529,077	$ 7,529,077
HVACE Components	$ (72,918)	$ (72,918)	$ (105,524)	$ (105,524)
Increased Fan & HVAC Efficiency VAV Fans	$ 92,539	$ 92,539	$ 92,539	$ 92,539
Reduced Ventilation in Repair Bays & Vehicle Corridor plus Transfer Air from Office to Repair Bays	$ 6,709	$ 6,709	$ 6,709	$ 6,709
Floor Radiant Heating	$ -	$ -	$ 124,237	$ 124,237
Solar Collector Wall	$ -	$ 92,342	$ -	$ 92,342
Advanced Lighting Systems	$ 3,029	$ 3,029	$ 3,029	$ 3,029
Increased Building Envelope Efficiency	$ 173,315	$ 173,315	$ 173,315	$ 173,315
Increased Window Efficiency	$ 18,232	$ 18,232	$ 18,232	$ 18,232
Dual Flush Toilets	$ 2,632	$ 2,632	$ 2,632	$ 2,632
Waterless Urinals	$ (1,159)	$ (1,159)	$ (1,159)	$ (1,159)
0.5gpm Flow Faucets	$ 6,911	$ 6,911	$ 6,911	$ 6,911
1.5gpm Flow Showerheads	$ 505	$ 505	$ 505	$ 505
Light Tubes	$ 17,886	$ 17,886	$ 17,886	$ 17,886
Skylights	$ 22,001	$ 22,001	$ 22,001	$ 22,001
Transluscent Sandwich Panels	$ 11,991	$ 11,991	$ 11,991	$ 11,991
Enhanced Commissioning	$ 62,455	$ 62,455	$ 62,455	$ 62,455
Measurement & Verification	$ 69,458	$ 69,458	$ 69,458	$ 69,458
Rainwater Harvesting	$ 85,101	$ 85,101	$ 85,101	$ 85,101
Add-on Cost	$ 498,687	$ 591,029	$ 590,318	$ 682,660
Revised Cost	$ 8,027,764	$ 8,120,106	$ 8,119,395	$ 8,211,737
Pecent Increase	6.62%	7.85%	7.84%	9.07%
Notes	(1) These costs are shown in contract costs			
	(2) Building Envelope includes foundation insulation, wall panels, wall insulation, roof insulation, door insulation, all vapor barrier			
	(3) The total cost of the HVAC package is the sum of the HVAC package and the floor radiant heating and solar wall collector			

Table B.19 Cost breakdown for TEMF – Fort Bliss

TEMF - Fort Lewis	Low Energy Package 1	Low Energy Package 2	Low Energy Package 3	Low Energy Package 4
Baseline Building	$ 8,302,808	$ 8,302,808	$ 8,302,808	$ 8,302,808
HVACE Components	$ (80,345)	$ (80,345)	$ (116,273)	$ (116,273)
Increased Fan & HVAC Efficiency VAV Fans	$ 101,965	$ 101,965	$ 101,965	$ 101,965
Reduced Ventilation in Repair Bays & Vehicle Corridor plus Transfer Air from Office to Repair Bays	$ 7,392	$ 7,392	$ 7,392	$ 7,392
Floor Radiant Heating	$ -	$ -	$ 136,891	$ 136,891
Solar Collector Wall	$ -	$ 101,747	$ -	$ 101,747
Advanced Lighting Systems	$ 3,338	$ 3,338	$ 3,338	$ 3,338
Increased Building Envelope Efficiency	$ 202,173	$ 202,173	$ 202,173	$ 202,173
Increased Window Efficiency	$ 20,089	$ 20,089	$ 20,089	$ 20,089
Dual Flush Toilets	$ 2,900	$ 2,900	$ 2,900	$ 2,900
Waterless Urinals	$ (1,278)	$ (1,278)	$ (1,278)	$ (1,278)
0.5gpm Flow Faucets	$ 7,614	$ 7,614	$ 7,614	$ 7,614
1.5gpm Flow Showerheads	$ 556	$ 556	$ 556	$ 556
Light Tubes	$ 19,708	$ 19,708	$ 19,708	$ 19,708
Skylights	$ 24,242	$ 24,242	$ 24,242	$ 24,242
Transluscent Sandwich Panels	$ 13,212	$ 13,212	$ 13,212	$ 13,212
Enhanced Commissioning	$ 68,816	$ 68,816	$ 68,816	$ 68,816
Measurement & Verification	$ 76,533	$ 76,533	$ 76,533	$ 76,533
Rainwater Harvesting	$ 118,929	$ 118,929	$ 118,929	$ 118,929
Add-on Cost	$ 585,844	$ 687,591	$ 686,807	$ 788,554
Revised Cost	$ 8,888,652	$ 8,990,399	$ 8,989,615	$ 9,091,362
Pecent Increase	7.06%	8.28%	8.27%	9.50%
Notes	(1) These costs are shown in contract costs			
	(2) Building Envelope includes foundation insulation, wall panels, wall insulation, roof insulation, door insulation, all vapor barrier			
	(3) The total cost of the HVAC package is the sum of the HVAC package and the floor radiant heating and solar wall collector			

Table B.20 Cost breakdown for TEMF – Fort Lewis

TEMF - Fort Carson	Low Energy Package 1	Low Energy Package 2	Low Energy Package 3	Low Energy Package 4
Baseline Building	$ 7,610,110	$ 7,610,110	$ 7,610,110	$ 7,610,110
HVACE Components	$ (73,594)	$ (73,594)	$ (106,502)	$ (106,502)
Increased Fan & HVAC Efficiency VAV Fans	$ 93,396	$ 93,396	$ 93,396	$ 93,396
Reduced Ventilation in Repair Bays & Vehicle Corridor plus Transfer Air from Office to Repair Bays	$ 6,771	$ 6,771	$ 6,771	$ 6,771
Floor Radiant Heating	$ -	$ -	$ 125,387	$ 125,387
Solar Collector Wall	$ -	$ 93,197	$ -	$ 93,197
Advanced Lighting Systems	$ 3,056	$ 3,056	$ 3,056	$ 3,056
Increased Building Envelope Efficiency	$ 249,350	$ 249,350	$ 249,350	$ 249,350
Increased Window Efficiency	$ 18,401	$ 18,401	$ 18,401	$ 18,401
Dual Flush Toilets	$ 2,656	$ 2,656	$ 2,656	$ 2,656
Waterless Urinals	$ (1,170)	$ (1,170)	$ (1,170)	$ (1,170)
0.5gpm Flow Faucets	$ 6,974	$ 6,974	$ 6,974	$ 6,974
1.5gpm Flow Showerheads	$ 510	$ 510	$ 510	$ 510
Light Tubes	$ 18,051	$ 18,051	$ 18,051	$ 18,051
Skylights	$ 22,205	$ 22,205	$ 22,205	$ 22,205
Transluscent Sandwich Panels	$ 12,102	$ 12,102	$ 12,102	$ 12,102
Enhanced Commissioning	$ 63,033	$ 63,033	$ 63,033	$ 63,033
Measurement & Verification	$ 70,101	$ 70,101	$ 70,101	$ 70,101
Rainwater Harvesting	$ 108,935	$ 108,935	$ 108,935	$ 108,935
Add-on Cost	$ 600,777	$ 693,974	$ 693,256	$ 786,453
Revised Cost	$ 8,210,887	$ 8,304,084	$ 8,303,366	$ 8,396,563
Pecent Increase	7.89%	9.12%	9.11%	10.33%
Notes	(1) These costs are shown in contract costs			
	(2) Building Envelope includes foundation insulation, wall panels, wall insulation, roof insulation, door insulation, all vapor barrier			
	(3) The total cost of the HVAC package is the sum of the HVAC package and the floor radiant heating and solar wall collector			

Table B.21 Cost breakdown for TEMF – Fort Carson

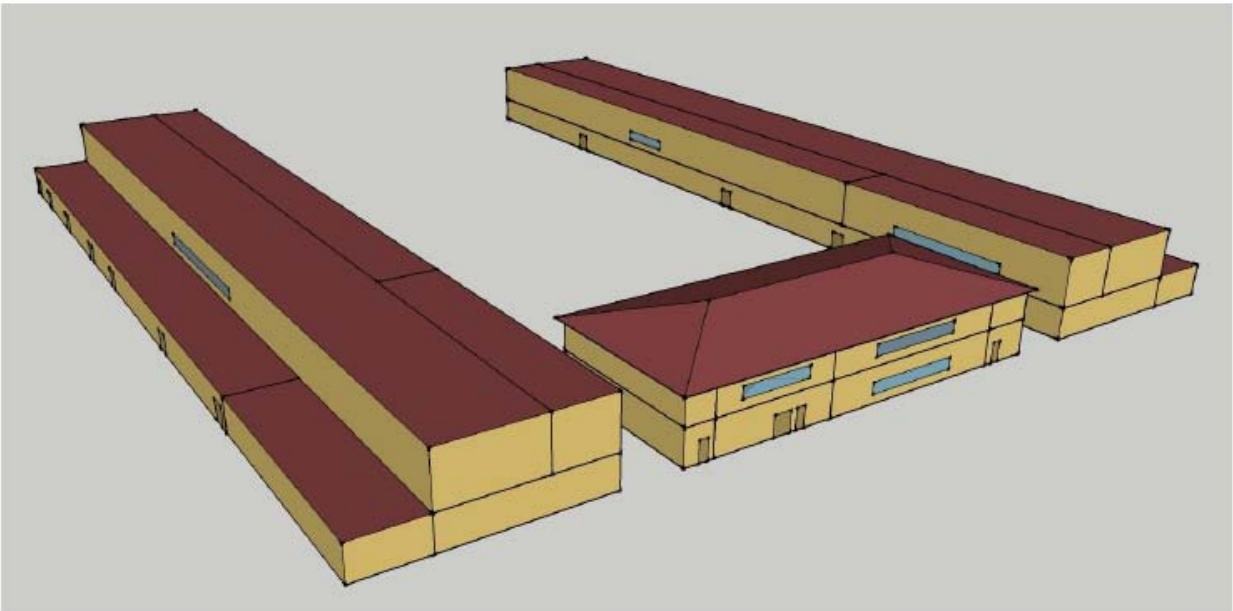
All new Army facilities have been required to increasingly reduce site energy consumption in response to EPACT 2005, then ECB 2010-14, then the Army Sustainable Design and Development Policy Update (Environmental and Energy Performance, October 27, 2010). As the results below show, the TEMF standard Army design including the Low Energy Package 3 EEMs, easily meets all the current site energy reduction mandates for new Army facilities.

Climate Zone	ASHRAE 90.1-2004 EUI (kBTU/sq ft-yr)	ASHRAE 90.1-2007 EUI (kBTU/sq ft-yr)	EPACT 2005 Target EUI + plug loads (kBTU/sq ft-yr)	ASHRAE 189.1 Target EUI (kBTU/sq ft-yr)	ECB 2010-14 Target EUI + plug loads (kBTU/sq ft-yr)	Low Energy Package Site EUI including plug loads (kBTU/sq ft-yr)
1A	43	41	32	33	27	15
2A	52	50	39	40	33	19
2B	49	47	36	37	31	19
3A	63	60	46	48	39	20
3B	54	52	40	41	34	19
3C	50	48	37	38	32	18
4A	82	78	59	62	50	25
4B	68	65	50	52	42	21
4C	71	68	52	54	44	23
5A	100	96	72	76	60	29
5B	87	83	63	66	53	25
6A	115	110	83	87	69	33
6B	106	101	76	81	63	30
7A	141	135	101	107	84	39
8A	214	205	152	163	126	59

Table B.22 TEMF Site Energy EUIs of recommended Low Energy Package Compared to the required site energy reduction targets

Appendix C:

COF



Baseline*: 4th Brigade Combat Team Complex (Heavy); Fort Stewart, Georgia

Figure C.1 COF Rendering of baseline COF configuration

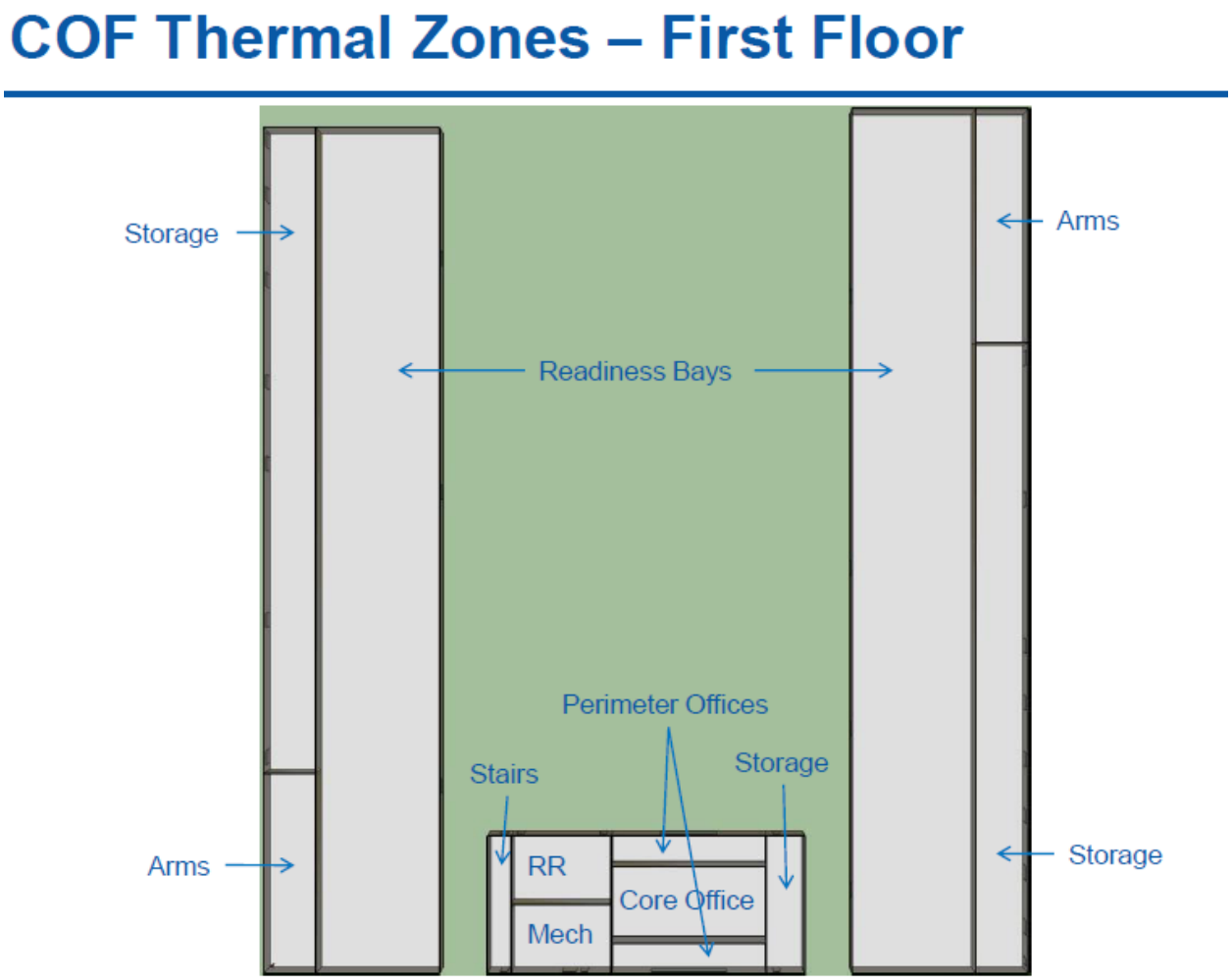


Figure C.2 COF Rendering of first floor of COF baseline configuration

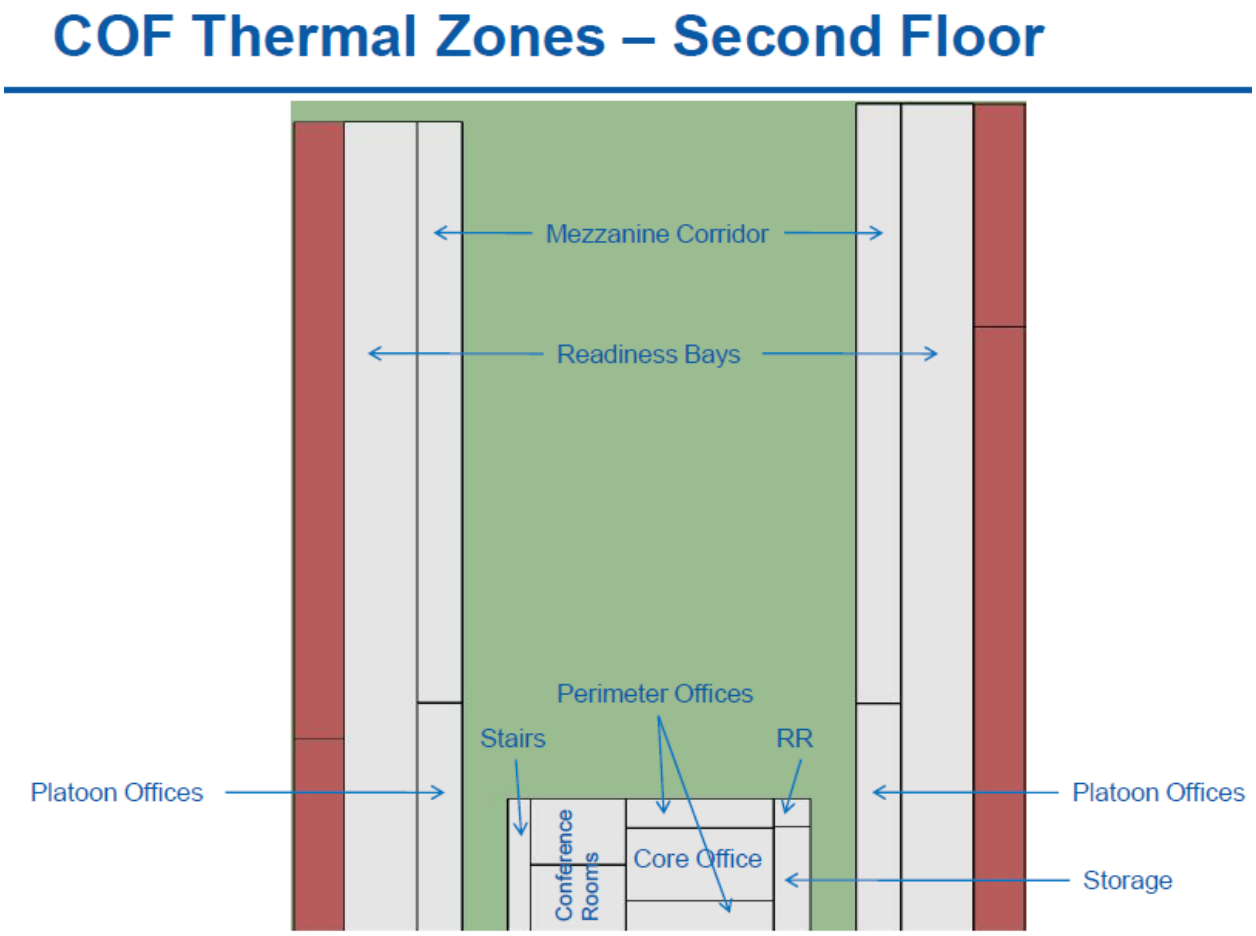
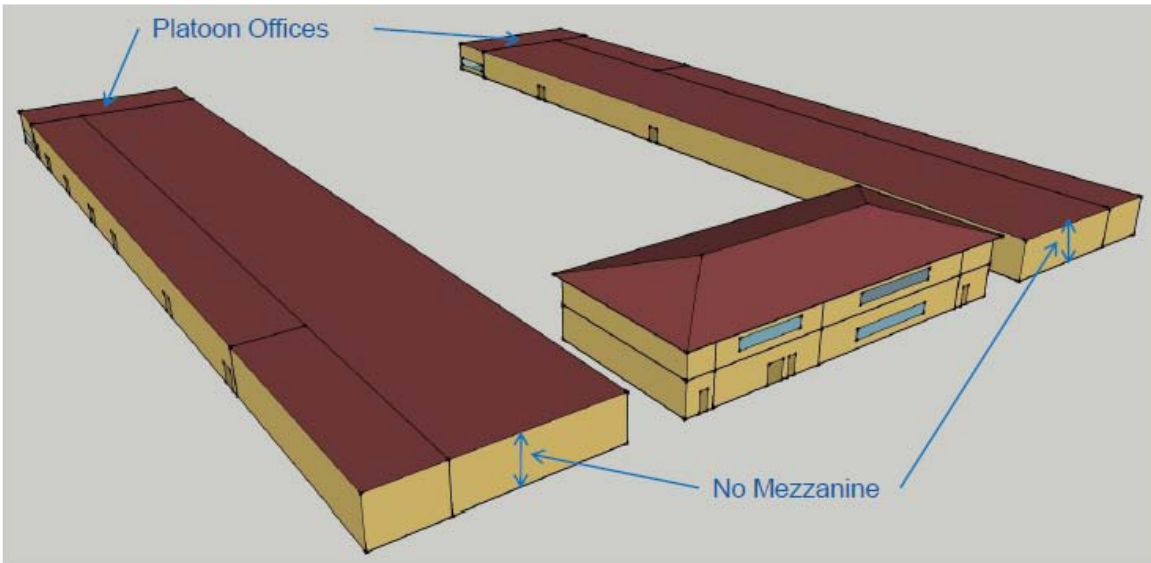


Figure C.3 COF Rendering of second floor of COF baseline configuration

COF Energy Model – Alternate Construction



• Considered the energy impacts of re-designing the readiness bays without mezzanines – reducing the volume of air that needs to be heated and cooled

Figure C.4 COF Rendering of redesigned COF configuration – Alternate Construction

Parameter	Baseline*	Low Energy Option
Envelope	ASHRAE 90.1-2007 compliant envelope constructions	Passiv Haus insulation, Passiv Haus rated windows– applied to whole building. Reduced infiltration rates from 0.4 cfm/ft2 to 0.15 cfm/ft2
Lighting	Lighting Power Densities calculated from drawings	Lighting Power Densities recommended by Atellier Ten
Daylighting	No daylighting controls	-Increased Skylight to Floor Area (SFA) fraction to 3% over readiness bays, platoon offices, mezzanine corridor, and storage spaces - Added daylighting controls with 500 lux setpoint
HVAC Efficiency	-Standard efficiency CV fans - Chiller Efficiency: 2.9 COP - Condensing Boiler	-Increased fan efficiency (recommendations from Al Woody): efficiencies increased to 70% - Added VAV fans - Chiller COP increased to 4.45 - Condensing Boiler
Energy Recovery	None	Climate zones 1A-4B (Readiness Bays and Admin)
Indirect Evaporative Cooling	None	Climate zones 4C-8A – IDEC and DCV (Admin Building)
DOAS with Fan Coils in Readiness Bays	None	Climate zones 2B and 3B (Readiness Bays)
Transpired Solar Collectors	None	Climate zones 2A-8

Table C.1 Baseline and energy efficient inputs for energy modeling - COF

	Design Criteria			Control Strategies				Technologies				Approach				
				Levels	Automatic Interface											
Space	Target Illuminance at Task [fc] (Design Goal)	Target Lighting Power Density [W/ft²] (Project Design Goal)	Allowable Lighting Power Density [W/ft²] (ASHRAE/IESNA Std 90.1-2004/2007)	Switching - (blank) Multi-Level - M Full Dimming - D	V - Vacancy [Manual ON / Auto OFF] O - Occupancy [Auto ON / Auto OFF]	Daylight (e.g. Photosensors)	Schedule (e.g. Astronomical time-clock)	Linear Fluorescent	Compact Fluorescent	Ceramic Metal Halide	Light Emitting Diodes	Overhead General Lighting	Overhead Ambient Lighting	Task Lighting	Wallwash / Perimeter Lighting	Adjustable Accent Lighting
Conference Room	40	0.80	1.3	M/D	V			✓				•			•	
Corridor	10	0.50	0.5		O			✓				•			•	
Mechanical / Electrical	30	0.70	1.5		V			✓				•				
Office (Enclosed)	40	0.90	1.1	M	V			✓			✓		•	•		
Readiness Bays	20	0.75	0.9		V		⏲	✓				•				
Restroom / Shower	20	0.80	0.9		V			✓	✓		✓	•			•	
Stair	10	0.50	0.6	M	O			✓				•				
Storage (General)	10	0.50	0.8		V			✓				•				•
Telecom / SIPRNET	50	1.20	1.5		V			✓				•				
Storage / Vaults (Occupied)	40	0.65	1.9		V			✓			✓	•				

Table C.2 Atelier Ten Lighting Design Guide Recommendations - COF

Space	Lighting	Controls
Conference Room	Provide light on people's faces if video conferencing, glare control	Multi-scene preset scene controller may be appropriate in some cases; Use multi-level or dimming ballasts where appropriate
Corridor		Occupancy sensors to reduce load to 25%-50% when vacancy is detected. Multi-Level ballasts may be appropriate in many cases
Mechanical / Electrical	Locate luminaires relative to working areas and equipment	Dual-technology vacancy sensors with long time out
Office (Enclosed)	Use task/ambient scheme with furniture or ceiling mounted ambient lighting and furniture mounted task lighting	Bi-level luminaires and vacancy sensors in private perimeter offices is sufficient for energy savings (photosensors not req)
Readiness Bays		Use vacancy sensors to capture daylight savings
Restroom / Shower	Lighting over sink and toilet wall will often be enough for entire restroom	Dual-technology vacancy sensor
Stair	Locate luminaires to provide 10fc at landings	Use bi-level luminaire with integrated occupancy sensor
Storage (General)	Locate and specify luminaires to light vertical surfaces	
Telecom / SIPRNET	Lighting should be designed to provide 50 fc, LPDs will may be higher for very small telecom rooms and lower for larger rooms.	
Storage / Vaults (Occupied)	Provide lighing on desks and work areas as well as vertical surfaces	

Table C.3 Atelier Ten Lighting Design Guide Notes – COF

Fan Efficiency				
Zone	Baseline		Recommendation	
	AHU	Fan Type	AHU	Fan Type
3C Readiness Bays	0.66	Constant Volume	0.70	Variable Volume
3C Readiness Top	0.66	Constant Volume	0.70	Variable Volume
3C Arms	0.66	Constant Volume	0.70	Variable Volume
3C Storage	0.66	Constant Volume	0.70	Variable Volume
3C Office	0.66	Constant Volume	0.70	Variable Volume
3C Corridor	0.66	Constant Volume	0.70	Variable Volume
Admin Conference1	0.5	Constant Volume	0.70	Variable Volume
Admin Conference2	0.5	Constant Volume	0.70	Variable Volume
Admin CoreOffice1	0.5	Constant Volume	0.70	Variable Volume
Admin CoreOffice2	0.5	Constant Volume	0.70	Variable Volume
Admin Mechanical	0.5	Constant Volume	0.70	Variable Volume
Admin Perimeter Office11	0.5	Constant Volume	0.70	Variable Volume
Admin Perimeter Office12	0.5	Constant Volume	0.70	Variable Volume
Admin Perimeter Office21	0.5	Constant Volume	0.70	Variable Volume
Admin Perimeter Office22	0.5	Constant Volume	0.70	Variable Volume
Admin Restroom1	0.5	Constant Volume	0.70	Variable Volume
Admin Restroom2	0.5	Constant Volume	0.70	Variable Volume
Admin Roof	0.5	Constant Volume	0.70	Variable Volume
Admin Stair1	0.5	Constant Volume	0.70	Variable Volume
Admin Stair2	0.5	Constant Volume	0.70	Variable Volume
Admin Storage1	0.5	Constant Volume	0.70	Variable Volume
Admin Storage2	0.5	Constant Volume	0.70	Variable Volume
4C Readiness Bays	0.6	Constant Volume	0.70	Variable Volume
4C Readiness Top	0.6	Constant Volume	0.70	Variable Volume
4C Arms	0.6	Constant Volume	0.70	Variable Volume
4C Storage	0.6	Constant Volume	0.70	Variable Volume
4C Office	0.6	Constant Volume	0.70	Variable Volume
4C Corridor	0.6	Constant Volume	0.70	Variable Volume

Table C.4 Fan efficiency values for COF

Glazing Table					
Baseline					
	Vertical Glazing Area (ft^2)				Horizontal Glazing Area (ft^2)
Zone	North	East	South	West	Exposed Roof Area
3C Readiness Bays	0	0	0	0	0
3C Readiness Top	0	0	0	256	0
3C Arms	0	0	0	0	0
3C Storage	0	0	0	0	0
3C Office	0	192	0	0	0
3C Corridor	0	96	0	0	0
Admin Conference1	96	0	0	0	0
Admin Conference2	0	0	96	0	0
Admin CoreOffice1	0	0	0	0	0
Admin CoreOffice2	0	0	0	0	0
Admin Mechanical	0	0	0	0	0
Admin Perimeter Office11	128	0	0	0	0
Admin Perimeter Office12	0	0	128	0	0
Admin Perimeter Office21	128	0	0	0	0
Admin Perimeter Office22	0	0	128	0	0
Admin Restroom1	0	0	0	0	0
Admin Restroom2	0	0	0	0	0
Admin Roof	0	0	0	0	0
Admin Stair1	0	0	0	0	0
Admin Stair2	0	0	0	0	0
Admin Storage1	0	0	0	0	0
Admin Storage2	0	0	0	0	0
4C Readiness Bays	0	0	0	0	0
4C Readiness Top	0	256	0	0	0
4C Arms	0	0	0	0	0
4C Storage	0	0	0	0	0
4C Office	0	0	0	192	0
4C Corridor	0	0	0	96	0

Table C.5 Glazing values for baseline COF

Glazing Table					
LowE					
	Vertical Glazing Area (ft^2)				Horizontal Glazing Area (ft^2)
Zone	North	East	South	West	Exposed Roof Area
3C Readiness Bays	0	0	0	0	0
3C Readiness Top	0	0	0	256	240
3C Arms	0	0	0	0	0
3C Storage	0	0	0	0	192
3C Office	0	192	0	0	64
3C Corridor	0	96	0	0	176
Admin Conference1	96	0	0	0	0
Admin Conference2	0	0	96	0	0
Admin CoreOffice1	0	0	0	0	0
Admin CoreOffice2	0	0	0	0	0
Admin Mechanical	0	0	0	0	0
Admin Perimeter Office11	128	0	0	0	0
Admin Perimeter Office12	0	0	128	0	0
Admin Perimeter Office21	128	0	0	0	0
Admin Perimeter Office22	0	0	128	0	0
Admin Restroom1	0	0	0	0	0
Admin Restroom2	0	0	0	0	0
Admin Roof	0	0	0	0	0
Admin Stair1	0	0	0	0	0
Admin Stair2	0	0	0	0	0
Admin Storage1	0	0	0	0	0
Admin Storage2	0	0	0	0	0
4C Readiness Bays	0	0	0	0	0
4C Readiness Top	0	256	0	0	240
4C Arms	0	0	0	0	0
4C Storage	0	0	0	0	192
4C Office	0	0	0	192	64
4C Corridor	0	0	0	96	176

Table C.6 Glazing values for low energy COF

Lighting Power Density Levels				
Zone	Baseline		Recommendation	
	(W/ft^2)	(W/m^2)	(W/ft^2)	(W/m^2)
3C Readiness Bays	0.25	2.69	0.19	2.05
3C Readiness Top	0.85	9.12	0.66	7.10
3C Arms	0.69	7.46	0.65	7.00
3C Storage	0.78	8.35	0.50	5.38
3C Office	0.90	9.64	0.90	9.69
3C Corridor	0.66	7.05	0.50	5.38
Admin Conference1	0.84	9.08	0.80	8.61
Admin Conference2	0.84	9.08	0.80	8.61
Admin CoreOffice1	0.66	7.06	0.66	7.06
Admin CoreOffice2	0.66	7.06	0.66	7.06
Admin Mechanical	0.58	6.26	0.58	6.26
Admin Perimeter Office11	0.76	8.20	0.76	8.20
Admin Perimeter Office12	0.76	8.20	0.76	8.20
Admin Perimeter Office21	0.76	8.20	0.76	8.20
Admin Perimeter Office22	0.76	8.20	0.76	8.20
Admin Restroom1	0.69	7.39	0.69	7.39
Admin Restroom2	0.67	7.18	0.67	7.18
Admin Roof				
Admin Stair1	0.66	7.13	0.50	5.38
Admin Stair2	0.66	7.13	0.50	5.38
Admin Storage1	1.11	11.93	0.50	5.38
Admin Storage2	0.70	7.56	0.50	5.38
4C Readiness Bays	0.25	2.71	0.19	2.05
4C Readiness Top	0.86	9.28	0.66	7.10
4C Arms	0.77	8.31	0.65	7.00
4C Storage	0.84	9.01	0.50	5.38
4C Office	0.90	9.64	0.90	9.69
4C Corridor	0.66	7.10	0.50	5.38

Table C.7 Lighting Power Density values for COF

COF Climate Zone 1A				
	Item	***Component***	***Baseline***	***Recommendation***
				Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-15 ci
		Metal Building	R-19	
		Attic and Other	R-30	
	Walls	Mass	NR	R-13
		Steel Framed	R-13	
		Metal Building	R-13	
	Floors Over Unconditioned Space	Mass	NR	NR
		Steel Joist	NR	NR
		Wood Framed and Other	NR	NR
	Slab-on-Grade	Unheated	NR	NR
	Doors	Swinging	U-0.7	U-0.7
		Non-Swinging	U-1.45	U-1.45
	Infiltration	Areas that are Mechanicalanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10% See Glazing Table	<10% See Glazing Table
		Thermal transmittance	U-1.22	U-0.26
		Solar heat gain coefficient (SHGC)	0.25	0.25
	Skylights	Percent Roof Area	None	3% in Readiness Bays See Glazing Table
		Thermal transmittance	U-1.98	U-1.36
		SHGC	0.36	0.19
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Chiller	COP 2.9	COP > 4
		Fans	Constant Volume with 0.6-0.65 efficiency	Variable Volume with 0.7 efficiency
		Gas Boiler	Natural Draft Condensing 90%	Natural Draft Condensing 90%
		Hydronic Radiant Floor Heat	None	None
		ERV	None	All Zones
		Economizer	None	All Zones
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	None	All Zones
		Transpired Solar Collectors	None	None

Table C.8 Recommended prescriptive values for low energy model – COF CZ 1A

COF Climate Zone 2A, 3B				
	Item	***Component***	***Baseline***	***Recommendation***
				Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-15 ci
		Metal Building	R-19	
		Attic and Other	R-30	
	Walls	Mass	NR	R-13
		Steel Framed	R-13	
		Metal Building	R-13	
	Floors Over Unconditioned Space	Mass	R-4.2 ci	R-4.2 ci
		Steel Joist	R-19	R-19
		Wood Framed and Other	R-19	R-19
	Slab-on-Grade	Unheated	NR	NR
	Doors	Swinging	U-0.7	U-0.7
		Non-Swinging	U-1.45	U-1.45
	Infiltration	Areas that are Mechanicalanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10% See Glazing Table	<10% See Glazing Table
		Thermal transmittance	U-1.22	U-0.26
		Solar heat gain coefficient (SHGC)	0.25	0.25
	Skylights	Percent Roof Area	None	3% in Readiness Bays See Glazing Table
		Thermal transmittance	U-1.98	U-1.36
		SHGC	0.36	0.19
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Chiller	COP 2.9	COP >4
		Fans	Constant Volume with 0.6-0.65 efficiency	Variable Volume with 0.7 efficiency
		Gas Boiler	Natural Draft Condensing 90%	Natural Draft Condensing 90%
		Hydronic Radiant Floor Heat	None	None
		ERV	None	All Zones
		Economizer	None	All Zones
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	None	All Zones
		Transpired Solar Collectors	None	Readi Bldg B: 425 ft^2 Readi Bldg C: 360 ft^2 Admin Bldg: 290 ft^2

Table C.9 Recommended prescriptive values for low energy model – COF CZ 2A, 2B

	COF Climate Zone 3A, 3B, 3C			
	Item	***Component***	***Baseline***	***Recommendation***
				Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-35 (R-15 ci for 3C)
		Metal Building	R-19	
		Attic and Other	R-30	
	Walls	Mass	R-5.7 ci	R-24 (R-13 for 3C)
		Steel Framed	R-13	
		Metal Building	R-13	
	Floors Over Unconditioned Space	Mass	R-6.3 ci	R-10.4 ci (R-6.3 ci for 3C)
		Steel Joist	R-19	R-30 (R-19 for 3C)
		Wood Framed and Other	R-19	R-30 (R-19 for 3C)
	Slab-on-Grade	Unheated	NR	R-14 (NR for 3C)
	Doors	Swinging	U-0.7	U-0.7
		Non-Swinging	U-1.45	U-0.5
	Infiltration	Areas that are Mechanicalanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10% See Glazing Table	<10% See Glazing Table
		Thermal transmittance	U-0.57 (U-1.22 for 3C)	U-0.26
		Solar heat gain coefficient (SHGC)	0.39 (0.61 for 3C)	0.39
	Skylights	Percent Roof Area	None	3% in Readiness Bays See Glazing Table
		Thermal transmittance	U-1.98	U-0.69
		SHGC	0.36	0.16
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Chiller	COP 2.9	COP > 4
		Fans	Constant Volume with 0.6-0.65 efficiency	Variable Volume with 0.7 efficiency
		Gas Boiler	Natural Draft Condensing 90%	Natural Draft Condensing 90%
		Hydronic Radiant Floor Heat	None	None
		ERV	None	All Zones
		Economizer	None	All Zones
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	None	All Zones
		Transpired Solar Collectors	None	Readi Bldg B: 425 ft^2 Readi Bldg C: 360 ft^2 Admin Bldg: 290 ft^2

Table C.10 Recommended prescriptive values for low energy model – COF CZ 3A, 3B, 3C

COF Climate Zone 4A, 4B, 4C				
	Item	***Component***	***Baseline***	***Recommendation***
				Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-47 (R-35 for 4C)
		Metal Building	R-19	
		Attic and Other	R-30	
	Walls	Mass	R-5.7 ci	R-31 (R-24 for 4C)
		Steel Framed	R-13	
		Metal Building	R-13	
	Floors Over Unconditioned Space	Mass	R-6.3 ci	R-12.5 ci
		Steel Joist	R-19	R-30
		Wood Framed and Other	R-19	R-30
	Slab-on-Grade	Unheated	NR	R-19 (R-14 for 4C)
	Doors	Swinging	U-0.7	U-0.5
		Non-Swinging	U-1.45	U-0.5
	Infiltration	Areas that are Mechanicalanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10% See Glazing Table	<10% See Glazing Table
		Thermal transmittance	U-0.57	U-0.18
		Solar heat gain coefficient (SHGC)	0.39	0.39
	Skylights	Percent Roof Area	None	3% in Readiness Bays See Glazing Table
		Thermal transmittance	U-1.98	U-0.69
		SHGC	0.36	0.32
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Chiller	COP 2.9	COP > 4
		Fans	Constant Volume with 0.6-0.65 efficiency	Variable Volume with 0.7 efficiency
		Gas Boiler	Natural Draft Condensing 90%	Natural Draft Condensing 90%
		Hydronic Radiant Floor Heat	None	None
		ERV	None	All Zones
		Economizer	None	All Zones
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	None	All Zones
		Transpired Solar Collectors	None	Readi Bldg B: 425 ft^2 Readi Bldg C: 360 ft^2 Admin Bldg: 290 ft^2

Table C.11 Recommended prescriptive values for low energy model – COF CZ 4A, 4B, 4C

COF Climate Zone 5A, 5B				
	Item	***Component***	***Baseline***	***Recommendation***
				Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-57
		Metal Building	R-19	
		Attic and Other	R-30	
	Walls	Mass	R-7.6 ci	R-38
		Steel Framed	R-13 + R-3.8 ci	
		Metal Building	R-13	
	Floors Over Unconditioned Space	Mass	R-8.3 ci	R-12.5 ci
		Steel Joist	R-19	R-30
		Wood Framed and Other	R-30	R-30
	Slab-on-Grade	Unheated	NR	R-23
	Doors	Swinging	U-0.7	U-0.5
		Non-Swinging	U-1.45	U-0.5
	Infiltration	Areas that are Mechanicalanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10% See Glazing Table	<10% See Glazing Table
		Thermal transmittance	U-0.57	U-0.18
		Solar heat gain coefficient (SHGC)	0.49	0.49
	Skylights	Percent Roof Area	None	3% in Readiness Bays See Glazing Table
		Thermal transmittance	U-1.98	U-0.69
		SHGC	0.36	0.36
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Chiller	COP 2.9	COP > 4
		Fans	Constant Volume with 0.6-0.65 efficiency	Variable Volume with 0.7 efficiency
		Gas Boiler	Natural Draft Condensing 90%	Natural Draft Condensing 90%
		Hydronic Radiant Floor Heat	None	None
		ERV	None	All Zones
		Economizer	None	All Zones
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	None	All Zones
		Transpired Solar Collectors	None	Readi Bldg B: 425 ft^2 Readi Bldg C: 360 ft^2 Admin Bldg: 290 ft^2

Table C.12 Recommended prescriptive values for low energy model – COF CZ 5A, 5B

	COF Climate Zone 6A, 6B			
	Item	***Component***	***Baseline***	***Recommendation***
				Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-71
		Metal Building	R-19	
		Attic and Other	R-38	
	Walls	Mass	R-9.5 ci	R-47
		Steel Framed	R-13 + R-3.8 ci	
		Metal Building	R-13	
	Floors Over Unconditioned Space	Mass	R-8.3 ci	R-12.5 ci
		Steel Joist	R-30	R-30
		Wood Framed and Other	R-30	R-30
	Slab-on-Grade	Unheated	NR	R-28
	Doors	Swinging	U-0.7	U-0.5
		Non-Swinging	U-1.45	U-0.5
	Infiltration	Areas that are Mechanicalanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10% See Glazing Table	<10% See Glazing Table
		Thermal transmittance	U-0.57	U-0.18
		Solar heat gain coefficient (SHGC)	0.49	0.49
	Skylights	Percent Roof Area	None	3% in Readiness Bays See Glazing Table
		Thermal transmittance	U-1.98	U-0.69
		SHGC	0.36	0.46
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Chiller	COP 2.9	COP > 4
		Fans	Constant Volume with 0.6-0.65 efficiency	Variable Volume with 0.7 efficiency
		Gas Boiler	Natural Draft Condensing 90%	Natural Draft Condensing 90%
		Hydronic Radiant Floor Heat	None	None
		ERV	None	All Zones
		Economizer	None	All Zones
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	None	All Zones
		Transpired Solar Collectors	None	Readi Bldg B: 425 ft^2 Readi Bldg C: 360 ft^2 Admin Bldg: 290 ft^2

Table C.13 Recommended prescriptive values for low energy model – COF CZ 6A, 6B

	COF Climate Zone 7			
	Item	***Component***	***Baseline***	***Recommendation***
				Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-94
		Metal Building	R-19	
		Attic and Other	R-38	
	Walls	Mass	R-11.4 ci	R-63
		Steel Framed	R-13 + R-7.5 ci	
		Metal Building	R-13 + R-13	
	Floors Over Unconditioned Space	Mass	R-8.3 ci	R-14.6 ci
		Steel Joist	R-30	R-38
		Wood Framed and Other	R-30	R-30
	Slab-on-Grade	Unheated	NR	R-38
	Doors	Swinging	U-0.7	U-0.5
		Non-Swinging	U-1.45	U-0.5
	Infiltration	Areas that are Mechanicalanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10% See Glazing Table	<10% See Glazing Table
		Thermal transmittance	U-0.57	U-0.18
		Solar heat gain coefficient (SHGC)	0.49	0.49
	Skylights	Percent Roof Area	None	3% in Readiness Bays See Glazing Table
		Thermal transmittance	U-1.98	U-0.69
		SHGC	0.36	0.64
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Chiller	COP 2.9	COP > 4
		Fans	Constant Volume with 0.6-0.65 efficiency	Variable Volume with 0.7 efficiency
		Gas Boiler	Natural Draft Condensing 90%	Natural Draft Condensing 90%
		Hydronic Radiant Floor Heat	None	None
		ERV	None	All Zones
		Economizer	None	All Zones
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	None	All Zones
		Transpired Solar Collectors	None	Readi Bldg B: 425 ft^2 Readi Bldg C: 360 ft^2 Admin Bldg: 290 ft^2

Table C.14 Recommended prescriptive values for low energy model – COF CZ 7

	COF Climate Zone 8			
	Item	***Component***	***Baseline***	***Recommendation***
				Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-20 ci	R-106
		Metal Building	R-13 + R-19	
		Attic and Other	R-38	
	Walls	Mass	R-13.3 ci	R-71
		Steel Framed	R-13 + R-7.5 ci	
		Metal Building	R-13 + R-13	
	Floors Over Unconditioned Space	Mass	R-12.5 ci	R-14.6 ci
		Steel Joist	R-30	R-38
		Wood Framed and Other	R-30	R-30
	Slab-on-Grade	Unheated	R-10 for 24 in.	R-37
	Doors	Swinging	U-0.7	U-0.5
		Non-Swinging	U-1.45	U-0.5
	Infiltration	Areas that are Mechanicalanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10% See Glazing Table	<10% See Glazing Table
		Thermal transmittance	U-0.46	U-0.18
		Solar heat gain coefficient (SHGC)	NR	0.49
	Skylights	Percent Roof Area	None	3% in Readiness Bays See Glazing Table
		Thermal transmittance	U-1.98	U-0.58
		SHGC	0.36	0.64
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Chiller	COP 2.9	COP > 4
		Fans	Constant Volume with 0.6-0.65 efficiency	Variable Volume with 0.7 efficiency
		Gas Boiler	Natural Draft Condensing 90%	Natural Draft Condensing 90%
		Hydronic Radiant Floor Heat	None	None
		ERV	None	All Zones
		Economizer	None	All Zones
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	None	All Zones
		Transpired Solar Collectors	None	Readi Bldg B: 425 ft^2 Readi Bldg C: 360 ft^2 Admin Bldg: 290 ft^2

Table C.15 Recommended prescriptive values for low energy model – COF CZ 8

PDF file to a new email message

Site EUI For Each EEM

1. Whole building baseline
2. Baseline model of just the readiness bays
3. Readiness Bays baseline with alternate construction
4. Readiness Bays - Reduced lighting power density per Atelier Ten recommendations
5. Readiness Bays - Reduced LPD and increased daylighting in readiness bays (added skylights to 3% of roof area)
6. Readiness Bays – Reduced LPD, passiv haus envelope construction, and reduced infiltration rates
7. Readiness Bays – Reduced LPD, increased daylighting, passiv haus envelope construction, and reduced infiltration rates
8. Readiness Bays – Cool roof added to climate zones 1-5
9. Readiness Bays – High efficiency HVAC – including ERV and DCV for climate zones 1A-4B, and IDEC and DCV for climate zones 4C-8A
10. Readiness Bays – High efficiency HVAC with DOAS and fan coil unit
11. Readiness Bays – Best options out of EEMs 4-10 (highlighted options)
12. Whole Building with best options out of EEMs 4-10 for Readiness Bays and EEM 8 applied to Admin
13. Whole Building – EEM 12 with alternate construction applied to Readiness Bays

			EEMs Applied Individually to Readiness Bays Baseline										
EEMs:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Site Energy [kBtu/ft2]	**Whole Building Baseline**	**Readi-Bays Baseline**	**Readi-Bays - Baseline with Alternate Construction**	**Readi-Bays Baseline with Lighting Power Density Reduction**	**Readi-Bays - Baseline with LPD Reduction and Increased Daylighting**	**Readi-Bays - Baseline with LPD Reduction and Passiv Haus Envelope**	**Readi-Bays - Baseline w/ LPD Reduction with Increased Daylighting and Passiv Haus Envelope**	**Readi-Bays - Baseline with Cool Roof in Climate Zones 1-5**	**Readi-Bays - Baseline w/ High Efficiency HVAC - ERV and VAV (CZ 1A-4B), IDEC and VAV (CZ 4C-8A)**	**Readi-Bays - w/ High Efficiency HVAC - DOAS, ERV and Fan Coils**	**Readi-Bays - Best of EEMs 4-10 (EEMs highlighted in gray)**	**Whole Building - Best of EEMs 4-10 for Readi-Bays, EEM 8 applied to Admin**	**Whole Building - EEM 13 with Alternate Construction for Readi-Bays (EEM 3)**
1A Miami	58	47	40	44	42	38	37	45	38	40	27	29	23
2A Houston	62	53	39	51	50	39	38	53	40	43	26	30	24
2B Phoenix	60	48	32	46	44	35	35	47	42	38	32	35	29
3A Memphis	72	60	42	59	57	43	42	60	42	48	26	30	25
3B El Paso	59	48	31	46	44	34	33	48	39	37	31	34	29
3C San Francisco	54	43	29	41	39	30	29	43	34	37	20	25	21
4A Baltimore	78	70	48	68	67	50	48	70	43	57	25	29	25
4B Albuquerque	67	57	38	56	54	39	38	57	39	44	21	26	21
4C Seattle	68	57	39	56	55	40	38	58	41	46	21	26	23
5A Chicago	94	83	59	82	81	58	57	84	50	70	24	29	25
5B Colorado Springs	79	69	47	67	66	47	45	69	44	56	20	25	21
6A Burlington	103	92	66	91	90	65	63	92	52	81	24	29	25
6B Helena	94	83	58	82	81	56	55	83	51	70	22	27	23
7A Duluth	117	108	78	107	106	76	74	108	58	98	24	30	26
8A Fairbanks	163	152	112	151	152	107	105	152	76	155	32	37	33

Table C.16 Site EUI for each EEM package - COF

Site Energy Savings For Each EEM

1. Whole building baseline
2. Baseline model of just the readiness bays
3. Readiness Bays baseline with alternate construction
4. Readiness Bays - Reduced lighting power density per Atelier Ten recommendations
5. Readiness Bays - Reduced LPD and increased daylighting in readiness bays (added skylights to 3% of roof area)
6. Readiness Bays – Reduced LPD, passiv haus envelope construction, and reduced infiltration rates
7. Readiness Bays – Reduced LPD, increased daylighting, passiv haus envelope construction, and reduced infiltration rates
8. Readiness Bays – Cool roof added to climate zones 1-5
9. Readiness Bays – High efficiency HVAC – including ERV and DCV for climate zones 1A-4B, and IDEC and DCV for climate zones 4C-8A
10. Readiness Bays – High efficiency HVAC with DOAS and fan coil unit
11. Readiness Bays – Best options out of EEMs 4-10 (highlighted options)
12. Whole Building with best options out of EEMs 4-10 for Readiness Bays and EEM 8 applied to Admin
13. Whole Building – EEM 12 with alternate construction applied to Readiness Bays

			EEMs Applied Individually to Readiness Bays Baseline										
EEMs:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Site Energy Savings Compared to Baseline	**Whole Building Baseline**	**Readi-Bays Baseline**	**Readi-Bays - Baseline with Alternate Construction**	**Readi-Bays - Baseline with Lighting Power Density Reduction**	**Readi-Bays - Baseline with LPD Reduction and Increased Daylighting**	**Readi-Bays - Baseline with LPD Reduction and Passiv Haus Envelope**	**Readi-Bays - Baseline w/ LPD Reduction with Increased Daylighting and Passiv Haus Envelope**	**Readi-Bays - Baseline with Cool Roof in Climate Zones 1-5**	**Readi-Bays - Baseline w/ High Efficiency HVAC - ERV and VAV (CZ 1A-4B), IDEC and VAV (CZ 4C-8A)**	**Readi-Bays - w/ High Efficiency HVAC - DOAS, ERV and Fan Coils**	**Readi-Bays - Best of EEMs 4-10 (EEMs highlighted in gray)**	**Whole Building - Best of EEMs 4-10 for Readi-Bays, EEM 8 applied to Admin**	**Whole Building - EEM 13 with Alternate Construction for Readi-Bays (EEM 3)**
1A Miami	-	-	16%	6%	11%	20%	22%	5%	20%	15%	43%	50%	60%
2A Houston	-	-	26%	4%	7%	28%	29%	1%	25%	20%	51%	52%	61%
2B Phoenix	-	-	33%	5%	8%	26%	27%	2%	13%	21%	34%	42%	52%
3A Memphis	-	-	31%	3%	6%	29%	31%	0%	30%	19%	57%	58%	65%
3B El Paso	-	-	34%	4%	8%	29%	31%	1%	19%	24%	36%	42%	50%
3C San Francisco	-	-	33%	3%	8%	29%	33%	-2%	20%	14%	53%	54%	61%
4A Baltimore	-	-	31%	2%	5%	29%	31%	0%	38%	18%	65%	62%	68%
4B Albuquerque	-	-	34%	3%	6%	31%	33%	0%	32%	24%	63%	62%	69%
4C Seattle	-	-	32%	2%	4%	30%	33%	-1%	29%	20%	63%	62%	67%
5A Chicago	-	-	29%	1%	3%	30%	32%	-1%	40%	16%	71%	69%	73%
5B Colorado Springs	-	-	31%	2%	4%	31%	34%	-1%	36%	19%	70%	68%	73%
6A Burlington	-	-	29%	1%	2%	30%	31%	0%	44%	12%	74%	72%	76%
6B Helena	-	-	31%	1%	2%	32%	34%	0%	38%	16%	73%	71%	75%
7A Duluth	-	-	28%	1%	2%	30%	31%	0%	46%	9%	77%	75%	78%
8A Fairbanks	-	-	26%	1%	0%	30%	31%	0%	50%	-2%	79%	77%	80%

Table C.17 Site energy savings (%) for each EEM package - COF

Admin A	Baseline Package	Low Energy Package 1	Difference
Baseline Building	-	$ 4,052,257	
HVAC Components	$ 999,597	$ 937,946	$ (61,651)
Increased Fan & Pump Efficiencies	$ -	$ 99,269	$ 99,269
-	$ -	$ -	$ -
Solar Wall Collector	$ -	$ 12,833	$ 12,833
Advanced Lighting Systems	$ 342,346	$ 346,076	$ 3,730
Increased Building Envelope Efficiency	$ 141,668	$ 250,641	$ 108,973
Increased Window Efficiency	$ 38,333	$ 77,387	$ 39,054
Dual Flush Toilets	$ 39,367	$ 42,072	$ 2,705
0.5gpm Flow Faucets	$ 35,032	$ 48,665	$ 13,633
Waterless Urinals	$ 18,599	$ 16,480	$ (2,119)
Skylights	$ -	$ -	$ -
Enhanced Commissioning	$ -	$ 69,233	$ 69,233
Measurement & Vertification	$ -	$ 64,909	$ 64,909
Rainwater Harvesting	$ -	$ 88,446	$ 88,446
Total Cost	$ 1,614,942	$ 2,053,957	
Add-on Cost		$ 439,015	
Revised Cost		$ 4,491,272	
Pecent Increase		10.83%	

Notes (1) These costs are shown in contract costs

(2) Building Envelope includes foundation insulation, wall panels, wall insulation, roof insulation, door insulation, all vapor barrier

Table C.18 Sample cost breakdown for COF Admin A Building – Fort Campbell

Readiness B	Baseline Package	Low Energy Package 1	Difference
Baseline Building	-	$ 5,367,809	
HVAC Components	$ 741,825	$ 747,051	$ 5,226
Increased Fan & Pump Efficiencies	$ -	$ 14,682	$ 14,682
ERV Systems	$ -	$ 23,863	$ 23,863
Solar Wall Collector	$ -	$ 18,808	$ 18,808
Advanced Lighting Systems	$ 418,193	$ 450,830	$ 32,637
Increased Building Envelope	$ 511,230	$ 837,318	$ 326,088
Increased Window Efficiency	$ 37,526	$ 75,757	$ 38,231
Dual Flush Toilets	$ -	$ -	$ -
0.5gpm Flow Faucets	$ 24,702	$ 31,878	$ 7,176
Waterless Urinals	$ -	$ -	$ -
Skylights	$ -	$ 82,241	$ 82,241
Enhanced Commissioning	$ -	$ -	$ -
Measurement & Vertification	$ -	$ -	$ -
Rainwater Harvesting	$ -	$ 46,075	$ 46,075
Total Cost	$ 1,733,476	$ 2,328,503	
Add-on Cost		$ 595,027	
Revised Cost		$ 5,962,836	
Pecent Increase		11.09%	

Notes

(1) These costs are shown in contract costs

(2) Building Envelope includes foundation insulation, wall panels, wall insulation, roof insulation, door insulation, all vapor barrier

(3) Enhanced Commissioning and Measurement & Verifcation is included in the Admin Building

Table C.19 Sample cost breakdown for COF Readiness B Building – Fort Campbell

Readiness C	Baseline Package	Low Energy Package 1	Difference
Baseline Building	-	$ 5,211,194	
HVAC Components	$ 682,542	$ 686,462	$ 3,920
Increased Fan & Pump Efficiencies	$ -	$ 11,012	$ 11,012
ERV Systems	$ -	$ 17,897	$ 17,897
Solar Wall Collector	$ -	$ 15,931	$ 15,931
Advanced Lighting Systems	$ 404,495	$ 437,794	$ 33,299
Increased Building Envelope	$ 500,923	$ 831,536	$ 330,613
Increased Window Efficiency	$ 33,289	$ 75,757	$ 42,468
Dual Flush Toilets	$ -	$ -	$ -
0.5gpm Flow Faucets	$ 24,702	$ 31,878	$ 7,176
Waterless Urinals	$ -	$ -	$ -
Skylights	$ -	$ 80,956	$ 80,956
Enhanced Commissioning	$ -	$ -	$ -
Measurement & Vertification	$ -	$ -	$ -
Rainwater Harvesting	$ -	$ 46,075	$ 46,075
Total Cost	$ 1,645,951	$ 2,235,298	
Add-on Cost		$ 589,347	
Revised Cost		$ 5,800,541	
Pecent Increase		11.31%	

Notes (1) These costs are shown in contract costs

(2) Building Envelope includes foundation insulation, wall panels, wall insulation, roof insulation, door insulation, all vapor barrier

(3) Enhanced Commissioning and Measurement & Verifcation is included in the Admin Building

Table C.20 Sample cost breakdown for COF Readiness C Building – Fort Campbell

No other Cost Breakdowns for COF are available. Detailed cost estimates can be provided by request only.

All new Army facilities have been required to increasingly reduce site energy consumption in response to EPACT 2005, then ECB 2010-14, then the Army Sustainable Design and Development Policy Update (Environmental and Energy Performance, October 27, 2010). As the results below show, the COF standard Army design including the recommended Low Energy Package, easily meets all the current site energy reduction mandates for new Army facilities.

Climate Zone	ASHRAE 90.1-2004 EUI (kBTU/sq ft-yr)	ASHRAE 90.1-2007 EUI (kBTU/sq ft-yr)	EPACT 2005 Target EUI + plug loads (kBTU/sq ft-yr)	ASHRAE 189.1 Target EUI (kBTU/sq ft-yr)	ECB 2010-14 Target EUI + plug loads (kBTU/sq ft-yr)	Low Energy Package Site EUI including plug loads (kBTU/sq ft-yr)
1A	29	28	22	22	19	23
2A	33	32	28	25	22	24
2B	34	33	29	26	22	29
3A	35	33	30	27	23	25
3B	33	32	27	25	22	29
3C	27	26	25	21	18	21
4A	38	36	33	29	25	23
4B	35	33	29	27	23	21
4C	33	32	29	25	22	23
5A	43	41	38	33	27	25
5B	39	37	33	30	25	21
6A	49	47	43	37	31	25
6B	47	45	40	36	30	23
7A	57	54	49	43	35	26
8A	79	76	72	60	48	33

Table C.21 COF Site Energy EUIs of recommended Low Energy Package Compared to the required site energy reduction targets

Appendix D:

Bde HQ

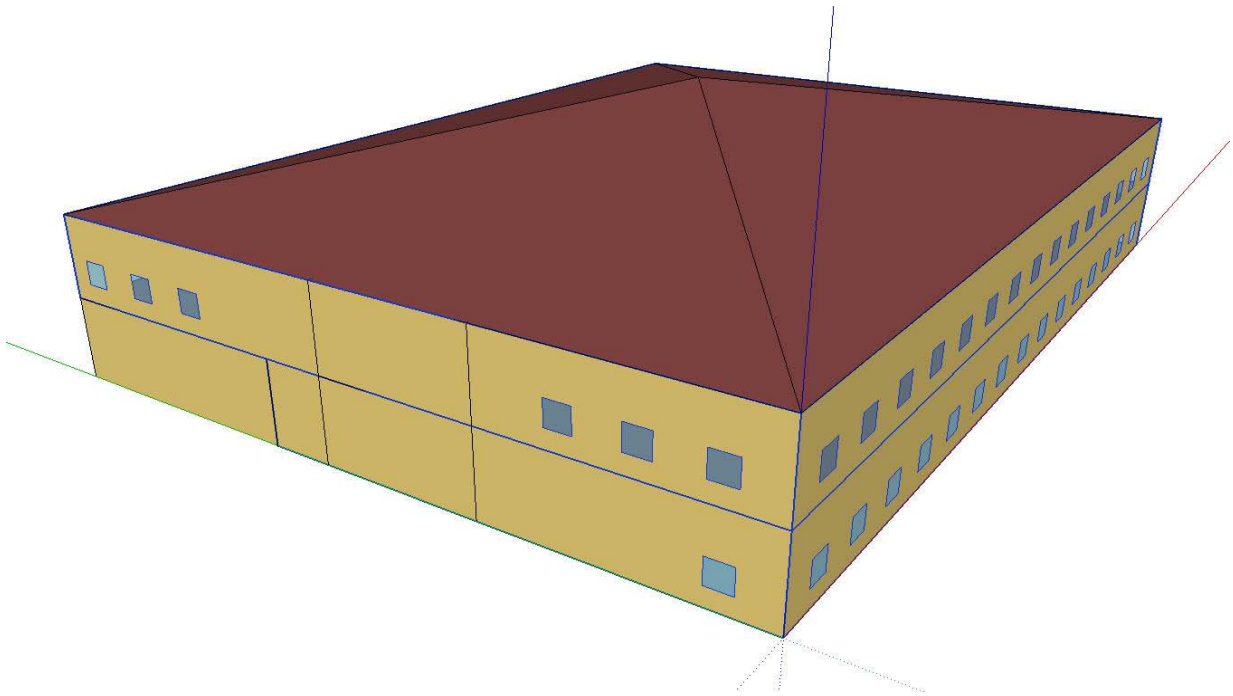


Figure D.1 Rendering of BDE HQ configuration

Parameter	Baseline (V0)	Low Energy (V5 – VAV and ERV)
Envelope – Roof	ASHRAE Std 90.1 compliant	Passive Haus (see attached) Cool Roof in CZ 1-5
Envelope-Walls, floors	ASHRAE Std 90.1 compliant	Passive Haus (see attached)
Envelope - Windows	ASHRAE Std 90.1 compliant	Passive Haus (see attached); (CZ 1-3C use DPW), and (CZ 4A – 8A use TPW)
Envelope - airtightness	.25 cfm/sq ft envelope area @75pa	.15 cfm/sq ft envelope area @75pa High traffic entry vestibule
Lighting		Lighting Power Densities recommended by AtellierTen Advanced controls
HVAC VAV	Standard VAV serving the Office and NOC/BOC/SCIF Office Fan: 2A 19055 CFM 3B 17426 CFM 4A 18195 CFM 4C 15967 CFM 7A 16151 CFM NOC/BOC/SCIF Fan: 2A 7927 CFM 3B 8045 CFM 4A 7757 CFM 4C 7234 CFM 7A 7396 CFM	VAV with ERV Serving the Office and NOC/BOC/SCIF Office Fan: 2A 11173 CFM 3B 10903 CFM 4A 10571 CFM 4C 9857 CFM 7A 9967 CFM NOC/BOC/SCIF Fan: 2A 6795 CFM 3B 7396 CFM 4A 6699 CFM 4C 6549 CFM 7A 6800 CFM VAV has ERV, 0.8 effectiveness

Table D.1a BDE HQ Baseline and low energy component values

Parameter	Baseline (V0)	Low Energy (V5 – VAV and ERV)
HVAC (continued)	Total Coils Cooling: 2A 1217 kBtu/h 3B 1013 kBtu/h 4A 1151 kBtu/h 4C 890 kBtu/h 7A 965 kBtu/h Total Coils Heating: 2A 2644 kBtu/h 3B 2408 kBtu/h 4A 2805 kBtu/h 4C 2493 kBtu/h 7A 2941 kBtu/h	Total Coils Cooling: 2A 824 kBtu/h 3B 728 kBtu/h 4A 779 kBtu/h 4C 634 kBtu/h 7A 691 kBtu/h Total Coils Heating: 2A 2372 kBtu/h 3B 2235 kBtu/h 4A 2518 kBtu/h 4C 2287 kBtu/h 7A 2454 kBtu/h
Chiller	Stnd Effic 2A 71 tons 3B 56 tons 4A 66 tons 4C 44 tons 7A 51 tons	High Effic 2A 50 tons 3B 40 tons 4A 46 tons 4C 32 tons 7A 37 tons
Boiler	Stnd Effic 2A 1771 Kbtu/h 3B 1483 Kbtu/h 4A 1769 Kbtu/h 4C 1540 Kbtu/h 7A 1678 Kbtu/h	High Effic Condensing 2A 1271 Kbtu/h 3B 1148 Kbtu/h 4A 1287 Kbtu/h 4C 1176 Kbtu/h 7A 1263 Kbtu/h

Table D.1b (Continued) BDE HQ Baseline and low energy component values

	Design Criteria			Control Strategies				Technologies				Approach				
				Levels	Automatic Interface											
Space	Target Illuminance at Task [fc] (Design Goal)	Target Lighting Power Density [W/ft²] (Project Design Goal)	Allowable Lighting Power Density [W/ft²] (ASHRAE/IESNA Std 90.1-2004/2007)	Switching - (blank) Multi-Level - M Full Dimming - D	V - Vacancy [Manual ON / Auto OFF] O - Occupancy [Auto ON / Auto OFF]	Daylight (e.g. Photosensors)	Schedule (e.g Astronomical time-clock)	Linear Fluorescent	Compact Fluorescent	Ceramic Metal Halide	Light Emitting Diodes	Overhead General Lighting	Overhead Ambient Lighting	Task Lighting	Wall wash / Perimeter Lighting	Adjustable Accent Lighting
Classroom / Training	40	0.75	1.4	M	V	☼		✓				•			•	
Conference Room	40	0.80	1.3	M/D	V			✓				•			•	
Corridor	10	0.50	0.5		O			✓				•			•	
Mechanical / Electrical	30	0.70	1.5		V			✓				•				
Office (Enclosed)	40	0.90	1.1	M	V			✓			✓		•	•		
Office (Open)	40	0.70	1.1	M/D	V	☼	⏲	✓		✓	✓		•	•	•	•
Restroom / Shower	20	0.80	0.9		V			✓	✓		✓	•			•	
Server Room	30	0.85	1.5		O			✓				•				
Stair	10	0.50	0.6	M	O			✓				•				
Storage (General)	10	0.50	0.8		V			✓				•				•
Telecom / SIPRNET	50	1.20	1.5		V			✓				•				

Table D.2 Atelier Ten Lighting Design Guide Recommendations - BDE HQ

Space	Lighting	Controls
Classroom / Training	Light teaching wall; minimize glare	Provide zoning and circuiting for lecture mode and AV mode, control teaching wall luminaires independent of general lighting
Conference Room	Provide light on people's faces if video conferencing, glare control	Multi-scene preset scene controller may be appropriate in some cases; Use multi-level or dimming ballasts where appropriate
Corridor		Occupancy sensors to reduce load to 25%-50% when vacancy is detected. Multi-Level ballasts may be appropriate in many cases
Mechanical / Electrical	Locate luminaires relative to working areas and equipment	Dual-technology vacancy sensors with long time out
Office (Enclosed)	Use task/ambient scheme with furniture or ceiling mounted ambient lighting and furniture mounted task lighting	Bi-level luminaires and vacancy sensors in private perimeter offices is sufficient for energy savings (photosensors not req)
Office (Open)	Use task/ambient scheme with furniture or ceiling mounted ambient lighting and furniture mounted task lighting	
Restroom / Shower	Lighting over sink and toilet wall will often be enough for entire restroom	Dual-technology vacancy sensor
Server Room	Locate and specify luminaires to light vertical surfaces between server racks	Locate one occupancy sensor per row of server racks
Stair	Locate luminaires to provide 10fc at landings	Use bi-level luminaire with integrated occupancy sensor
Storage (General)	Locate and specify luminaires to light vertical surfaces	
Telecom / SIPRNET	Lighting should be designed to provide 50 fc, LPDs will may be higher for very small telecom rooms and lower for larger rooms.	

Table D.3 Atelier Ten Lighting Design Guide Notes – BDE HQ

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BgHQ Office Internal Load Schedules

Hr	Occupancy			Lighting			Plug Loads		
	Wk	Sat	Sun	Wk	Sat	Sun	Wk	Sat	Sun
1	0.00	0.00	0.00	0.05	0.05	0.05	0.30	0.30	0.30
2	0.00	0.00	0.00	0.05	0.05	0.05	0.30	0.30	0.30
3	0.00	0.00	0.00	0.05	0.05	0.05	0.30	0.30	0.30
4	0.00	0.00	0.00	0.05	0.05	0.05	0.30	0.30	0.30
5	0.00	0.00	0.00	0.05	0.05	0.05	0.30	0.30	0.30
6	0.00	0.00	0.00	0.10	0.05	0.05	0.30	0.30	0.30
7	0.20	0.00	0.00	0.30	0.05	0.05	0.30	0.30	0.30
8	0.95	0.00	0.00	0.90	0.05	0.05	0.90	0.30	0.30
9	0.95	0.00	0.00	0.90	0.05	0.05	0.90	0.30	0.30
10	0.95	0.00	0.00	0.90	0.05	0.05	0.90	0.30	0.30
11	0.95	0.00	0.00	0.90	0.05	0.05	0.90	0.30	0.30
12	0.95	0.00	0.00	0.90	0.05	0.05	0.90	0.30	0.30
13	0.50	0.00	0.00	0.90	0.05	0.05	0.80	0.30	0.30
14	0.95	0.00	0.00	0.90	0.05	0.05	0.90	0.30	0.30
15	0.95	0.00	0.00	0.90	0.05	0.05	0.90	0.30	0.30
16	0.95	0.00	0.00	0.90	0.05	0.05	0.90	0.30	0.30
17	0.95	0.00	0.00	0.90	0.05	0.05	0.90	0.30	0.30
18	0.30	0.00	0.00	0.50	0.05	0.05	0.30	0.30	0.30
19	0.30	0.00	0.00	0.30	0.05	0.05	0.30	0.30	0.30
20	0.00	0.00	0.00	0.30	0.05	0.05	0.30	0.30	0.30
21	0.00	0.00	0.00	0.20	0.05	0.05	0.30	0.30	0.30
22	0.00	0.00	0.00	0.20	0.05	0.05	0.30	0.30	0.30
23	0.00	0.00	0.00	0.10	0.05	0.05	0.30	0.30	0.30
24	0.00	0.00	0.00	0.05	0.05	0.05	0.30	0.30	0.30
Peak	250 ft2/Person			0.75 W/ft^2 on average, 0.7 W/ft2 for general office area			1.2 W/ ft^2 Includes server and telephone cabinets		

High Performance Building Assumptions with Advanced Lighting Controls and Design, Reduced Internal loads.

Table D.4 BDE HQ occupancy, lighting, plug load and service hot water schedule

B	Baseline Energy Budget
P1	Lighting Load and Electric Power Load Density Reduction from 1.67 W/ft^2 to 0.835 W/ft^2 applied to B
P2	Reduced Electric Power Load Density from 1.7 W/ft^2 to 1.2 W/ft^2 in the Office Areas average for all spaces
P3	Passive Haus Specification; Increased Insulation, Advanced Windows and Air Tightness, reduce OA pressurization air due to air tightness
P4	Efficient VAV Sys: Increase Chiller and Boiler Efficiencies and all variable high efficiency pumps and fans.
P5	Energy Recovery [ERV] and VAV with P4
P6	Indirect evaporative pre-cooling (IDEC) and VAV with P4
P7	Dedicated Outdoor Air System (DOAS) with P4
P8	DOAS and ERV with P4
P9	DOAS and IDEC with P4
P10	DOAS, IDEC and radiant heating and cooling with V4
P11	DOAS, ERV and free cooling chiller with P4
P12	DOAS, ERV and Ground Source Heat Pump (GSHP) with P4
P13	GSHP, ERV and VAV with P4

Site Energy Totals with Plug Loads [kBtu/ft2]	2003 CBECS Government Office	CBECS Site Budget	Baseline Building	Low Energy Package 1												
			B	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
1A Miami	73	26	61	58	48	45	37	36	35	44	44	44	38	44	35	33
2A Houston	75	26	55	52	44	39	33	33	32	40	40	40	35	40	33	30
2B Phoenix	73	26	67	64	54	45	37	37	27	38	38	37	35	37	33	31
3A Memphis	71	25	54	52	46	37	32	31	31	38	38	38	34	37	32	29
3B El Paso	66	23	47	45	38	34	30	30	26	35	35	34	32	32	31	29
3C San Francisco	65	23	38	36	30	28	27	27	26	32	33	32	32	32	30	26
4A Baltimore	79	28	54	52	47	33	30	29	29	36	35	36	32	34	31	28
4B Albuquerque	68	24	50	48	42	32	29	29	26	33	33	33	31	30	31	28
4C Seattle	72	25	42	41	37	28	26	26	26	32	32	32	32	30	30	26
5A Chicago	85	30	59	57	53	34	30	29	30	36	35	36	32	33	31	28
5B Colorado Springs	73	26	50	49	44	31	28	28	26	33	32	33	30	29	30	28
6A Burlington	94	33	60	58	55	33	30	27	29	36	33	36	31	32	30	27
6B Helena	83	29	56	55	51	31	29	27	27	34	32	34	30	29	30	27
7A Duluth	98	34	67	65	63	34	31	28	31	36	33	36	31	31	31	27
8A Fairbanks	133	47	88	87	85	43	37	31	36	41	35	41	34	33	32	29

Bde HQ Office	Cumulative % Savings (Site)												
	P1-B	P2-P1	P3-P2	P4-P3	P5-P4	P6-P4	P7-P4	P8-P4	P9-P4	P10-P4	P11-P4	P12-P4	P13-P4
1A Miami	-5%	-21%	-26%	-38%	-40%	-42%	-27%	-27%	-28%	-38%	-27%	-43%	-46%
2A Houston	-4%	-19%	-29%	-39%	-40%	-42%	-26%	-26%	-28%	-35%	-28%	-40%	-45%
2B Phoenix	-4%	-18%	-33%	-44%	-45%	-59%	-43%	-43%	-45%	-48%	-45%	-50%	-54%
3A Memphis	-4%	-16%	-33%	-41%	-43%	-44%	-29%	-30%	-30%	-37%	-33%	-41%	-47%
3B El Paso	-5%	-20%	-28%	-36%	-37%	-44%	-26%	-26%	-27%	-31%	-31%	-33%	-39%
3C San Francisco	-5%	-23%	-26%	-30%	-28%	-33%	-16%	-14%	-16%	-18%	-17%	-21%	-31%
4A Baltimore	-3%	-13%	-38%	-44%	-46%	-46%	-33%	-35%	-33%	-40%	-38%	-42%	-48%
4B Albuquerque	-4%	-16%	-35%	-41%	-41%	-48%	-33%	-34%	-33%	-38%	-39%	-38%	-44%
4C Seattle	-3%	-13%	-35%	-38%	-39%	-39%	-24%	-25%	-24%	-24%	-29%	-30%	-39%
5A Chicago	-2%	-10%	-42%	-48%	-51%	-49%	-38%	-41%	-38%	-45%	-44%	-48%	-52%
5B Colorado Springs	-3%	-13%	-39%	-44%	-45%	-48%	-34%	-37%	-35%	-40%	-42%	-40%	-45%
6A Burlington	-2%	-8%	-45%	-50%	-54%	-51%	-40%	-44%	-40%	-48%	-47%	-49%	-54%
6B Helena	-2%	-9%	-44%	-49%	-51%	-52%	-39%	-43%	-40%	-46%	-48%	-46%	-51%
7A Duluth	-2%	-6%	-48%	-54%	-58%	-54%	-45%	-51%	-45%	-53%	-53%	-54%	-59%
8A Fairbanks	-1%	-3%	-51%	-58%	-64%	-59%	-53%	-60%	-53%	-61%	-62%	-64%	-67%
Avg % Savings	-3%	-14%	-37%	-44%	-46%	-47%	-34%	-36%	-34%	-40%	-39%	-43%	-48%

Table D.5 Bde HQ Office site baseline and low energy EUIs and cumulative % savings for EEM packages

Source Energy Totals with Plug Loads [kBtu/ft2]	2003 CBECS Government Office	CBECS Source Budget	Baseline Building	Low Energy Package 1												
			B	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
1A Miami	203	85	201	192	158	149	124	120	117	147	147	145	125	146	115	108
2A Houston	198	85	176	168	139	127	110	108	105	132	133	130	117	130	108	99
2B Phoenix	193	84	220	210	177	148	124	122	90	126	127	122	114	121	110	101
3A Memphis	183	76	166	159	132	118	104	102	99	124	124	122	111	120	105	95
3B El Paso	160	74	151	143	117	111	99	98	86	114	115	112	107	107	104	95
3C San Francisco	163	73	123	116	92	92	87	90	84	105	108	105	104	104	99	86
4A Baltimore	188	78	152	145	121	104	95	94	91	114	114	113	105	109	102	91
4B Albuquerque	170	72	150	143	117	104	95	95	83	107	107	106	102	99	101	91
4C Seattle	168	73	123	117	97	87	84	84	82	103	103	102	102	98	98	84
5A Chicago	185	77	152	146	124	102	94	92	91	112	111	111	103	106	101	92
5B Colorado Springs	170	72	141	134	111	97	90	90	82	104	103	104	98	95	99	90
6A Burlington	194	81	147	141	120	96	90	88	88	108	106	107	99	101	100	90
6B Helena	178	74	143	137	116	94	89	88	83	104	102	104	97	94	99	89
7A Duluth	193	77	150	144	126	95	89	86	88	106	103	106	97	98	100	89
8A Fairbanks	228	91	172	166	149	103	95	90	92	108	102	107	98	97	104	95

Bde HQ Office	Cumulative % Savings (Source)												
	P1-B	P2-P1	P3-P2	P4-P3	P5-P4	P6-P4	P7-P4	P8-P4	P9-P4	P10-P4	P11-P4	P12-P4	P13-P4
1A Miami	-5%	-21%	-26%	-38%	-40%	-42%	-27%	-27%	-28%	-38%	-27%	-43%	-46%
2A Houston	-5%	-21%	-28%	-38%	-39%	-41%	-25%	-25%	-26%	-34%	-26%	-39%	-44%
2B Phoenix	-4%	-19%	-32%	-44%	-44%	-59%	-43%	-42%	-45%	-48%	-45%	-50%	-54%
3A Memphis	-4%	-20%	-29%	-38%	-39%	-41%	-26%	-25%	-27%	-33%	-28%	-37%	-43%
3B El Paso	-5%	-23%	-27%	-34%	-35%	-43%	-25%	-24%	-26%	-30%	-30%	-32%	-37%
3C San Francisco	-6%	-25%	-25%	-29%	-27%	-32%	-14%	-12%	-15%	-16%	-16%	-19%	-30%
4A Baltimore	-4%	-20%	-31%	-37%	-38%	-40%	-25%	-25%	-25%	-31%	-28%	-33%	-40%
4B Albuquerque	-5%	-22%	-30%	-37%	-36%	-45%	-28%	-29%	-29%	-32%	-34%	-33%	-39%
4C Seattle	-5%	-21%	-29%	-32%	-32%	-33%	-17%	-16%	-17%	-17%	-21%	-21%	-31%
5A Chicago	-4%	-19%	-33%	-39%	-40%	-40%	-27%	-27%	-27%	-33%	-30%	-34%	-40%
5B Colorado Springs	-5%	-21%	-31%	-36%	-36%	-42%	-26%	-27%	-26%	-30%	-33%	-30%	-36%
6A Burlington	-4%	-18%	-34%	-39%	-40%	-40%	-26%	-28%	-27%	-32%	-31%	-32%	-39%
6B Helena	-4%	-19%	-34%	-38%	-38%	-42%	-27%	-29%	-28%	-32%	-35%	-31%	-38%
7A Duluth	-4%	-16%	-37%	-41%	-43%	-41%	-29%	-31%	-30%	-35%	-35%	-33%	-40%
8A Fairbanks	-3%	-13%	-40%	-45%	-48%	-46%	-37%	-41%	-37%	-43%	-44%	-39%	-45%
Avg % Savings	-5%	-20%	-31%	-38%	-38%	-42%	-27%	-27%	-28%	-32%	-31%	-34%	-40%

Table D.6 Bde HQ Office source baseline and low energy EUIs and cumulative % savings for EEM packages

Site Energy Totals with Plug Loads [kBtu/ft2]	2003 CBECS Government Office	CBECS Site Budget	Baseline Building	Low Energy Package 1												
			B	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
1A Miami	73	26	168	165	165	160	142	142	140	150	151	150	127	151	149	148
2A Houston	75	26	155	153	153	150	135	136	133	149	149	148	126	145	144	139
2B Phoenix	73	26	182	180	180	173	150	156	125	143	144	143	125	140	145	142
3A Memphis	71	25	148	146	146	143	131	132	128	149	149	149	126	141	141	133
3B El Paso	66	23	143	142	142	141	129	132	120	142	142	142	123	134	140	133
3C San Francisco	65	23	135	133	133	135	125	136	122	137	137	137	122	136	137	129
4A Baltimore	79	28	138	137	137	134	125	127	123	147	146	147	124	134	140	128
4B Albuquerque	68	24	147	145	145	145	132	137	118	139	138	139	122	129	139	130
4C Seattle	72	25	124	122	122	124	118	121	117	138	137	138	121	130	137	123
5A Chicago	85	30	136	134	134	131	123	125	122	148	145	148	124	132	139	126
5B Colorado Springs	73	26	138	136	136	136	127	131	116	139	137	139	122	126	138	127
6A Burlington	94	33	131	130	130	127	121	122	119	145	142	145	122	128	138	123
6B Helena	83	29	133	132	132	130	123	127	114	141	138	140	122	125	137	123
7A Duluth	98	34	129	127	127	125	119	121	118	144	141	144	122	126	138	122
8A Fairbanks	133	47	129	128	128	128	121	123	118	142	137	142	121	123	137	120

Bde HQ NOC/BOC/SCIF	Cumulative % Savings (Site)												
	P1-B	P2-P1	P3-P2	P4-P3	P5-P4	P6-P4	P7-P4	P8-P4	P9-P4	P10-P4	P11-P4	P12-P4	P13-P4
1A Miami	-1%	-1%	-4%	-15%	-15%	-16%	-10%	-10%	-11%	-24%	-10%	-11%	-11%
2A Houston	-1%	-1%	-3%	-13%	-12%	-14%	-4%	-4%	-4%	-19%	-6%	-7%	-10%
2B Phoenix	-1%	-1%	-5%	-18%	-15%	-32%	-21%	-21%	-22%	-32%	-23%	-21%	-22%
3A Memphis	-1%	-1%	-3%	-12%	-10%	-13%	1%	1%	1%	-15%	-5%	-4%	-10%
3B El Paso	-1%	-1%	-2%	-10%	-8%	-16%	-1%	-1%	-1%	-15%	-7%	-2%	-7%
3C San Francisco	-1%	-1%	0%	-7%	1%	-9%	1%	2%	1%	-9%	1%	2%	-4%
4A Baltimore	-1%	-1%	-3%	-10%	-8%	-11%	6%	5%	6%	-10%	-3%	1%	-7%
4B Albuquerque	-1%	-1%	-2%	-10%	-7%	-20%	-5%	-6%	-6%	-17%	-13%	-6%	-12%
4C Seattle	-1%	-1%	0%	-5%	-2%	-6%	11%	10%	11%	-3%	5%	10%	-1%
5A Chicago	-1%	-1%	-3%	-9%	-8%	-10%	9%	7%	9%	-9%	-3%	3%	-7%
5B Colorado Springs	-1%	-1%	-1%	-8%	-5%	-16%	0%	-1%	0%	-12%	-9%	0%	-8%
6A Burlington	-1%	-1%	-3%	-8%	-7%	-9%	10%	8%	10%	-7%	-2%	5%	-6%
6B Helena	-1%	-1%	-2%	-8%	-4%	-14%	5%	4%	5%	-8%	-6%	3%	-8%
7A Duluth	-1%	-1%	-3%	-8%	-7%	-8%	12%	9%	12%	-5%	-3%	7%	-6%
8A Fairbanks	-1%	-1%	-1%	-6%	-5%	-9%	10%	6%	10%	-6%	-5%	6%	-7%
Avg % Savings	-1%	-1%	-2%	-10%	-7%	-14%	2%	1%	2%	-13%	-6%	-1%	-8%

Table D.7 Bde HQ NOC/BOC/SCIF site baseline and low energy EUIs and cumulative % savings for EEM packages

Source Energy Totals with Plug Loads [kBtu/ft2]	2003 CBECS Government Office	CBECS Source Budget	Baseline Building	Low Energy Package 1												
			B	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
1A Miami	203	85	553	546	546	530	470	471	463	497	499	495	421	499	491	490
2A Houston	198	85	510	504	504	493	445	449	438	489	491	488	415	478	474	458
2B Phoenix	193	84	603	594	594	572	497	514	411	472	475	471	411	463	478	470
3A Memphis	183	76	483	477	477	468	429	435	421	488	490	488	413	463	466	437
3B El Paso	160	74	471	465	465	462	426	433	394	464	467	464	403	440	462	439
3C San Francisco	163	73	441	435	435	440	410	448	400	448	451	447	400	446	451	424
4A Baltimore	188	78	449	444	444	440	410	417	403	478	479	478	407	441	459	421
4B Albuquerque	170	72	482	475	475	475	434	449	388	452	454	451	400	422	455	427
4C Seattle	168	73	404	399	399	403	387	397	382	447	449	447	395	427	449	401
5A Chicago	185	77	437	431	431	428	403	410	398	477	477	477	405	432	456	412
5B Colorado Springs	170	72	449	443	443	445	415	430	380	449	450	448	398	413	452	414
6A Burlington	194	81	420	414	414	413	393	400	388	466	465	466	400	419	452	404
6B Helena	178	74	429	423	423	425	401	416	373	452	452	452	398	409	450	402
7A Duluth	193	77	409	404	404	403	387	393	384	462	461	461	398	410	451	396
8A Fairbanks	228	91	407	402	402	406	389	399	376	449	447	449	394	398	446	390

Bde HQ NOC/BOC/SCIF	Cumulative % Savings (Source)												
	P1-B	P2-P1	P3-P2	P4-P3	P5-P4	P6-P4	P7-P4	P8-P4	P9-P4	P10-P4	P11-P4	P12-P4	P13-P4
1A Miami	-1%	-1%	-4%	-15%	-15%	-16%	-10%	-10%	-10%	-24%	-10%	-11%	-11%
2A Houston	-1%	-1%	-3%	-13%	-12%	-14%	-4%	-4%	-4%	-19%	-6%	-7%	-10%
2B Phoenix	-1%	-1%	-5%	-18%	-15%	-32%	-22%	-21%	-22%	-32%	-23%	-21%	-22%
3A Memphis	-1%	-1%	-3%	-11%	-10%	-13%	1%	1%	1%	-15%	-4%	-4%	-9%
3B El Paso	-1%	-1%	-2%	-10%	-8%	-16%	-1%	-1%	-2%	-15%	-7%	-2%	-7%
3C San Francisco	-1%	-1%	0%	-7%	2%	-9%	2%	2%	2%	-9%	1%	2%	-4%
4A Baltimore	-1%	-1%	-2%	-9%	-7%	-10%	6%	7%	6%	-9%	-2%	2%	-6%
4B Albuquerque	-1%	-1%	-1%	-10%	-7%	-20%	-6%	-6%	-6%	-17%	-12%	-6%	-11%
4C Seattle	-1%	-1%	0%	-4%	-2%	-6%	11%	11%	11%	-2%	6%	11%	-1%
5A Chicago	-1%	-1%	-2%	-8%	-6%	-9%	9%	9%	9%	-7%	-1%	4%	-6%
5B Colorado Springs	-1%	-1%	-1%	-8%	-4%	-15%	0%	0%	0%	-11%	-8%	1%	-8%
6A Burlington	-1%	-1%	-2%	-6%	-5%	-8%	11%	11%	11%	-5%	0%	8%	-4%
6B Helena	-1%	-1%	-1%	-6%	-3%	-13%	5%	5%	5%	-7%	-5%	5%	-6%
7A Duluth	-1%	-1%	-1%	-5%	-4%	-6%	13%	13%	13%	-3%	0%	10%	-3%
8A Fairbanks	-1%	-1%	0%	-5%	-2%	-8%	10%	10%	10%	-3%	-2%	10%	-4%
Avg % Savings	-1%	-1%	-2%	-9%	-7%	-13%	2%	2%	2%	-12%	-5%	0%	-8%

Table D.8 Bde HQ NOC/BOC/SCIF source baseline and low energy EUIs and cumulative % savings for EEM packages

Site Energy Totals with Plug Loads [kBtu/ft2]	2003 CBECS Government Office	CBECS Site Budget	Baseline Building	Low Energy Package 1												
			B	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
1A Miami	73	26	83	81	76	72	61	60	59	71	71	70	56	71	56	56
2A Houston	75	26	75	73	69	64	55	56	54	66	66	66	54	65	54	52
2B Phoenix	73	26	91	89	83	75	63	64	47	63	63	62	53	61	54	52
3A Memphis	71	25	72	71	67	59	53	53	51	64	63	64	53	61	52	49
3B El Paso	66	23	66	64	60	57	51	52	45	59	59	59	51	56	52	49
3C San Francisco	65	23	55	53	49	49	46	50	44	56	56	56	50	55	50	46
4A Baltimore	79	28	70	69	66	54	49	50	48	61	60	60	52	57	51	47
4B Albuquerque	68	24	68	66	63	56	51	52	43	57	56	57	50	52	51	47
4C Seattle	72	25	56	55	52	46	44	45	43	55	55	55	49	52	49	44
5A Chicago	85	30	73	72	70	54	49	49	48	60	59	60	52	55	51	46
5B Colorado Springs	73	26	66	64	61	52	48	49	43	56	55	56	50	51	51	46
6A Burlington	94	33	73	72	70	51	47	47	46	59	57	59	50	53	50	45
6B Helena	83	29	69	68	66	50	47	47	43	57	55	57	50	50	50	45
7A Duluth	98	34	78	77	75	51	47	46	47	58	56	58	50	51	50	45
8A Fairbanks	133	47	97	96	95	59	52	48	51	60	55	60	52	51	50	45

Bde HQ Combined	Cumulative % Savings (Site)												
	P1-B	P2-P1	P3-P2	P4-P3	P5-P4	P6-P4	P7-P4	P8-P4	P9-P4	P10-P4	P11-P4	P12-P4	P13-P4
1A Miami	-3%	-9%	-14%	-27%	-28%	-30%	-15%	-15%	-16%	-33%	-15%	-32%	-33%
2A Houston	-2%	-9%	-15%	-26%	-26%	-29%	-12%	-12%	-13%	-28%	-13%	-28%	-31%
2B Phoenix	-3%	-9%	-18%	-31%	-30%	-48%	-31%	-31%	-32%	-41%	-33%	-40%	-43%
3A Memphis	-2%	-7%	-18%	-27%	-27%	-30%	-12%	-12%	-12%	-26%	-15%	-28%	-32%
3B El Paso	-3%	-9%	-14%	-22%	-21%	-31%	-9%	-10%	-10%	-22%	-14%	-20%	-25%
3C San Francisco	-3%	-10%	-9%	-16%	-9%	-19%	2%	3%	2%	-8%	1%	-8%	-16%
4A Baltimore	-2%	-6%	-22%	-30%	-29%	-32%	-13%	-14%	-13%	-26%	-19%	-27%	-33%
4B Albuquerque	-2%	-8%	-17%	-25%	-23%	-36%	-16%	-17%	-16%	-26%	-23%	-24%	-30%
4C Seattle	-2%	-6%	-18%	-22%	-19%	-23%	-1%	-2%	-1%	-13%	-7%	-12%	-21%
5A Chicago	-2%	-5%	-27%	-33%	-34%	-35%	-18%	-20%	-18%	-30%	-25%	-31%	-37%
5B Colorado Springs	-2%	-7%	-21%	-27%	-25%	-35%	-15%	-16%	-15%	-24%	-23%	-23%	-30%
6A Burlington	-1%	-4%	-30%	-35%	-36%	-36%	-19%	-22%	-19%	-30%	-28%	-31%	-38%
6B Helena	-2%	-5%	-28%	-33%	-32%	-38%	-18%	-21%	-18%	-28%	-28%	-27%	-35%
7A Duluth	-1%	-3%	-34%	-39%	-41%	-40%	-25%	-28%	-25%	-35%	-34%	-36%	-43%
8A Fairbanks	-1%	-2%	-39%	-46%	-50%	-47%	-38%	-43%	-38%	-46%	-47%	-48%	-53%
Avg % Savings	-2%	-7%	-22%	-29%	-29%	-34%	-16%	-17%	-16%	-28%	-21%	-28%	-33%

Table D.9 Bde Combined building site baseline and low energy EUIs and cumulative % savings for EEM packages

Source Energy Totals with Plug Loads [kBtu/ft2]	2003 CBECS Government Office	CBECS Source Budget	Baseline Building	Low Energy Package 1												
			B	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
1A Miami	203	85	278	271	252	239	202	200	195	237	236	234	185	237	188	185
2A Houston	198	85	246	239	223	211	183	184	177	219	219	217	180	216	179	172
2B Phoenix	193	84	302	294	274	249	208	212	157	208	209	205	177	204	180	173
3A Memphis	183	76	230	224	209	196	174	176	167	210	210	209	177	203	174	163
3B El Paso	160	74	214	208	193	188	169	172	149	196	197	195	170	187	173	164
3C San Francisco	163	73	179	174	159	164	152	165	147	184	186	184	167	184	166	152
4A Baltimore	188	78	210	205	192	177	161	164	156	198	198	197	171	187	169	156
4B Albuquerque	170	72	214	209	194	185	167	173	143	186	186	186	167	174	170	156
4C Seattle	168	73	173	168	156	151	144	150	141	181	181	181	161	172	164	146
5A Chicago	185	77	208	203	190	171	158	160	154	194	193	193	169	181	167	153
5B Colorado Springs	170	72	198	192	179	170	157	162	140	182	182	182	164	167	168	151
6A Burlington	194	81	198	193	181	162	151	153	148	187	186	187	165	172	165	149
6B Helena	178	74	195	190	178	161	151	156	139	182	181	182	164	165	166	148
7A Duluth	193	77	197	193	182	157	148	149	146	184	181	183	163	166	165	147
8A Fairbanks	228	91	215	211	201	163	152	151	147	179	174	179	162	160	166	149

Bde HQ Combined	Cumulative % Savings (Source)												
	P1-B	P2-P1	P3-P2	P4-P3	P5-P4	P6-P4	P7-P4	P8-P4	P9-P4	P10-P4	P11-P4	P12-P4	P13-P4
1A Miami	-3%	-9%	-14%	-27%	-28%	-30%	-15%	-15%	-16%	-33%	-15%	-32%	-33%
2A Houston	-3%	-9%	-14%	-25%	-25%	-28%	-11%	-11%	-12%	-27%	-12%	-27%	-30%
2B Phoenix	-3%	-9%	-17%	-31%	-30%	-48%	-31%	-31%	-32%	-41%	-32%	-40%	-43%
3A Memphis	-3%	-9%	-15%	-24%	-24%	-27%	-8%	-8%	-9%	-23%	-12%	-24%	-29%
3B El Paso	-3%	-10%	-12%	-21%	-20%	-31%	-9%	-8%	-9%	-21%	-13%	-19%	-24%
3C San Francisco	-3%	-11%	-9%	-15%	-8%	-18%	3%	4%	2%	-7%	2%	-7%	-15%
4A Baltimore	-3%	-9%	-16%	-23%	-22%	-26%	-6%	-6%	-6%	-19%	-11%	-20%	-26%
4B Albuquerque	-3%	-10%	-14%	-22%	-20%	-33%	-13%	-13%	-13%	-22%	-19%	-21%	-27%
4C Seattle	-3%	-10%	-13%	-16%	-13%	-18%	5%	5%	4%	-7%	0%	-5%	-15%
5A Chicago	-2%	-8%	-18%	-24%	-23%	-26%	-7%	-7%	-7%	-19%	-13%	-20%	-26%
5B Colorado Springs	-3%	-10%	-14%	-21%	-18%	-29%	-8%	-8%	-8%	-17%	-15%	-15%	-23%
6A Burlington	-2%	-8%	-18%	-24%	-23%	-25%	-5%	-6%	-6%	-16%	-13%	-16%	-25%
6B Helena	-2%	-9%	-17%	-22%	-20%	-29%	-6%	-7%	-7%	-16%	-15%	-15%	-24%
7A Duluth	-2%	-8%	-20%	-25%	-24%	-26%	-7%	-8%	-7%	-17%	-16%	-16%	-25%
8A Fairbanks	-2%	-7%	-24%	-29%	-30%	-32%	-17%	-19%	-17%	-25%	-25%	-23%	-31%
Avg % Savings	-3%	-9%	-16%	-23%	-22%	-28%	-9%	-9%	-9%	-21%	-14%	-20%	-26%

Table D.10 Bde HQ Combined building source baseline and low energy EUIs and cumulative % savings for EEM packages

Bde HQ - Fort Campbell	Low Energy Package 1	Low Energy Package 2	Low Energy Package 3	Low Energy Package 4
Baseline Building	$ 8,535,728	$ 8,535,728	$ 8,535,728	$ 8,535,728
HVAC Components	$ (14,401)	$ 430,523	$ 666,666	$ 801,133
Advanced Lighting Systems	$ (39,358)	$ (39,358)	$ (39,358)	$ (39,358)
Increased Building Envelope	$ 173,596	$ 173,596	$ 173,596	$ 173,596
Increased Window Efficiency	$ 61,663	$ 61,663	$ 61,663	$ 61,663
Entrance Vestibules	$ 42,608	$ 42,608	$ 42,608	$ 42,608
Dual Flush Toilets	$ 2,213	$ 2,213	$ 2,213	$ 2,213
Urinals	$ (1,329)	$ (1,329)	$ (1,329)	$ (1,329)
1.5gpm Flow Showerheads	$ 825	$ 825	$ 825	$ 825
0.5gpm Flow Faucets	$ 10,046	$ 10,046	$ 10,046	$ 10,046
Enhanced Commissioning	$ 58,364	$ 58,364	$ 58,364	$ 58,364
Measurement & Verification	$ 51,540	$ 51,540	$ 51,540	$ 51,540
Rainwater Harvesting	$ 84,094	$ 84,094	$ 84,094	$ 84,094
Add-on Cost	$ 429,861	$ 874,785	$ 1,110,928	$ 1,245,395
Revised Cost	$ 8,965,589	$ 9,410,513	$ 9,646,656	$ 9,781,123
Pecent Increase	5.04%	10.25%	13.02%	14.59%
Notes	(1) These costs are shown in contract costs			
	(2) Baseline builds to meet LEED Silver			

Table D.11 Cost breakdown for BDE HQ – Fort Campbell

Bde HQ - Fort Lewis	Low Energy Package 1	Low Energy Package 2	Low Energy Package 3	Low Energy Package 4
Baseline Building	$ 10,122,092	$ 10,122,092	$ 10,122,092	$ 10,122,092
HVAC Components	$ 1,668	$ 531,127	$ 812,138	$ 984,669
Advanced Lighting Systems	$ (46,836)	$ (46,836)	$ (46,836)	$ (46,836)
Increased Building Envelope	$ 177,753	$ 177,753	$ 177,753	$ 177,753
Increased Window Efficiency	$ 73,379	$ 73,379	$ 73,379	$ 73,379
Entrance Vestibules	$ 50,703	$ 50,703	$ 50,703	$ 50,703
Dual Flush Toilets	$ 2,634	$ 2,634	$ 2,634	$ 2,634
Urinals	$ (1,582)	$ (1,582)	$ (1,582)	$ (1,582)
1.5gpm Flow Showerheads	$ 982	$ 982	$ 982	$ 982
0.5gpm Flow Faucets	$ 11,954	$ 11,954	$ 11,954	$ 11,954
Enhanced Commissioning	$ 55,149	$ 55,149	$ 55,149	$ 55,149
Measurement & Verification	$ 61,333	$ 61,333	$ 61,333	$ 61,333
Rainwater Harvesting	$ 100,072	$ 100,072	$ 100,072	$ 100,072
Add-on Cost	$ 487,209	$ 1,016,668	$ 1,297,679	$ 1,470,210
Revised Cost	$ 10,609,301	$ 11,138,760	$ 11,419,771	$ 11,592,302
Pecent Increase	4.81%	10.04%	12.82%	14.52%
Notes	(1) These costs are shown in contract costs			
	(2) Baseline builds to meet LEED Silver			

Table D.12 Cost breakdown for BDE HQ – Fort Lewis

Bde HQ - Fort Drum	Low Energy Package 1	Low Energy Package 2	Low Energy Package 3	Low Energy Package 4
Baseline Building	$ 9,894,934	$ 9,894,934	$ 9,894,934	$ 9,894,934
HVAC Components	$ (36,263)	$ 475,399	$ 746,965	$ 904,690
Advanced Lighting Systems	$ (45,262)	$ (45,262)	$ (45,262)	$ (45,262)
Increased Building Envelope	$ 419,371	$ 419,371	$ 419,371	$ 419,371
Increased Window Efficiency	$ 70,913	$ 70,913	$ 70,913	$ 70,913
Entrance Vestibules	$ 48,999	$ 48,999	$ 48,999	$ 48,999
Dual Flush Toilets	$ 2,545	$ 2,545	$ 2,545	$ 2,545
Urinals	$ (1,529)	$ (1,529)	$ (1,529)	$ (1,529)
1.5gpm Flow Showerheads	$ 950	$ 950	$ 950	$ 950
0.5gpm Flow Faucets	$ 11,553	$ 11,553	$ 11,553	$ 11,553
Enhanced Commissioning	$ 53,295	$ 53,295	$ 53,295	$ 53,295
Measurement & Verification	$ 59,271	$ 59,271	$ 59,271	$ 59,271
Rainwater Harvesting	$ 96,708	$ 96,708	$ 96,708	$ 96,708
Add-on Cost	$ 680,551	$ 1,192,213	$ 1,463,779	$ 1,621,504
Revised Cost	$ 10,575,485	$ 11,087,147	$ 11,358,713	$ 11,516,438
Pecent Increase	6.88%	12.05%	14.79%	16.39%
Notes	(1) These costs are shown in contract costs			
	(2) Baseline builds to meet LEED Silver			

Table D.13 Cost breakdown for BDE HQ – Fort Drum

Bde HQ - Fort Wainwright	Low Energy Package 1	Low Energy Package 2	Low Energy Package 3	Low Energy Package 4
Baseline Building	$18,362,721	$18,362,721	$18,362,721	$18,362,721
HVAC Components	$ 11,885	$ 964,022	$ 1,469,370	$ 1,738,528
Advanced Lighting Systems	$ (84,226)	$ (84,226)	$ (84,226)	$ (84,226)
Increased Building Envelope	$ 1,214,046	$ 1,214,046	$ 1,214,046	$ 1,214,046
Increased Window Efficiency	$ 131,959	$ 131,959	$ 131,959	$ 131,959
Entrance Vestibules	$ 91,181	$ 91,181	$ 91,181	$ 91,181
Dual Flush Toilets	$ 4,737	$ 4,737	$ 4,737	$ 4,737
Urinals	$ (2,846)	$ (2,846)	$ (2,846)	$ (2,846)
1.5gpm Flow Showerheads	$ 1,766	$ 1,766	$ 1,766	$ 1,766
0.5gpm Flow Faucets	$ 21,498	$ 21,498	$ 21,498	$ 21,498
Enhanced Commissioning	$ 99,175	$ 99,175	$ 99,175	$ 99,175
Measurement & Verification	$ 110,295	$ 110,295	$ 110,295	$ 110,295
Rainwater Harvesting	$ 179,962	$ 179,962	$ 179,962	$ 179,962
Add-on Cost	$ 1,779,432	$ 2,731,569	$ 3,236,917	$ 3,506,075
Revised Cost	$ 20,142,153	$ 21,094,290	$ 21,599,638	$ 21,868,796
Pecent Increase	9.69%	14.88%	17.63%	19.09%
Notes	(1) These costs are shown in contract costs			
	(2) Baseline builds to meet LEED Silver			

Table D.14 Cost breakdown for BDE HQ – Fort Wainwright

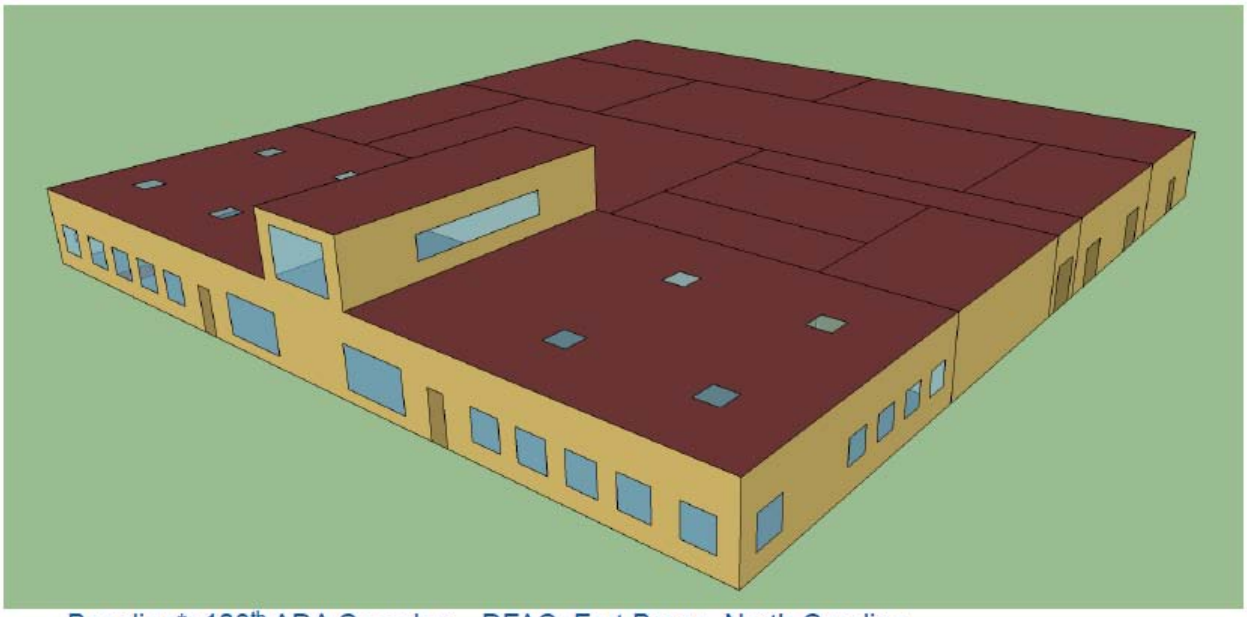
All new Army facilities have been required to increasingly reduce site energy consumption in response to EPACT 2005, then ECB 2010-14, then the Army Sustainable Design and Development Policy Update (Environmental and Energy Performance, October 27, 2010). As the results below show, the Admin portion of the Bde HQ standard Army design including the recommended Low Energy Packages, meets most of the current site energy reduction mandates for new Army facilities.

Climate Zone	ASHRAE 90.1-2004 EUI (kBTU/sq ft-yr)	ASHRAE 90.1-2007 EUI (kBTU/sq ft-yr)	EPACT 2005 Target EUI + plug loads (kBTU/sq ft-yr)	ASHRAE 189.1 Target EUI (kBTU/sq ft-yr)	ECB 2010-14 Target EUI + plug loads (kBTU/sq ft-yr)	Low Energy Package 3 Site EUI including plug loads (kBTU/sq ft-yr)
1A	41	39	32	31	28	33
2A	40	39	31	31	27	30
2B	42	40	32	32	28	31
3A	43	41	33	33	29	29
3B	39	37	30	29	26	29
3C	35	34	28	27	24	26
4A	47	45	36	36	31	28
4B	42	40	32	32	28	28
4C	42	40	32	32	28	26
5A	54	52	41	41	35	28
5B	47	45	36	36	31	28
6A	61	59	46	47	39	27
6B	57	55	43	44	37	27
7A	71	67	52	54	45	27
8A	103	98	75	78	63	29

Table D.15 Admin portion of Bde HQ Site Energy EUIs Compared to the required site energy reduction targets

Appendix E:

DFAC



Baseline*: 108th ADA Complex – DFAC, Fort Bragg, North Carolina

Figure E.1 Rendering of baseline DFAC configuration

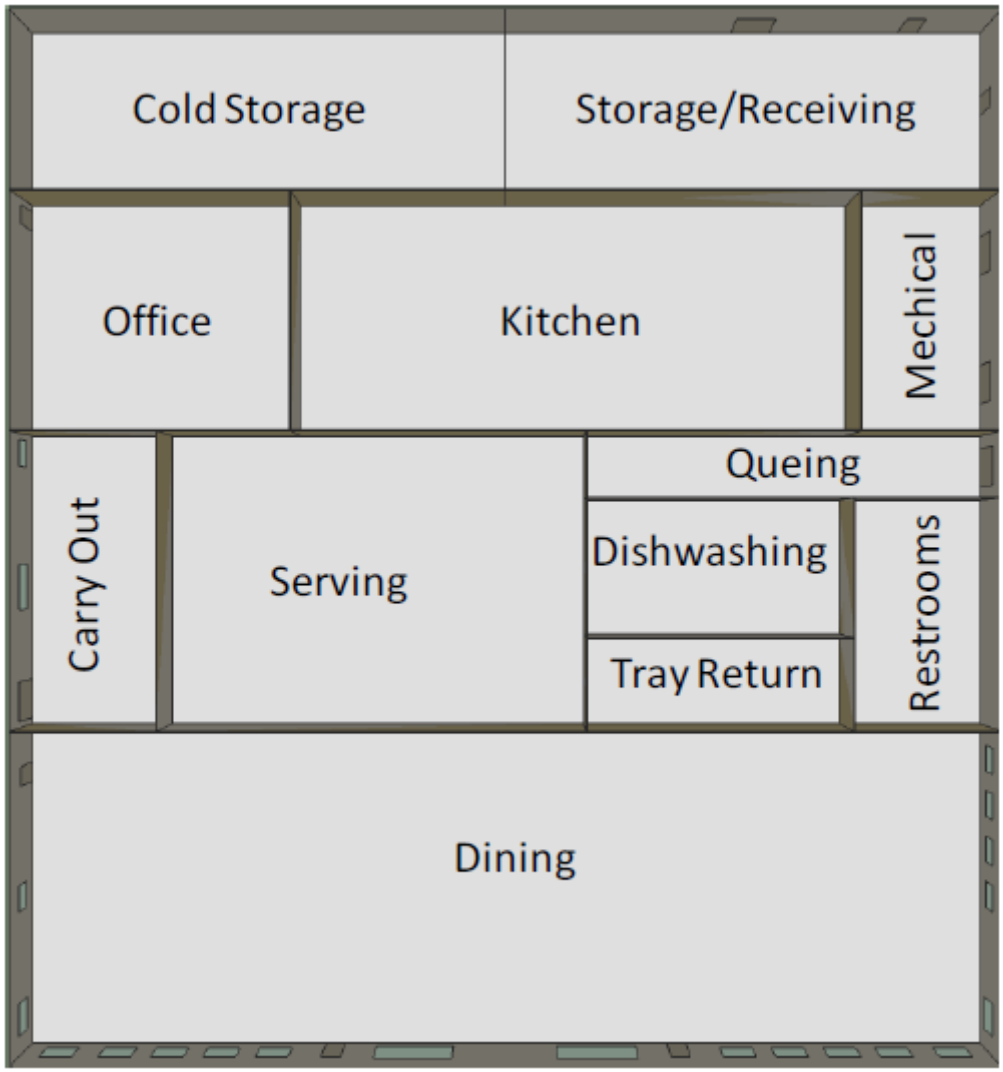


Figure E.2 DFAC Rendering of first floor of DFAC baseline configuration thermal zones

Parameter	Baseline*	Low Energy
Envelope	ASHRAE 90.1-2007 compliant envelope constructions	Passiv Haus insulation, Passiv Haus rated windows– applied to whole building. Reduced infiltration rates from 0.4 cfm/ft2 to 0.15 cfm/ft2
Lighting	Lighting Power Densities calculated from drawings	Lighting Power Densities recommended by Atellier Ten
Daylighting	No daylighting controls	Increased Skylight to Floor Area (SFA) fraction to 3% over office, dining and servery areas. Added daylighting controls with 500 lux setpoint
HVAC Efficiency	-Standard efficiency CV fans - Cooling coil efficiencies: 3.11-3.81 (COP) - Make-up air units in the kitchen, servery and carry out - Exhaust fans in the kitchen, servery and carry out	- Increased fan efficiencies -Cooling coil efficiencies increased to 3.85 (COP) - Reduced flow in exhaust hoods by 1) adding side panels (~26% reduction) and 2) adding side panels with demand controls (~41% reduction)
Refrigeration	4 walk-in freezers/coolers	Increased efficiency of units including lighting power density
Equipment Power Densities	-Equipment power densities calculated from drawings - Schedules taken from EPAct 2005 study	-Kitchen equipment power density reduction as recommended by Fischer Nickel, Inc. - Also considered all electric, high efficiency kitchen equipment

Table E.1 Baseline and energy efficient inputs for energy modeling – DFAC

Baseline - 108th ADA Complex - DFAC, Fort Bragg, North Carolina

Zone	Hood	Hood Equip No	Serves Equip No	Equipment Type	Duty	Length (ft)	Flow per Length (cfm/ft)	Flow (cfm)	Static Press. (in w.g.)	Fan Power (kW)	Total Fan Eff.
Kitchen	Exhaust Hood - Double sland Type	39	27	Range		23.5	521	12240	1.6	1.92	
			2x 28	Braising pans							
			2x 30	Floor troughs w/grate							
			3x 32	Convection ovens							
			32a	Combination oven/steamer							
			36	Kettles							
			2x38	Kettles w/stand							
			40	Floor troughs w/grate							
			2x 45	Pot filler/spray hose assemblies							
Kitchen	Exhaust Hood - Wall Type	39a	42	Fryers & Filter		15	255	3830	1.6	0.48	
			2x 47	Steamers							
Kitchen	Exhaust Hood	55	50	Utensil washer		5	150	750	0.25	?	
Kitchen	Exhaust Hood	53	54	Sink heater		4	150	600	0.25	?	
Servery	Exhaust Hood - Wall Type	139	138	Conveyor pizza oven		4	255	1020	1.6	0.12	
Servery	Exhaust Hood - Island Type	71	70	Griddles & stands		8	263	2100	1.6	0.24	
			70a	Splash guards							
Servery	Exhaust Hood - Island Type	71	70	Griddles & stands		8	298	2380	1.6	0.24	
			70a	Splash guards							
Servery	Exhaust Hood - Island Type	71	69	Griddle & stand		6	397	2380	1.6	0.24	
			70a	Splash guards							
Servery	Exhaust Hood - Wall Type	71a	2x 43	Fryers		6	255	1530	1.6	0.72	
			44	Filter station							
Carry out	Exhaust Hood - Wall Type	C10	2x C12	Fryers w/filter		13.5	264	3570	1.6	0.24	
			C13	Griddle & stand							
			C17	Combination oven/steamer							

Table E.2 Baseline DFAC input values

	Design Criteria			Control Strategies				Technologies				Approach				
				Levels	Automatic Interface											
Space	Target Illuminance at Task [fc] (Design Goal)	Target Lighting Power Density [W/ft²] (Project Design Goal)	Allowable Lighting Power Density [W/ft²] (ASHRAE/IESNA Std 90.1-2004/2007)	Switching - (blank) Multi-Level - M Full Dimming - D	V - Vacancy [Manual ON / Auto OFF] O - Occupancy [Auto ON / Auto OFF]	Daylight (e.g. Photosensors)	Schedule (e.g. Astronomical time-clock)	Linear Fluorescent	Compact Fluorescent	Ceramic Metal Halide	Light Emitting Diodes	Overhead General Lighting	Overhead Ambient Lighting	Task Lighting	Wallwash / Perimeter Lighting	Adjustable Accent Lighting
Corridor	10	0.50	0.5		O			✓				•			•	
Dining Area	20	0.50	0.9		O	☼	⏲	✓	✓	✓	✓	•			•	
Dishwashing	50	0.65	1.2		V			✓				•				
Kitchen / Food Prep	50	0.65	1.2		O			✓				•				
Mechanical / Electrical	30	0.70	1.5		V			✓				•				
Office (Enclosed)	40	0.90	1.1	M	V			✓			✓		•	•		
Restroom / Shower	20	0.80	0.9		V			✓	✓		✓	•			•	
Serving Area	50	0.70	1.2				⏲	✓	✓	✓	✓	•		•		•
Stair	10	0.50	0.6	M	O			✓				•				
Storage (Dry Food)	10	0.70	0.8		V			✓				•				
Storage (General)	10	0.50	0.8		V			✓				•				•

Table E.3 Atelier Ten Lighting Design Guide Recommendations - DFAC

Space	Lighting	Controls
Corridor		Occupancy sensors to reduce load to 25%-50% when vacancy is detected. Multi-Level ballasts may be appropriate in many cases
Dining Area		Daylight controls for perimeter luminaires closest to window walls
Dishwashing	Locate luminaires relative to working areas and equipment	
Kitchen / Food Prep	Locate luminaires relative to work areas; Shielded luminaires or coated lamps required	
Mechanical / Electrical	Locate luminaires relative to working areas and equipment	Dual-technology vacancy sensors with long time out
Office (Enclosed)	Use task/ambient scheme with furniture or ceiling mounted ambient lighting and furniture mounted task lighting	Bi-level luminaires and vacancy sensors in private perimeter offices is sufficient for energy savings (photosensors not req)
Restroom / Shower	Lighting over sink and toilet wall will often be enough for entire restroom	Dual-technology vacancy sensor
Serving Area	Locate luminaires relative to serving areas; Shielded luminaires or coated lamps required; Use accent lighting for food display areas	
Stair	Locate luminaires to provide 10fc at landings	Use bi-level luminaire with integrated occupancy sensor
Storage (Dry Food)	Locate and specify luminaires to light vertical surfaces	
Storage (General)	Locate and specify luminaires to light vertical surfaces	

Table E.4 Atelier Ten Lighting Design Guide Notes – DFAC

Exhaust Fan Recommendations
(Fisher Nickel, Inc.)

ECM #1: Adding Side Panels & Changing Hood Styles

FNi Comments:

1. High-efficiency alternative appliances and all-electric appliances will not, as stand-alone ECMs, significantly reduce exhaust air requirements. Adding side panels and changing hood styles will allow significant reductions in exhaust and makeup air flow rates.

2. Change the makeup air from integral (perforated plate on exterior vertical face of hood) to ceiling mounted perforated plate or fabric diffusers, locate at least 10 feet from hood if possible.

Zone	Exhaust Fan No.	Flow (cfm)	Static Press. (in w.g.)	Fan Power (HP)	Total Fan Eff.	ECM #1: Adding Side Panels & Changing Hood Styles
Kitchen	EF-1	4896	1.2	1.5	62%	Add full end panels; 20% exhaust reduction. Note cfm/lf is based on one side of double island; considered as two wall-mounted flow rate is 208 cfm/lf.
	EF-2	4896	1.2	1.5	62%	Add full end panels; 20% exhaust reduction
	EF-3	2298	0.5	0.3	60%	Flow rate is high for appliances in baseline, reduced by 20%; add side panels, another 20% exhaust reduction
	EF-5	1080	0.3	0.2	25%	Add side panels; 20% exhaust reduction
Carry Out	EF-4	2860	1.2	1.0	54%	Add side panels; 20% exhaust reduction
Dishwashing	EF-6	750	0.3	0.25	14%	No change to flight conveyor dishwasher exhaust.
Servery	EF-9	816	1.2	0.4	39%	Add quarter side panels; 20% exhaust reduction
	EF-10	1190	0.5	0.2	47%	Change hood type to pass-over (backshelf); 50% exhaust reduction
	EF-11	1050	0.5	0.2	41%	Change hood type to pass-over (backshelf); 50% exhaust reduction
	EF-12	1190	0.5	0.2	47%	Change hood type to pass-over (backshelf); 50% exhaust reduction
	EF-13	1530	1.2	0.5	58%	Add side panels; 20% exhaust reduction

ECM #2: Adding Variable Demand Controls to Some Hoods

Zone	Exhaust Fan No.	Flow (cfm)	Static Press. (in w.g.)	Fan Power (HP)	Total Fan Eff.	
Kitchen	EF-1	3427	0.56	0.53	57%	Add Variable Demand Controls; assume average flow rate at 70% of ECM #1
	EF-2	3427	0.56	0.53	57%	Add Variable Demand Controls; assume average flow rate at 70% of ECM #1
	EF-3	1609	0.32	0.15	54%	Add Variable Demand Controls; assume average flow rate at 70% of ECM #1
	EF-5	1080	0.3	0.2	25%	
Carry Out	EF-4	2002	0.56	0.35	50%	Add Variable Demand Controls; assume average flow rate at 70% of ECM #1
Dishwashing	EF-6	750	0.3	0.25	14%	
Servery	EF-9	816	1.2	0.4	39%	
	EF-10	1190	0.5	0.2	47%	
	EF-11	1050	0.5	0.2	41%	
	EF-12	1190	0.5	0.2	47%	
	EF-13	1530	1.2	0.5	58%	

Table E.5 Exhaust fan recommendations for DFAC

FAN SCHEDULE

MARK	LOCATION	SERVICE	TYPE	CFM	ESP (IN WG)	FAN RPM	MAX SONES	DRIVE	MOTOR HP	ELECTRICAL V/P/HZ	NOTES
EF-1	ROOF	KITCHEN HOOD	POWER ROOF VENTILATOR	6120	1.8	882	21	BELT	3	460/3/60	1,4,5,6
EF-2	ROOF	KITCHEN HOOD	POWER ROOF VENTILATOR	6120	1.8	882	21	BELT	3	460/3/60	1,4,5,6
EF-3	ROOF	KITCHEN HOOD	POWER ROOF VENTILATOR	3830	1.8	1463	22	BELT	2	460/3/60	1,4,5,6
EF-4	ROOF	KITCHEN HOOD	POWER ROOF VENTILATOR	3575	1.8	1445	20	BELT	2	460/3/60	1,4,5,6
EF-5	ROOF	DISHWASHING	POWER ROOF VENTILATOR	1350	0.4	1774	12.2	BELT	1/3	115/1/60	1
EF-6	ROOF	DISHWASHING	POWER ROOF VENTILATOR	750	0.3	1123	6.0	BELT	1/4	115/1/60	1
EF-7	ROOF	CAN WASH	PANEL TYPE POWER WALL VENTILATOR	500	0.1	1650	5.5	DIRECT	1/30	115/1/60	2
EF-8	ROOF	TOILET EXHAUST	POWER ROOF VENTILATOR	520	0.5	1461	8.3	DIRECT	1/8	115/1/60	1,2
EF-9	ROOF	KITCHEN HOOD	POWER ROOF VENTILATOR	1020	1.8	1930	16.6	BELT	3/4	460/3/60	1,4,5,6
EF-10	ROOF	KITCHEN HOOD	POWER ROOF VENTILATOR	2380	1.8	1389	17.5	BELT	1 1/2	460/3/60	1,4,5,6
EF-11	ROOF	KITCHEN HOOD	POWER ROOF VENTILATOR	2100	1.8	1338	15.7	BELT	1	460/3/60	1,4,5,6
EF-12	ROOF	KITCHEN HOOD	POWER ROOF VENTILATOR	2380	1.8	1389	17.5	BELT	1 1/2	460/3/60	1,4,5,6
EF-13	ROOF	KITCHEN HOOD	POWER ROOF VENTILATOR	1530	1.8	1709	12.2	BELT	1	460/3/60	1,4,5,6
EF-14	ROOF	TOILET EXHAUST	POWER ROOF VENTILATOR	700	0.5	1345	8.0	DIRECT	1/4	115/1/60	1,2
EF-15	ABOVE CEILING	VENT PIPE BELOW FREEZERS	CENTRIFUGAL	400	1.7	2362	13.6	BELT	1/3	115/1/60	7,8,9
EF-16	ABOVE CEILING	RECYCLING ROOM	INLINE CENTRIFUGAL	160	0.3	1452	4.2	DIRECT	1/30	115/1/60	2,3
SF-1	MECH RM	TEMP CONTROL	INLINE CENTRIFUGAL	2000	0.4	1140	10.0	DIRECT	1/3	115/1/60	2, 3

NOTES:
1. PROVIDE WITH ROOF CURB AS SHOWN IN DETAIL.
2. PROVIDE WITH MOTOR OPERATED ISOLATION DAMPER.
3. SUPPORT IN-LINE FAN WITH SPRING VIBRATION ISOLATORS, MIN. 1" STATIC DEFLECTION.
4. CONFIRM DUCT AND HOOD PD WITH EQUIPMENT PROVIDED.
5. EXHAUST CFM FOR THE HOODS PROVIDED BY THE KITCHEN EQUIPMENT SCHEDULE ON THE QF SHEETS.
6. PROVIDE WITH VARIABLE FREQUENCY DRIVE IN APPROPRIATE WEATHERPROOF ENCLOSURE. EF SHALL BE UL RATED. SHALL INCLUDE GREASE TRAP WITH DRAIN CONNECTION.
7. MOUNT FAN ON VIBRATION ISOLATION MOUNTS ON A STEEL PLATE. HANG THE STEEL PLATE FROM THE STRUCTURE ABOVE WITH 4 THREADED STEEL RODS.
8. FAN DISCHARGE SHALL BE DIRECTED UPWARDS.
9. PROVIDE WITH BELT GUARD.

Table E.6 DFAC fan schedule

Zone:	Hood Schedule - Total Flow Per Zone	Reduction in exhaust flow rate
Kitchen	9543	45%
Servery	5776	39%
Carry Out	2002	44%
Dishwashing	750	0%
Totals	18071	41%

Table E.7 DFAC hood schedule

Lighting Power Density Levels				
	Baseline		Recommendation	
Zone	(W/ft^2)	(W/m^2)	(W/ft^2)	(W/m^2)
Dining	0.67	7.19	0.50	5.38
CarryOut	1.39	14.96	0.65	7.00
Servery	1.52	16.33	0.70	7.53
Tray Return	2.17	23.37	0.50	5.38
Queing	0.68	7.36	0.50	5.38
Restroom	2.49	26.84	0.80	8.61
Kitchen	1.03	11.14	0.65	7.00
Utility	1.35	14.58	0.70	7.53
Cold Storage	0.50	5.34	0.50	5.38
Storage Receiving	0.74	7.93	0.70	7.53
Office	0.85	9.11	0.85	9.15
Dishwashing	1.22	13.12	0.65	7.00

Table E.8 Lighting Power Density values for DFAC

DFAC Climate Zone 1A				
	Item	***Component***	***Baseline***	***Recommendation***
				Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-15 ci
		Metal Building	R-19	
		Attic and Other	R-30	
	Walls	Mass	NR	R-13
		Steel Framed	R-13	
		Metal Building	R-13	
	Floors Over Unconditioned Space	Mass	NR	NR
		Steel Joist	NR	NR
		Wood Framed and Other	NR	NR
	Slab-on-Grade	Unheated	NR	NR
	Doors	Swinging	U-0.7	U-0.7
		Non-Swinging	U-1.45	U-1.45
	Infiltration	Areas that are Mechanicalanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.4 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10%	<10%
		Thermal transmittance	U-1.22	U-0.26
		Solar heat gain coefficient (SHGC)	0.25	0.25
	Skylights	Percent Roof Area	None	3% in Office, Servery and Dining areas
		Thermal transmittance	U-1.98	U-1.36
		SHGC	0.36	0.19
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Cooling Coil	COP 2.9	COP > 3.85
		Fans	Constant Volume (see Fan Efficiency Table)	Variable Volume (see Fan Efficiency Table)
		Heating Coil	0.8	0.8
		Hydronic Radiant Floor Heat	None	None
		ERV	None	On dishwasher equipment
		Economizer	None	None
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	None	On exhaust hoods and make-up air units
		Transpired Solar Collectors	None	None

Table E.9 Recommended prescriptive values for low energy model – DFAC CZ 1A

DFAC Climate Zone 2A, 2B				
	Item	***Component***	***Baseline***	***Recommendation*** Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-15 ci
		Metal Building	R-19	
		Attic and Other	R-30	
	Walls	Mass	NR	R-13
		Steel Framed	R-13	
		Metal Building	R-13	
	Floors Over Unconditioned Space	Mass	R-4.2 ci	R-4.2 ci
		Steel Joist	R-19	R-19
		Wood Framed and Other	R-19	R-19
	Slab-on-Grade	Unheated	NR	NR
	Doors	Swinging	U-0.7	U-0.7
		Non-Swinging	U-1.45	U-1.45
	Infiltration	Areas that are Mechanicalanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.4 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10%	<10%
		Thermal transmittance	U-1.22	U-0.26
		Solar heat gain coefficient (SHGC)	0.25	0.25
	Skylights	Percent Roof Area	None	3% in Office, Servery and Dining areas
		Thermal transmittance	U-1.98	U-1.36
		SHGC	0.36	0.19
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Cooling Coil	COP 2.9	COP > 3.85
		Fans	Constant Volume (see Fan Efficiency Table)	Variable Volume (see Fan Efficiency Table)
		Heating Coil	0.8	0.8
		Hydronic Radiant Floor Heat	None	None
		ERV	None	On dishwasher equipment
		Economizer	None	None
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	None	On exhaust hoods and make-up air units
		Transpired Solar Collectors	None	None

Table E.10 Recommended prescriptive values for low energy model – DFAC CZ 2A, 2B

DFAC Climate Zone 3A, 3B, 3C				
	Item	***Component***	***Baseline***	***Recommendation***
				Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-35 (R-15 ci for 3A,B)
		Metal Building	R-19	
		Attic and Other	R-30	
	Walls	Mass	R-5.7 ci	R-24 (R-13 for 3A,B)
		Steel Framed	R-13	
		Metal Building	R-13	
	Floors Over Unconditioned Space	Mass	R-6.3 ci	R-10.4 A,Bi (R-6.3 A,Bi for 3A,B)
		Steel Joist	R-19	R-30 (R-19 for 3A,B)
		Wood Framed and Other	R-19	R-30 (R-19 for 3A,B)
	Slab-on-Grade	Unheated	NR	R-14 (NR for 3A,B)
	Doors	Swinging	U-0.7	U-0.7
		Non-Swinging	U-1.45	U-0.5
	Infiltration	Areas that are Mechanicalanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10%	<10%
		Thermal transmittance	U-0.57 (U-1.22 for 3C)	U-0.26
		Solar heat gain coefficient (SHGC)	0.39 (0.61 for 3C)	0.39
	Skylights	Percent Roof Area	None	3% in Office, Servery and Dining areas
		Thermal transmittance	U-1.98	U-0.69
		SHGC	0.36	0.16
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Cooling Coil	COP 2.9	COP > 3.85
		Fans	Constant Volume (see Fan Efficiency Table)	Variable Volume (see Fan Efficiency Table)
		Heating Coil	0.8	0.8
		Hydronic Radiant Floor Heat	None	None
		ERV	None	On dishwasher equipment
		Economizer	None	None
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	None	On exhaust hoods and make-up air units
		Transpired Solar Collectors	None	None

Table E.11 Recommended prescriptive values for low energy model – DFAC CZ 3A, 3B, 3C

DFAC Climate Zone 4A, 4B, 4C				
	Item	***Component***	***Baseline***	***Recommendation*** Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-47 (R-35 for 4B)
		Metal Building	R-19	
		Attic and Other	R-30	
	Walls	Mass	R-5.7 ci	R-31 (R-24 for 4B)
		Steel Framed	R-13	
		Metal Building	R-13	
	Floors Over Unconditioned Space	Mass	R-6.3 ci	R-12.5 ci
		Steel Joist	R-19	R-30
		Wood Framed and Other	R-19	R-30
	Slab-on-Grade	Unheated	NR	R-19 (R-14 for 4B)
	Doors	Swinging	U-0.7	U-0.5
		Non-Swinging	U-1.45	U-0.5
	Infiltration	Areas that are Mechanicalanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10%	<10%
		Thermal transmittance	U-0.57	U-0.18
		Solar heat gain coefficient (SHGC)	0.39	0.39
	Skylights	Percent Roof Area	None	3% in Office, Servery and Dining areas
		Thermal transmittance	U-1.98	U-0.69
		SHGC	0.36	0.32
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Cooling Coil	COP 2.9	COP > 3.85
		Fans	Constant Volume (see Fan Efficiency Table)	Variable Volume (see Fan Efficiency Table)
		Heating Coil	0.8	0.8
		Hydronic Radiant Floor Heat	None	None
		ERV	None	On dishwasher equipment
		Economizer	None	None
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	None	On exhaust hoods and make-up air units
		Transpired Solar Collectors	None	None

Table E.12 Recommended prescriptive values for low energy model – DFAC CZ 4A, 4B, 4C

DFAC Climate Zone 5A, 5B				
	Item	***Component***	***Baseline***	***Recommendation*** Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-57
		Metal Building	R-19	
		Attic and Other	R-30	
	Walls	Mass	R-7.6 ci	R-38
		Steel Framed	R-13 + R-3.8 ci	
		Metal Building	R-13	
	Floors Over Unconditioned Space	Mass	R-8.3 ci	R-12.5 ci
		Steel Joist	R-19	R-30
		Wood Framed and Other	R-30	R-30
	Slab-on-Grade	Unheated	NR	R-23
	Doors	Swinging	U-0.7	U-0.5
		Non-Swinging	U-1.45	U-0.5
	Infiltration	Areas that are Mechanicalanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10%	<10%
		Thermal transmittance	U-0.57	U-0.18
		Solar heat gain coefficient (SHGC)	0.49	0.49
	Skylights	Percent Roof Area	None	3% in Office, Servery and Dining areas
		Thermal transmittance	U-1.98	U-0.69
		SHGC	0.36	0.36
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Cooling Coil	COP 2.9	COP > 3.85
		Fans	Constant Volume (see Fan Efficiency Table)	Variable Volume (see Fan Efficiency Table)
		Heating Coil	0.8	0.8
		Hydronic Radiant Floor Heat	None	None
		ERV	None	On dishwasher equipment
		Economizer	None	None
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	None	On exhaust hoods and make-up air units
		Transpired Solar Collectors	None	None

Table E.13 Recommended prescriptive values for low energy model – DFAC CZ 5A, 5B

DFAC Climate Zone 6A, 6B				
	Item	***Component***	***Baseline***	***Recommendation*** Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-71
		Metal Building	R-19	
		Attic and Other	R-38	
	Walls	Mass	R-9.5 ci	R-47
		Steel Framed	R-13 + R-3.8 ci	
		Metal Building	R-13	
	Floors Over Unconditioned Space	Mass	R-8.3 ci	R-12.5 ci
		Steel Joist	R-30	R-30
		Wood Framed and Other	R-30	R-30
	Slab-on-Grade	Unheated	NR	R-28
	Doors	Swinging	U-0.7	U-0.5
		Non-Swinging	U-1.45	U-0.5
	Infiltration	Areas that are Mechanicalanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10%	<10%
		Thermal transmittance	U-0.57	U-0.18
		Solar heat gain coefficient (SHGC)	0.49	0.49
	Skylights	Percent Roof Area	None	3% in Office, Servery and Dining areas
		Thermal transmittance	U-1.98	U-0.69
		SHGC	0.36	0.46
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Cooling Coil	COP 2.9	COP > 3.85
		Fans	Constant Volume (see Fan Efficiency Table)	Variable Volume (see Fan Efficiency Table)
		Heating Coil	0.8	0.8
		Hydronic Radiant Floor Heat	None	None
		ERV	None	On dishwasher equipment
		Economizer	None	None
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	None	On exhaust hoods and make-up air units
		Transpired Solar Collectors	None	None

Table E.14 Recommended prescriptive values for low energy model – DFAC CZ 6A, 6B

DFAC Climate Zone 7				
	Item	***Component***	***Baseline***	***Recommendation***
				Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-15 ci	R-94
		Metal Building	R-19	
		Attic and Other	R-38	
	Walls	Mass	R-11.4 ci	R-63
		Steel Framed	R-13 + R-7.5 ci	
		Metal Building	R-13 + R-13	
	Floors Over Unconditioned Space	Mass	R-8.3 ci	R-14.6 ci
		Steel Joist	R-30	R-38
		Wood Framed and Other	R-30	R-30
	Slab-on-Grade	Unheated	NR	R-38
	Doors	Swinging	U-0.7	U-0.5
		Non-Swinging	U-1.45	U-0.5
	Infiltration	Areas that are Mechanicalanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10%	<10%
		Thermal transmittance	U-0.57	U-0.18
		Solar heat gain coefficient (SHGC)	0.49	0.49
	Skylights	Percent Roof Area	None	3% in Office, Servery and Dining areas
		Thermal transmittance	U-1.98	U-0.69
		SHGC	0.36	0.64
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Cooling Coil	COP 2.9	COP > 3.85
		Fans	Constant Volume (see Fan Efficiency Table)	Variable Volume (see Fan Efficiency Table)
		Heating Coil	0.8	0.8
		Hydronic Radiant Floor Heat	None	None
		ERV	None	On dishwasher equipment
		Economizer	None	None
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	None	On exhaust hoods and make-up air units
		Transpired Solar Collectors	None	None

Table E.15 Recommended prescriptive values for low energy model – DFAC CZ 7

DFAC Climate Zone 8				
	Item	***Component***	***Baseline***	***Recommendation*** Assembly Max
Envelope	**Roof**	Insulation Entirely Above Deck	R-20 ci	R-106
		Metal Building	R-13 + R-19	
		Attic and Other	R-38	
	Walls	Mass	R-13.3 ci	R-71
		Steel Framed	R-13 + R-7.5 ci	
		Metal Building	R-13 + R-13	
	Floors Over Unconditioned Space	Mass	R-12.5 ci	R-14.6 ci
		Steel Joist	R-30	R-38
		Wood Framed and Other	R-30	R-30
	Slab-on-Grade	Unheated	R-10 for 24 in.	R-37
	Doors	Swinging	U-0.7	U-0.5
		Non-Swinging	U-1.45	U-0.5
	Infiltration	Areas that are Mechanicalanically cooled (i.e. office, restrooms, etc.)	0.4 cfm/ft^2 @75 Pa	0.15 cfm/ft^2 @75 Pa
	Vertical Glazing	Window to Wall Ratio (WWR)	<10%	<10%
		Thermal transmittance	U-0.46	U-0.18
		Solar heat gain coefficient (SHGC)	NR	0.49
	Skylights	Percent Roof Area	None	3% in Office, Servery and Dining areas
		Thermal transmittance	U-1.98	U-0.58
		SHGC	0.36	0.64
Lighting	**Interior Lighting**	Lighting Power Density (LPD)	See Lighting Power Table	See Lighting Power Table
		Daylighting Controls	None	Dimming, 500 lux Setpoint
		Occupancy Controls	NR	Yes
HVAC	**HVAC**	Cooling Coil	COP 2.9	COP > 3.85
		Fans	Constant Volume (see Fan Efficiency Table)	Variable Volume (see Fan Efficiency Table)
		Heating Coil	0.8	0.8
		Hydronic Radiant Floor Heat	None	None
		ERV	None	On dishwasher equipment
		Economizer	None	None
		Ground Source Heat Pump (GSHP)	None	None
Ventilation	**Ventilation**	Outdoor Air Damper	None	None
		Demand Control	None	On exhaust hoods and make-up air units
		Transpired Solar Collectors	None	None

Table E.16 Recommended prescriptive values for low energy model – DFAC CZ 8

Site EUI For Each EEM

1. Baseline model built off of drawings for the 108th ADA Complex – DFAC, Fort Bragg, North Carolina
2. Lighting power density (LPD) reduction per recommendations by Atelier Ten. Daylighting strategies including 3% Skylight to Floor Area (SFA) fraction over the office, dining and servery areas. Dimmining daylight controls with 500 lux setpoint
3. Passiv Haus insulation
4. Passiv Haus insulation and LPD reduction
5. Passiv Haus insulation, LPD reduction, and daylighting strategies
6. Best of EEMs 2-5 with high efficiency HVAC system. High efficiency HVAC option includes increased fan efficiencies, increased cooling coil COP to 3.85, increased efficiencies of refrigeration units, increased efficiency of kitchen equipment per recommendation by Fisher Nickel Inc., reduction in exhaust fan flow rates by ~26% due to added side panels to exhaust hoods
7. Best of EEMs 2-5 with high efficiency HVAC system. This option is the same as Option 6, however demand controls were added to some of the hoods, further reducing the exhaust flows to a total of 41%
8. Same as Option 6, however kitchen equipment was replaced with all-electric equipment
9. Same as Option 7, however kitchen equipment was replaced with all-electric equipment

		EEMs Applied Individually to Baseline							
EEMs:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Site Energy [kBtu/ft2]	**Baseline**	**Lighting Power Density Reduction and Daylighting Strategies**	**Passiv Haus Insulation**	**Passiv Haus Insulation and LPD Reduction**	**Passiv Haus Insulation, LPD Reduction and Daylighting Strategies**	**Best of EEMs 2-5 and High Efficiency HVAC**	**Best of EEMs 2-5 and High Efficiency HVAC with demand control on exhaust fans**	**Best of EEMs 2-5, High Efficiency HVAC, and All-Electric Kitchen Equipment**	**Best of EEMs 2-5, High Efficiency HVAC with demand control on exhaust fans, All-Electric Kitchen Equipment**
1A Miami	354	339	361	351	349	272	268	227	221
2A Houston	373	361	378	368	367	297	287	256	243
2B Phoenix	363	351	367	357	357	287	277	248	235
3A Memphis	394	382	395	386	385	322	307	286	267
3B El Paso	369	358	371	362	361	297	284	259	243
3C San Francisco	359	349	361	353	352	297	281	257	239
4A Baltimore	428	419	425	417	416	356	336	323	297
4B Albuquerque	396	386	395	387	386	327	309	292	270
4C Seattle	402	394	400	393	392	337	316	304	278
5A Chicago	468	460	461	454	452	391	365	362	329
5B Colorado Springs	430	421	424	417	415	355	333	319	294
6A Burlington	509	501	497	491	489	425	393	399	359
6B Helena	481	473	470	463	461	399	369	369	335
7A Duluth	566	559	549	543	541	472	433	451	403
8A Fairbanks	730	726	699	695	693	606	547	593	525

Table E.17 Site EUI for each EEM package - DFAC

Site Energy Savings For Each EEM

1. Baseline model built off of drawings for the 108th ADA Complex – DFAC, Fort Bragg, North Carolina
2. Lighting power density (LPD) reduction per recommendations by Atelier Ten. Daylighting strategies including 3% Skylight to Floor Area (SFA) fraction over the office, dining and servery areas. Dimmining daylight controls with 500 lux setpoint
3. Passiv Haus insulation
4. Passiv Haus insulation and LPD reduction
5. Passiv Haus insulation, LPD reduction, and daylighting strategies
6. Best of EEMs 2-5 with high efficiency HVAC system. High efficiency HVAC option includes increased fan efficiencies, increased cooling coil COP to 3.85, increased efficiencies of refrigeration units, increased efficiency of kitchen equipment per recommendation by Fisher Nickel Inc., reduction in exhaust fan flow rates by ~26% due to added side panels to exhaust hoods
7. Best of EEMs 2-5 with high efficiency HVAC system. This option is the same as Option 6, however demand controls were added to some of the hoods, further reducing the exhaust flows to a total of 41%
8. Same as Option 6, however kitchen equipment was replaced with all-electric equipment
9. Same as Option 7, however kitchen equipment was replaced with all-electric equipment

		EEMs Applied Individually to Baseline							
EEMs:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Site Energy Savings Compared to Baseline	**Baseline**	**Lighting Power Density Reduction and Daylighting Strategies**	**Passiv Haus Insulation**	**Passiv Haus Insulation and LPD Reduction**	**Passiv Haus Insulation, LPD Reduction and Daylighting Strategies**	**Best of EEMs 2-5 and High Efficiency HVAC**	**Best of EEMs 2-5 and High Efficiency HVAC with demand control on exhaust fans**	**Best of EEMs 2-5, High Efficiency HVAC, and All-Electric Kitchen Equipment**	**Best of EEMs 2-5, High Efficiency HVAC with demand control on exhaust fans, All-Electric Kitchen Equipment**
1A Miami	-	4.0%	-2.1%	0.9%	1.2%	23.0%	24%	35.8%	38%
2A Houston	-	3.3%	-1.2%	1.4%	1.6%	20.5%	23%	31.3%	35%
2B Phoenix	-	3.2%	-1.2%	1.5%	1.5%	20.8%	24%	31.7%	35%
3A Memphis	-	2.9%	-0.3%	1.9%	2.2%	18.2%	22%	27.2%	32%
3B El Paso	-	3.0%	-0.6%	1.7%	2.1%	19.3%	23%	29.7%	34%
3C San Francisco	-	2.9%	-0.3%	1.7%	2.0%	17.3%	22%	28.4%	33%
4A Baltimore	-	2.1%	0.7%	2.5%	2.8%	16.9%	22%	24.5%	31%
4B Albuquerque	-	2.6%	0.3%	2.3%	2.7%	17.5%	22%	26.4%	32%
4C Seattle	-	2.0%	0.3%	2.1%	2.4%	16.1%	21%	24.2%	31%
5A Chicago	-	1.7%	1.5%	3.1%	3.4%	16.6%	22%	22.7%	30%
5B Colorado Springs	-	2.2%	1.3%	3.1%	3.5%	17.6%	23%	25.8%	32%
6A Burlington	-	1.4%	2.2%	3.6%	3.9%	16.5%	23%	21.6%	29%
6B Helena	-	1.7%	2.4%	3.8%	4.1%	17.2%	23%	23.2%	30%
7A Duluth	-	1.3%	3.0%	4.1%	4.4%	16.6%	23%	20.4%	29%
8A Fairbanks	-	0.6%	4.2%	4.8%	5.0%	17.0%	25%	18.7%	28%

Table E.18 Site energy savings (%) for each EEM package - DFAC

DFAC - Fort Campbell	Low Energy Package 1	Low Energy Package 2
Baseline Building	$ 9,749,134	$ 9,749,134
HVAC Components	$ (73,858)	$ (275,329)
Electric Kitchen Equipment	$ -	$ (33,313)
Advanced Lighting Systems	$ 11,138	$ 11,138
Increased Building Envelope	$ 214,472	$ 214,472
Increased Window Efficiency	$ 21,855	$ 21,855
Increased Efficiency Storefront	$ 2,887	$ 2,887
Increased Window Efficiency	$ 2,887	$ 2,887
Dual Flush Toilets	$ 1,989	$ 1,989
0.5gpm Flow Faucets	$ 8,416	$ 8,416
1.5gpm Flow Showerheads	$ 86	$ 86
Skylight	$ 24,391	$ 24,391
Enhanced Commissioning	$ 51,789	$ 51,789
Measurement & Verification	$ 68,742	$ 68,742
Rainwater Harvesting	$ 95,198	$ 95,198
Add-on Cost	$ 429,992	$ 195,208
Revised Cost	$ 10,179,126	$ 9,944,342
Pecent Increase	4.41%	2.00%

Notes (1) These costs are shown in contract costs
(2) Baseline builds to meet LEED Silver

Table E.19 Cost breakdown for DFAC building – Fort Campbell

All new Army facilities have been required to increasingly reduce site energy consumption in response to EPACT 2005, then ECB 2010-14, then the Army Sustainable Design and Development Policy Update (Environmental and Energy Performance, October 27, 2010). As the results below show, the DFAC standard Army design including the recommended Low Energy Packages, meets most of the current site energy reduction mandates for new Army facilities.

Climate Zone	ASHRAE 90.1-2004 EUI (kBTU/sq ft-yr)	ASHRAE 90.1-2007 EUI (kBTU/sq ft-yr)	EPACT 2005 Target EUI + plug loads (kBTU/sq ft-yr)	ASHRAE 189.1 Target EUI (kBTU/sq ft-yr)	ECB 2010-14 Target EUI + plug loads (kBTU/sq ft-yr)	Low Energy Package 3 Site EUI including plug loads (kBTU/sq ft-yr)
1A	355	339	282	270	248	221
2A	363	347	288	276	253	243
2B	348	333	277	264	244	235
3A	375	359	296	285	260	267
3B	355	339	282	270	248	243
3C	331	316	265	252	235	239
4A	402	384	315	306	275	297
4B	368	352	291	280	256	270
4C	372	356	294	283	258	278
5A	433	414	337	329	293	329
5B	393	376	309	299	270	294
6A	464	444	358	353	311	359
6B	435	416	338	331	294	335
7A	507	485	389	385	336	403
8A	630	602	475	479	406	525

Table E.20 DFAC Site Energy EUIs Compared to the required site energy reduction targets

Appendix F:

Lighting Report and Cut Sheets

LIGHTING DESIGN GUIDE

For BDE/BN HQ, COF, EPDF, TEMF, and UEPH Projects

Prepared for The Department of Defense, September 2010

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INTRODUCTION

The United States Department of Defense engaged Atelier Ten to provide a comprehensive lighting design guide to assist in the design of lighting systems that will provide a high-quality visual environment while using the least amount of energy. The recommendations and guidelines put forth in this document are provided to assist the designers of Department of Defense facilities when designing and specifying effective energy saving lighting strategies and are not a substitute for the thoughtful design of the lighting system for specific projects.

Lighting criteria and design strategies are adapted from the Illuminating Engineering Society of North America (IESNA) Recommended Practices, the International Association of Lighting Designers (IALD) principles, and Atelier Ten's collective professional experience with high-performance, sustainable lighting design. Recommendations and lighting layouts will need to be altered to meet the needs of specific spaces with different room geometry, space function, or surface finishes than those used here.

Key contributors to content of this document include:

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BUILDING DESCRIPTION

BRIGADE AND BATTALION HEADQUARTERS (BDE /BN HQ):
These facilities are typically two stories and comprised of administrative offices, special function rooms, classrooms and/or a secure section. Private offices are provided for select officers and other staff. Other space types include conference rooms, staff duty stations, message center and mail sorting, reception areas, secure documents room, showers, supplies and vending.

COMPANY OPERATIONS FACILITY (COF):
These facilities house Company administrative operations and are used to store and move supplies. The facilities are comprised of administrative modules and readiness modules. The building type is intended to be similar to office and warehouse type buildings in the private sector community.

ENLISTED PERSONNEL DINING FACILITY (EPDF):
These facilities are required by the Army to accommodate a specified range of soldiers during a meal period. There are three EPDF sizes based on feeding capacity ranges of: 251-500; 501-800; or 801-1300 personnel. Functionally, the Dining Facility consists of a patron dining area, a food service area, a kitchen, and food storage and receiving areas.

TACTICAL EQUIPMENT MAINTENANCE FACILITY (TEMF):
This building type is provided for maintaining and repairing vehicles, complete with equipment and parts storage and administrative offices. It is intended to be similar to heavy equipment or motor pool facilities in the private sector community.

UNACCOMPANIED ENLISTED PERSONNEL HOUSING (UEPH):
These facilities house single soldiers and are intended to be similar both functionally and technically to apartment-type dwellings in the private sector. Soldiers' rooms include: private sleeping areas, walk-in closets, a shared bathroom and kitchenette.

SUSTAINABLE LIGHTING DESIGN APPROACH

The lighting strategies outlined in this Lighting Design Guide are drawn from sustainable design principles. Providing sufficient functional lighting for visual tasks while maintaining comfortable visual environment is required for a lighting design to be considered successful. The goal of sustainable lighting design, and this document, is to satisfy these lighting design criteria using the fewest materials and least energy.

The three cornerstone strategies for sustainable lighting design that were used to create these guidelines are listed to the right and should be considered in every design.

More specific energy-saving lighting design tactics that help create visually comfortable, effective and efficient lighted environments applicable to many space types in addition to those outlined in this document are also listed on the right.

CORNERSTONE DESIGN STRATEGIES

- Provide appropriate illuminance levels without over-lighting
- Use efficient lamps, ballasts and luminaires
- Reduce electric lighting usage with controls

SPECIFIC DESIGN TACTICS

1. Optimize architecture to provide daylight in frequently occupied spaces
2. Apply light-colored (high-reflectance) surface finishes
3. Cluster similar tasks to improve lighting system energy efficiency
4. Locate luminaires close to tasks that require higher illuminance
5. Use linear fluorescent luminaires predominately
6. Use high efficiency ballasts with appropriate ballast factors
7. Use high-efficacy versions of lamps
8. Illuminate walls and ceilings to increase perception of brightness
9. Use daylight responsive lighting controls in frequently occupied spaces with daylight access
10. Use vacancy sensors in spaces with daylight access
11. Use occupancy sensors in spaces without daylight access
12. Control lighting with time-clocks for building-wide energy conservation

LAMPS
CONSIDERATIONS

There is a variety of commercially available lamp types, each with their own unique characteristics, which make some lamp types better suited for some applications. Important lamp performance properties include: light output, power consumption, luminous efficacy, rated lamp life, lamp lumen depreciation, color temperature, color rendering, dimmability, and sensitivity to voltage and temperature.

Below is a list of key lamp types used in energy efficient lighting systems along with recommendations for their use.

LINEAR FLUORESCENT

These discharge lamps require a ballast to operate and are typically the most efficacious (in lumens per Watt) lamp available for general interior lighting requirements. Linear fluorescent lamps are available today (2010) that operate more efficiently, more quietly, and provide better color performance than those available 15 years ago or more. Linear fluorescent lamps have high efficacy (80 – 100 lumens per watt), turn on and warm up virtually instantly, can be dimmed, have rated long lamp life (30,000 – 46,000 hours), and are relatively inexpensive. For these reasons, linear fluorescent lamps should be considered for the general lighting needs of nearly any interior space or application. Applications that call for small luminaires or precise optics, such as an accent light, often require the use of a different lamp type. With the products available today, four-foot high performance T8 lamps coupled with NEMA Premium ballasts are the most energy efficient and cost effective type of linear fluorescent lamps – exceeding T5/T5HO lamp and ballast combinations. However, the smaller diameter T5 lamps provide the advantage of greater luminaire efficiency in many cases.

COMPACT FLUORESCENT

These smaller, bent versions of linear fluorescent lamps provide many of the benefits of linear fluorescent lamps in a smaller form factor. Compact fluorescent lamps come in many shapes, sizes, and wattages. These lamps typically have good efficacy (50 – 60 lumens per watt), turn on and warm up quickly, can be dimmed, and have a reasonably long rated life (10,000 – 16,000 hours). The efficiency of luminaires that use compact fluorescent is typically low compared to linear fluorescent and ceramic metal halide, due to the size and shape of compact fluorescent lamps.

CERAMIC METAL HALIDE

Ceramic metal halide lamps are discharge lamps that are small enough to be considered a “point-source” for most architectural lighting applications but typically cannot be dimmed and take several minutes to fully ignite. The size, shape and efficacy of ceramic metal halide lamps make them excellent source for accent lighting or down-lighting when instant starting or dimming are not required. Low wattage versions of these lamps typically have good efficacy (55 – 70 lumens per watt), cannot be dimmed, have excellent color rendering (80 – 95 CRI), and reasonably long rated life (10,000 – 12,000 hours).

LIGHT EMITTING DIODES (LED)

LEDs are a solid state electronic light source and are relatively new to interior lighting. The performance of LED equipment varies greatly and the rapidly changing state of the technology can make this lamp type challenging to specify. Often LEDs are specified not as lamps, but as an integrated part of a luminaire, and therefore cannot be changed in the field. Generally, LEDs have a long rated life (50,000+ hours) and are energy efficient, producing 50 to 80 lumens per watt in many cases, and are dimmable. LEDs are the smallest light source available which means that luminaires using LEDs can be relatively very small with precise optics. LEDs are often a good choice for applications where the luminaire will be placed close to the lighted surface (such as task lighting) or when replacing a luminaire type that is otherwise inefficient when used with other lamp types, such as recessed downlights. Designers should specify LED luminaires that have been photometrically tested in accordance with IESNA LM-79 methods.

LAMPS

TECHNOLOGY SCHEDULE

L01 FLUORESCENT 32WT8
Four-foot linear fluorescent lamp, nominal wattage not to exceed 32W, initial lumen output of 3100 lm or greater, color rendering index of 80 or greater, rated lumen maintenance of 94% or greater

L02 FLUORESCENT 32WT8U
"U" Shaped fluorescent lamp, nominal wattage not to exceed 32W, initial lumen output of 2800 lm or greater, color rendering index of 80 or greater, rated lumen maintenance of 90% or greater

L03 COMPACT FLUORESCENT LONG TWIN-TUBE
Long twin-tube compact fluorescent lamp with double bi-pin base, nominal wattage of 36W or 40W, initial lumen output of 2900 lm or 3300 lm, respectively, color rendering index of 80 or greater, rated lumen maintenance of 90% or greater

L04 COMPACT FLUORESCENT TRIPLE TUBE
Compact fluorescent lamp in a triple-tube configuration, double bi-pin base, nominal wattage of 18W, 26W, or 32W, color rendering index of 80 or greater, lumen maintenance of 86% or greater

L05 COMPACT FLUORESCENT GU24 INTEGRATED BALLAST
Compact fluorescent lamp with integral ballast and GU24 base, medium screw base is not acceptable, nominal lamp wattage of 13W, 18W, or 26W

L06 20/39W CERAMIC METAL HALIDE
Ceramic Metal Halide Lamps with nominal wattage of 20W or 39W, color rendering index of 80 or greater

L07 FLUORESCENT 17WT8
Two-foot linear fluorescent lamp with a nominal wattage not to exceed 17W and initial lumen output of 1400 lm or greater, color rendering index of 80 or greater, rated lumen maintenance of 94% or greater

BALLASTS
CONSIDERATIONS

All discharge lamps, including fluorescent and metal halide, require a ballast to operate. Specifying an efficient ballast with the appropriate ballast factor, start method and controllability is critical for minimizing the connected lighting load, maintenance and energy use.

START METHODS

Fluorescent lamps are started using Instant Start or Program Start ballasts. Instant Start ballasts use the least power to operate lamps, but abruptly start the lamp which can shorten lamp life when the lamps are frequently switched. Program Start ballasts start lamps more gently so that lamp life is not as adversely affected by frequent starting, but these ballasts typically require more power than instant start ballasts. The lamp life and energy effects are typically minor, but the ballast starting method should be chosen carefully in applications where lamp switching cycles are less than 15 minutes or greater than three hours. Luminaires that are left on for long periods of time should generally use instant start ballasts for energy savings, and those that are switched on and off many times per day should be program start for extended lamp life. Both instant start and program start ballasts are widely available for linear fluorescent lamps. However, compact fluorescent ballasts are typically only available as program start.

Metal Halide lamps are manufactured to be started in one of two ways, probe-start or pulse-start. Specify electronic pulse-start ballasts and lamps whenever possible.

CONTROLLABILITY

Static output ballasts drive a given number of lamps at one specified ballast factor. These are fixed output devices and are less expensive than ballasts with variable ballast factors.

Multi-Step ballasts can operate lamps at two or more ballast factors. This is often referred to as stepped dimming as the lamp light output can be dimmed by incremental steps. These ballasts provide a more visually comfortable environment compared to multi-level switching, which essentially turns off a number of lamps to save energy. Bi-level and tri-level are the most common and can be controlled by multiple power feeds to a single ballast or by control wires.

Dimming ballasts have the ability to operate lamps with a variable ballast factor so the lamps may be brightened or dimmed in a smooth fashion. The load of the ballast is reduced when lamps are dimmed, providing energy savings. Dimming ballasts typically require additional control wires and come at a cost premium over static and multi-step ballasts.

EFFICIENCY

The efficiency of ballasts can vary considerably. To specify the most efficient ballast, choose the ballast with the lowest input wattage for the desired start method and ballast factor. Programs are in place to distinguish efficient ballasts from less efficient ones. The National Electrical Manufacturers Association (NEMA) has an efficiency standard for ballasts designed to operate T8 fluorescent lamps. In this program, ballasts that meet minimum performance criteria may be labeled as NEMA Premium. Specifying NEMA Premium ballasts where applicable is a convenient and effective way to guarantee that only the most efficient ballasts are used.

BALLAST FACTOR (BF)

Ballast Factor is the ratio of a lamp's lumen output on a particular ballast to the lamp's rated lumen output. By specifying the appropriate BF, the light output and power usage of a luminaire can be carefully chosen to meet the needs of specific applications. Ballasts for T8 linear fluorescent lamps are available in a range of BFs from 0.71 up to 1.37 or higher, while ballasts for many lamp types are only available with a 1.0 BF. Specifying ballasts with a higher ballast factor may allow for the use of fewer lamps per luminaire which often improves luminaire efficiency and also reduces the number of lamps to be maintained in a building.

BALLASTS

TECHNOLOGY SCHEDULE

B01 MULTI-LEVEL
Electronic ballast capable of operating lamps with two or more ballast factors, controlled by low-voltage control signal or multiple circuit feeds, ballasts for four-foot T8 fluorescent lamps should be labeled as NEMA premium (available for most linear fluorescent lamps, limited availability for other lamp types)

B02 DIMMING
Electronic ballast capable of smoothly dimming lamps with a range of ballast factors with a minimum range of at least 10% to 100% of maximum light output, ballasts for four-foot T8 fluorescent lamps should be labeled as NEMA premium, control signal may be digital, 0-10V, or carried over the power wires

B03 INSTANT START
Electronic ballast capable of operating lamps at one ballast factor, ignites lamp using the instant start method, typical ballast factors include 0.77, 0.88, 1.00, 1.18, or higher for linear fluorescent lamps, ballasts for four-foot T8 fluorescent lamps should be labeled as NEMA premium

B04 PROGRAM START
Electronic ballast capable of operating lamps at one ballast factor, ignites lamp using the program rapid start method, typical ballast factors include 0.71, 0.88, 0.99, or 1.15 for linear fluorescent lamps, ballasts for four-foot T8 fluorescent lamps should be labeled as NEMA premium

B05 ELECTRONIC CMH
Electronic pulse-start ballast for low-wattage ceramic metal halide lamps

LUMINAIRES
CONSIDERATIONS

Luminaires, often referred to as light fixtures, are a critical element of a lighting system as they determine how the light from lamps is directed into a space. Luminaires contain housing, mounting hardware, one or more lamps, and may contain any or all of the following: ballast, reflector, lens, shielding media. Many factors play into the selection of the optimal luminaire for a space or task. The luminaire categories listed below represent the majority of luminaires installed in DoD building projects. Understanding the advantages and disadvantages of these luminaires and the options with which they are provided is critical for specifying high performance lighting systems.

RECESSED TROFFERS

Recessed troffers with flat prismatic lenses or high-performance non-planar lenses are the most efficient troffers available. Specifying troffers with T8 lamping offers the greatest flexibility for providing the appropriate light level in a space with the thoughtful selection of lamp quantity and ballast factor. Higher luminaire efficiencies may be obtained by specifying luminaires designed specifically around the lamp type specified. Specifying that interior reflectors are painted after fabrication (PAF) often improves luminaire efficiency by 10% or more. Typically, the fewer lamps in a troffer, the more efficiently it operates. Two-foot by four-foot (2x4) troffers are typically the most efficient and least expensive to install however, the form factor and size of 1x4 or 2x2 troffers may make them better suited for many applications. In general, four-foot long troffers offer the best performance as they use four-foot lamps which are the most efficacious and cost effective.

LINEAR PENDANTS

Linear fluorescent pendants can offer an excellent combination of high efficiency, glare control, and light distribution and allow the location of the light source to be closer to the task area. Pendants with one lamp in cross-section almost always demonstrate the greatest luminaire efficiencies and the best optical performance. Specifying T8 lamps with high ballast factor ballasts or T5HO lamps are effective ways to use a one lamp cross-section without sacrificing light output.

RECESSED DOWNLIGHTS

Recessed downlights are one of the least efficient luminaire types available. These luminaire are often specified when low light levels are required or when the size and shape of downlight luminaire makes it easy to incorporate into a design. When specifying a downlight, consider those with open optics as they offer the highest efficiency. In many cases, LED downlights are good alternatives to compact fluorescent downlights as the LED versions are often provide greater light output using fewer watts. Larger aperture downlights are typically more efficient than smaller aperture downlights.

HIGH BAYS

The most efficient and effective high bay luminaires use fluorescent lamps. Luminaires that use T5 or T5HO are often more optically efficient than those that use T8 lamps, however T8 lamp and ballast combinations offer greater flexibility and system efficiency than T5/T5HO systems. In general, T8 high bays are the best choice except for when the increased light output provided by T5HO lamps is required. Designers should carefully consider the effect of the ambient air temperature at high bay mounting locations as fluorescent lamps are sensitive to temperature. Consult with the luminaire manufacturer to determine the best specification for the environment in which the luminaire will be used. Specifying high ballast factors will reduce the number of luminaires or lamps per luminaire which will provide easier system maintenance.

TASK LIGHTS

Task lights are an extremely effective way to deliver high illuminance to a work area with the minimal energy use. As the luminaire is typically within one to two feet from the task, it can be easy to “over-light” a task area. When specifying a task light, choose the lowest wattage option that provides the appropriate illuminance at the task. LED task lights often provide better optics and lower wattage options than fluorescent task lights. Consider task lights with integrated occupancy sensors or wiring task lights though occupancy sensor controlled power strips for maximum energy savings.

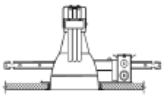
LUMINAIRES

TECHNOLOGY SCHEDULE

F01	Lensed Troffer		Fluorescent Recessed 2'x4' or 1'x4' high efficiency troffer with planar prismatic lens, designed for T8 lamping, painted after fabrication, min. 75% efficiency
F02	Wallbracket Direct/Indirect		Fluorescent wall mounted with shielding or lensing to reduce glare and direct light in the desired direction
F03	Non-Planar Lensed Troffer		Fluorescent recessed 2'x4', 1'x4', or 2'x2' high efficiency troffer with non-planar lens, designed for T8 lamping, painted after fabrication, min. 80% efficiency
F04	Suspended Direct/Indirect		Fluorescent suspended luminaire with downlight and uplight component, shielding to prevent glare at angles between 45° and 90°, wide distribution uplight component
F05	Furniture Integrated		Fluorescent furniture integrated luminaire, downlight and uplight component, shielding or baffling to minimize glare from uplight component
F06	Perimeter		Fluorescent recessed perimeter luminaire, baffling or shielding to prevent direct view of lamps from normal viewing angles
F07	Narrow Lensed Wrap		Fluorescent linear luminaire with lamp completely shielded by prismatic acrylic lens, one lamp in cross-section
F08	Wide Lensed Wrap		Fluorescent wide linear luminaire with lamps completely shielded by prismatic lens, two or three lamps in cross-section
F09	Undercabinet Task		Fluorescent low-profile under-cabinet luminaire with low ballast factor and integral switch
F10	Suspended Indirect		Fluorescent suspended linear luminaire with 100% uplight, wide light distribution, optional clear dust cover
F11	High Bay		Fluorescent suspended or surface mounted high efficiency high bay luminaire, min. 90% efficiency, optional wire guard, clear lens, and uplight component

LUMINAIRES

TECHNOLOGY SCHEDULE (CONT.)

F12	Wallwash		Fluorescent recessed 1'x4' or 1'x2' wallwasher with one lamp in cross-section
F13	Strip		Fluorescent strip-light, pull-chain optional
F14	Vanity		Fluorescent semi-decorative surface mounted luminaire with lamp completely shielded by lens
F15	Bi-level Occ Sens Wrap		Fluorescent surface mounted lens wrap with integrated occupancy sensor and bi-level ballast with user selectable standby light output level
F16	Suspended Direct		Fluorescent suspended linear luminaire, lensed with 100% downlight
F30	Table Lamp		Compact fluorescent table lamp, dedicated compact fluorescent socket, cord-and-plug power connection
F31	Downlight		Compact fluorescent recessed downlight, open optics or lensed if required
F32	Performance Round		Compact fluorescent or U-bent fluorescent round direct luminaire, pendant or surface mount, lens, painted after fabrication
F40	Adjustable Accent		Ceramic metal halide accent luminaire with adjustable aiming, 20W or 39W lamping
F50	Adjustable Accent		LED accent luminaire with adjustable aiming, photometrically tested in accordance IESNA LM-79 methods
F51	Task		LED undercabinet or adjustable table mounted task light, photometrically tested in accordance IESNA LM-79 methods
F52	Downlight		LED recessed downlight, lensed or open optics, photometrically tested in accordance IESNA LM-79 methods

AUTOMATIC CONTROLS

OCCUPANCY CONSIDERATIONS

Automatically reducing electric lighting when spaces are unoccupied provides significant energy savings. There are several factors to consider when specifying automatic occupancy based lighting controls for user acceptance and maximum energy savings.

OCCUPANCY SENSORS

These devices use infrared or ultrasonic sensing or both to determine if the area within its sensing zone is occupied by humans. The sensors automatically power on electric loads when occupancy is detected and power off electric loads after a set time-out period after vacancy is detected. These units can be coupled with toggle switches for manual override for increased energy savings.

VACANCY SENSORS

These devices are specialized occupancy sensors. When vacancy is detected, these sensor units automatically power off electric loads after a set time. Once the load has been switched off, it must be manually powered back on by switch or other device. In daylighted spaces, this technology increases energy savings by enabling users to leave lights off when daylight is sufficient.

MOUNTING

Sensors should be located and aimed to provide the best coverage for a given area. For smaller spaces, such as a private office or storage closet, a sensor integrated into a standard wall box provides sufficient coverage and is typically the most cost effective approach. For larger spaces such as corridors or open offices, one or more ceiling mounted sensor should be used to provide coverage to critical areas of the space. Sensors may also be integrated into luminaires. Luminaire integrated sensors are appropriate for small spaces or applications where wall or ceiling mounting is not feasible.

TIME-OUT

The time period between when a sensor detects vacancy in a space and when the load is switched is adjustable in the field. For areas with intermittent occupancy of short durations, a short time-out period, such as five minutes should be used. For areas that a false vacancy reading and subsequent darkness may create a safety or security concern, longer time out periods of 30 minutes or more should be considered. Typical time out periods between 20 and 30 minutes are suitable for most applications.

SENSING TECHNOLOGY

Occupancy and vacancy sensors typically use either ultrasonic or infrared sensing or both to determine if a space is occupied by people. Infrared sensors detect occupancy by changes in infrared signals created by people moving within the coverage area. These sensors are best used in spaces where there is a direct line of sight to the sensor from all areas where people will be within a space. Ultrasonic sensors detect changing ultrasonic frequencies created by movement within a space. Ultrasonic sensors are best used in spaces where obstructions prevent a direct line of sight to the sensor occupied areas. Dual-technology sensors may be used in spaces where using only infrared or ultrasonic sensors may not provide adequate coverage or for increased assurance that the sensors will sense occupancy.

AUTOMATIC CONTROLS

DAYLIGHT CONSIDERATIONS

Considerable energy savings can be achieved by reducing electric lighting loads when there is sufficient daylight in a space. Daylight responsive lighting controls must be designed and commissioned with care to ensure that the system operates effectively and without disruption of the occupants within the space. Shading devices, skylights and glazing should be specified and sized to provide usable daylight without excessive glare or heat gain.

AUTOMATIC DIMMING

Photosensors can be specified to dim electric lighting according to available daylight. Dimming systems have a greater initial cost than other alternatives, but provide the most seamless integration of electric light daylight. Dimming systems typically do not turn luminaire power completely off when ample daylight is available, instead lamps are reduced to 5% or 10% of full light output which requires 20% or more of the ballast rated power.

AUTOMATIC SWITCHING

Photosensors can be specified to switch off lighting when enough daylight is available. Switching systems open the circuit, so that luminaire power and light output are completely off. Photosensor setpoints for switching systems should be set to a higher value than with dimming systems to minimize the perception of the abrupt change in the lighting condition.

MANUAL SWITCHING

Many spaces are not regularly occupied during daylight hours or may have intermittent occupancy patterns. When occupancy sensors are used in intermittently occupied spaces, daylight responsive controls may not be needed as the electric lighting can be turned off by a vacancy sensor for much of the day. If ample daylight is available, an occupant entering a space will be less likely to manually power on the electric lighting. If the occupant does choose to turn on the lighting, it will stay on until they leave the room or manually turn the lighting off. This strategy works especially well with multi-level ballasts, as users will often elect to turn the electric lighting to a lower level when daylight is available.

AUTOMATIC CONTROLS

TECHNOLOGY SCHEDULE

C01 INFRARED OCCUPANCY / VACANCY SENSOR
Sensor capable of detecting motion by changes in the infrared signals, may be recessed or surface mounted, occupancy sensors may be low-voltage or line voltage, low-voltage sensors and low-voltage wall switches must be used for vacancy sensor mode

C02 ULTRA SONIC OCCUPANCY / VACANCY SENSOR
Sensor capable of detecting motion by changes in the ultrasonic signals, may be recessed or surface mounted, occupancy sensors may be low-voltage or line voltage, low-voltage sensors and low-voltage wall switches must be used for vacancy sensor mode

C03 DUAL TECH OCCUPANCY / VACANCY SENSOR
Sensor capable of detecting motion by changes in the ultrasonic and infrared signals, may be recessed or surface mounted, occupancy sensors may be low-voltage or line voltage, low-voltage sensors and low-voltage wall switches must be used for vacancy sensor mode

C04 WALLBOX OCCUPANCY / VACANCY SENSOR
Sensor mounted in a wallbox control station capable of detecting occupancy by either infrared or ultrasonic signals

C05 LUMINAIRE INTEGRATED OCCUPANCY SENSOR
Sensor mounted into a luminaire capable of detecting motion by changes in the infrared signal it receives

C07 DIMMING PHOTOSENSOR
Sensor that responds to a incident light to determine the quantity of daylight available, capable of sending low-voltage signal in order to dim electric lighting

C08 SWITCHING PHOTOSENSOR
Sensor that responds to a incident light to determine if the quantity of daylight present meets a determined setpoint, capable for sending a signal to switch off the electric lighting

SPACE SPECIFIC RECOMMENDATIONS

DESCRIPTION OF TYPICAL DESIGN GUIDE PAGE

Target Illuminance	Target LPD
30 fc	0.80 W/ft^2

Lighting Technologies
LAMP L01 Fluor 32WT8 **BALLAST** B01 Multi-Level B02 Dimming B03 Instant Start B04 Program Start **LUMINAIRE** F01 Lensed Troffer F03 Non-Planar Lensed Troffer F04 Suspended Direct/Indirect F06 Perimeter F07 Narrow Lensed Wrap F08 Wide Lensed Wrap F09 or F51 Task F10 Suspended Indirect F11 High Bay F13 Strip F14 Vanity F16 Suspended Direct F31 or F52 Downlight **CONTROLS** C01 IR Occ/Vac Sensor C02 Ultra Sonic Occ/Vac Sensor C03 Dual Tech Occ/Vac Sensor C04 Wallbox Occ/Vac Sensor C05 Integrated Occ Sensor C07 Dimming Photosensor C08 Switching Photosensor

TARGET ILLUMINANCE
The target average maintained horizontal illuminance measured at the task area. For most spaces, a variance of 10% is acceptable.

TARGET LPD
Target lighting power density (LPD) for the space type. The actual LPD will vary for actual designs based on conditions of actual spaces, but the LPD for the space type shown here is achievable in most cases.

LIGHTING TECHNOLOGIES
Lighting technologies that are specifically applicable to the space type. The use of all technologies shown will not be required for every space. More detailed descriptions of these technologies are found in the previous section.

SPACE DESCRIPTION
General description of the space type.

CONSIDERATIONS
Summary of space-specific considerations that inform the lighting design.

LIGHTING APPROACH
A short description of a lighting design approach which may be used to minimize lighting power density while maintaining a quality visual environment.

CONTROLS
A brief summary of the type of automatic lighting controls that should be implemented in the space to reduce lighting energy use.

CLASSROOM / TRAINING

Target Illuminance	Target LPD
40 fc	0.75 W/ft^2

Lighting Technologies

LAMP
L01 Fluor 32WT8

BALLAST
B01 Multi-Level
B04 Program Start

LUMINAIRE
F03 Non-Planar Lensed Troffer
F04 Suspended Direct/Indirect
F12 Wallwash

CONTROLS
C01 IR Occ/Vac Sensor
C08 Switching Photosensor

SPACE DESCRIPTION
Classrooms may be used for any or all of the following activities: teaching, audio/visual (AV) presentations, team exercises, reading and note taking.

CONSIDERATIONS
Due to space activities, classrooms should be equipped with lighting systems that can provide different lighting scenes. For reading and writing tasks, the lighting system should be able to provide 40 fc or more on the work plane. For AV presentation mode the general classroom work plane illuminance should be able to be reduced to between 10 and 20 fc, with no more than 20 fc on the presentation wall. Lighting on teaching walls should be independent from general lighting system.

LIGHTING APPROACH
Use highly efficient recessed fluorescent luminaires with non-planar lenses in spaces with ceiling heights below 9'-6", otherwise use suspended direct/indirect fluorescent pendants. To provide for multiple uses of classrooms, the lighting system should be divided into two or more zones. Each luminaire in the general lighting zones should be capable of two or more light output modes to achieve recommended illuminances for reading and AV mode. At a minimum, this should include one for general lighting and one for the teaching wall. For larger perimeter classrooms with daylight access, three or more zones may be required, minimally including a general lighting zone, a general lighting daylight zone, and a teaching wall zone.

CONTROLS
Wall mounted lighting controls should be provided at room entries as well as additional controls at the teaching wall are desirable for larger classrooms. Vacancy sensors are preferred in spaces with access to daylight. Occupancy sensors that automatically set the general lighting to low output mode are acceptable for rooms with no daylight access.

CONFERENCE ROOM

Target Illuminance	Target LPD
40 fc	0.80 W/ft^2

Lighting Technologies

LAMP
L01 Fluor 32WT8

BALLAST
B01 Multi-Level
B02 Dimming
B04 Program Start

LUMINAIRE
F03 Non-Planar Lensed Troffer
F04 Suspended Direct/Indirect
F12 Wallwash

CONTROLS
C01 IR Occ/Vac Sensor
C07 Dimming Photosensor

SPACE DESCRIPTION
Conference rooms may host audio/visual (AV) presentations, meetings, videoconferences and teleconferences. These spaces typically have a large table in the center of the room and a presentation wall.

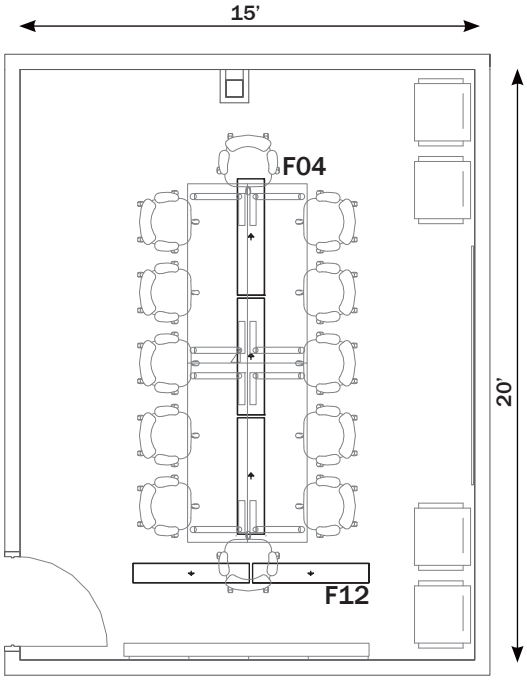
CONSIDERATIONS
Due to varying space functions, conference rooms should be equipped with lighting systems that can provide multiple lighting scenes. For reading and writing tasks, the lighting system should be able to provide 40 fc or more on the workplane. For AV presentation mode the general workplane illuminance should be able to be reduced to between 10 and 25 fc, with no more than 20 fc on the presentation wall. Harsh shadows on occupants' faces seated at the table should be avoided, especially if the space is equipped with videoconferencing equipment.

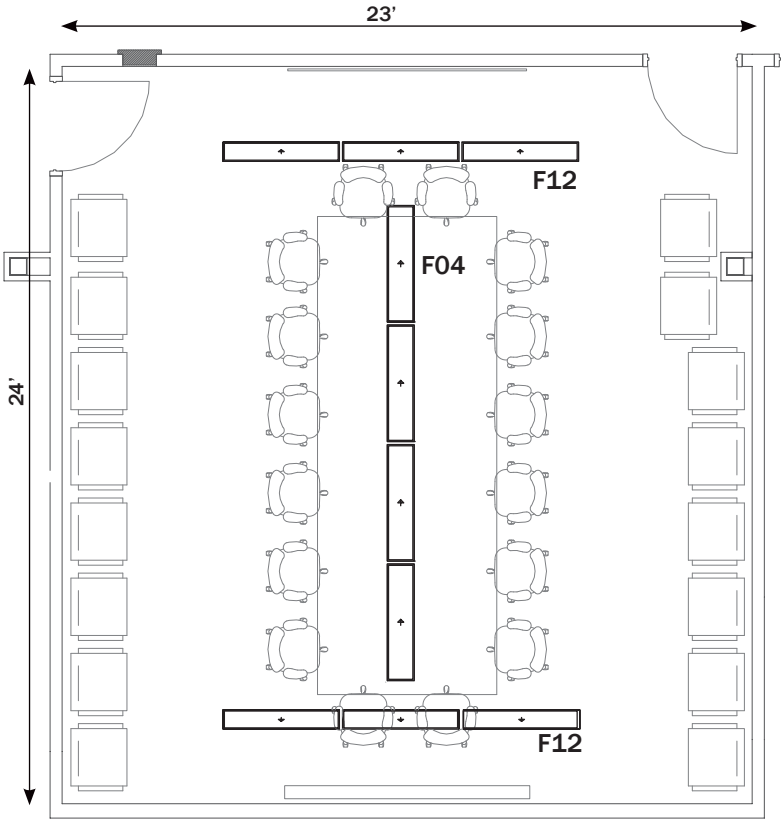
LIGHTING APPROACH
Use highly efficient recessed fluorescent luminaires with non-planar lenses in spaces with ceiling heights below 9'-6", otherwise use suspended direct/indirect fluorescent pendants. To provide for multiple uses of conference rooms, the lighting system should be divided into two or more zones. Each luminaire in the general lighting zones should be capable of two or more light output modes to achieve recommended illuminances for reading and AV mode. There should be two zones at a minimum - one for general lighting and one for the presentation wall. An additional dedicated lighting zone for lighting videoconferencing participants and the wall immediately behind them may be required.

CONTROLS
Occupancy sensors that automatically set the general lighting to low output mode are acceptable for rooms with no daylight access. If the space has access to daylight, vacancy sensors and controls for shading devices are recommended for AV needs.

CONFERENCE ROOM

SAMPLE LAYOUTS





SAMPLE SCHEMATIC LIGHTING LAYOUTS (NOT TO SCALE)

COMMENTS

Average LPD = 0.71 W/ft^2
Maintained illuminance on conference table = 40 - 60 fc
F04 mounted at 8'-6" AFF
Ceiling height = 9'-6" AFF

TYPE KEY

F04: (2) Lamp 32WT8, Direct Indirect, 0.88 BF, Bi-level ballast
F12: (1) Lamp 32WT8, 1'x4' Wallwasher, 0.88 BF

CONSOLIDATED BENCH REPAIR

Target Illuminance	Target LPD
50 fc	0.60 W/ft^2

Lighting Technologies

LAMP
L01 Fluor 32WT8

BALLAST
B03 Instant Start

LUMINAIRE
F01 Lensed Troffer

CONTROLS
C03 Dual Tech Occ/Vac Sensor

SPACE DESCRIPTION
Consolidated bench repair rooms are large workshops with benches and tools for repair work and maintenance. In TDA DOL facilities, there are designated work areas for a locksmith shop, paint shop, canvas leather and upholstery repair, furniture repair, and small arms repair, among others.

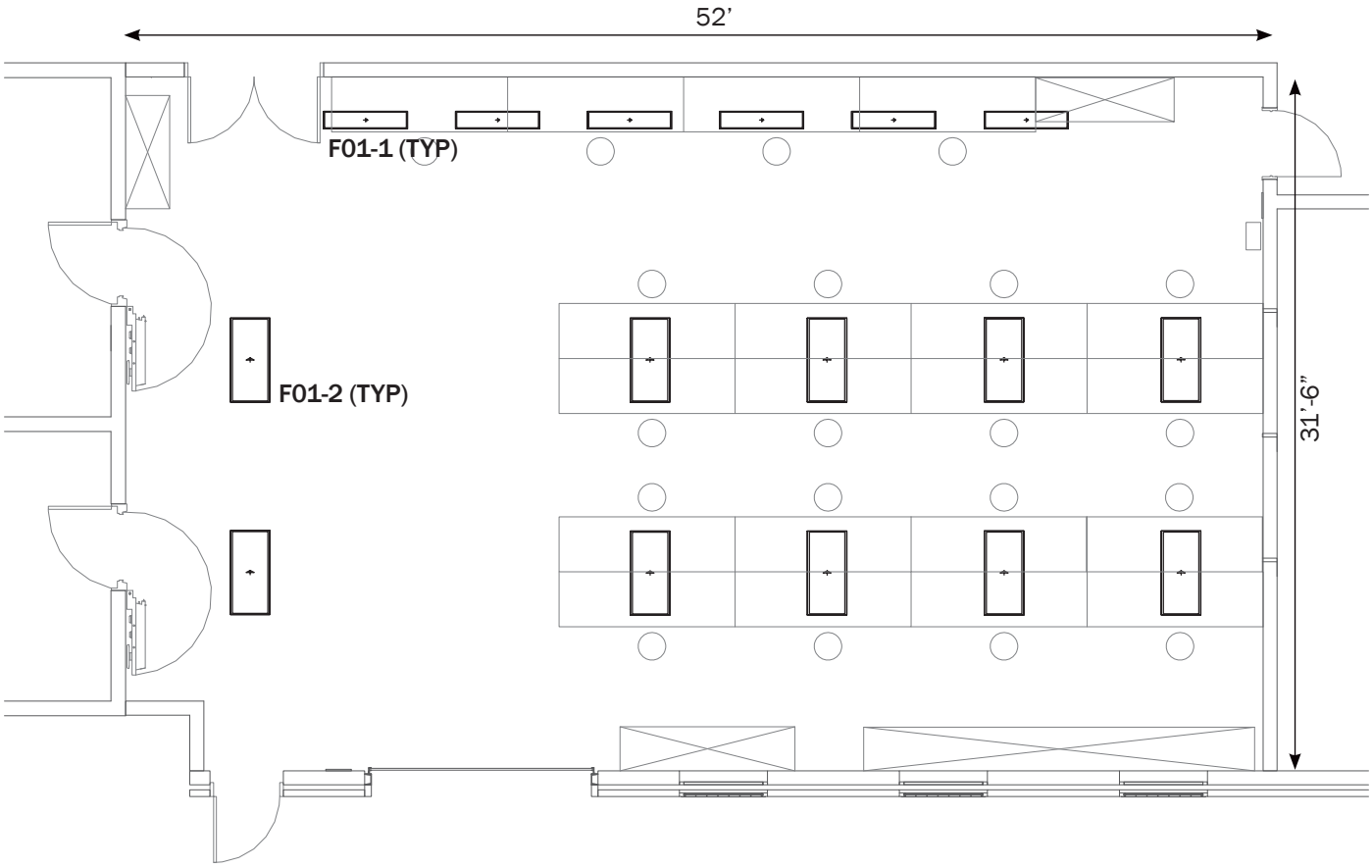
CONSIDERATIONS
The size and contrast of items being serviced in Consolidated Bench Repair areas varies. For general repair areas, 50 fc should be provided on the work bench. Higher illuminances may be required for work involving objects of small size and low contrast. Some shop areas may be busy while others are unoccupied.

LIGHTING APPROACH
Locate luminaires near/above task surfaces. Do not add additional lighting over circulation areas unless illuminance would otherwise be below 10fc. Use linear fluorescent luminaires. Select luminaires, lamps, and ballast factor combinations appropriately to provide sufficient illuminance without over-lighting. Provide additional task lighting for areas with detail work areas for items of small size and low contrast.

CONTROLS
Occupancy sensors should be zoned by shop area or groups of smaller areas. All task lighting should be controlled by independent localized vacancy sensors.

CONSOLIDATED BENCH REPAIR

SAMPLE LAYOUT



SAMPLE SCHEMATIC LIGHTING LAYOUT (NOT TO SCALE)

COMMENTS

LPD = 0.60 W/ft^2
Maintained illuminance on workbenches = 40 - 70 fc
Maintained average illuminance in circulation areas = 30 fc
Calculated with 80%/70%/20% ceiling/wall/floor reflectance and 80% Luminaire Dirt Depreciation

TYPE KEY

F01-1: (2) Lamp 32WT8, 1'x4' Lensed Troffer, 1.00 BF
F01-2: (2) Lamp 32WT8, 2'x4' Lensed Troffer, 1.00 BF

CORRIDOR

Target Illuminance	Target LPD
10 fc	0.50 W/ft^2

Lighting Technologies

LAMP
L01 Fluor 32WT8
L02 Fluor 32WT8U
L03 CFL 40W Long Twin-Tube

BALLAST
B01 Multi-Level
B04 Program Start

LUMINAIRE
F01 Lensed Troffer
F03 Non-Planar Lensed Troffer
F07 Narrow Lensed Wrap
F12 Wallwash

CONTROLS
C01 IR Occ/Vac Sensor

SPACE DESCRIPTION
Corridors are primarily used for circulation and may contain bulletin boards or other flat objects on display on the walls. Corridor perimeters may be defined by exterior glazing, full height partitions, partial-height partitions, or open to one or more sides.

CONSIDERATIONS
The primary task in corridors is wayfinding and facial recognition. Many corridors are intermittently occupied. Relatively low horizontal illuminance is required in corridors, 5 to 10 fc is sufficient for wayfinding. Providing vertical illuminance on the walls and occupants' faces is more important than horizontal illuminance on the floor.

LIGHTING APPROACH
Layout luminaires to prevent noticeable dark areas on walls without over-lighting. This can be achieved by using one lamp luminaires or low ballast factors or both. Wall mounted luminaires or highlighting one wall of the corridor with a wallwash luminaire may be desirable in some cases though it is more energy intensive. Back of house or spaces with a low level of finish should use surface mounted linear fluorescent luminaires with maximum efficiency, such as luminaires with wrapping lenses designed for corridors.

CONTROLS
Occupancy sensors should be used in enclosed corridors. If automatically turning the lighting in the corridor completely off poses a safety or security risk, the lighting may be reduced to a low light output, low power setting when vacancy is detected. This can be achieved with bi-level ballast or by circuiting several luminaires to remain on when vacancy is detected.

DINING

Target Illuminance	Target LPD
20 fc	0.60 W/ft^2

Lighting Technologies

LAMP
L01 Fluor 32WT8
L02 Fluor 32WT8U
L03 CFL Long Twin-Tube
L04 CFL Triple-Tube

BALLAST
B01 Multi-Level
B04 Program Start

LUMINAIRE
F10 Suspended Indirect
F16 Suspended Direct
F31 or F52 Downlight
F32 Performance Round

CONTROLS
C01 IR Occ/Vac Sensor
C07 Dimming Photosensor
C08 Switching Photosensor

SPACE DESCRIPTION
Dining areas area primarily used for personnel to eat meals. Seating is provided for counter tops as well as for small, medium, and large table dining. Large dining areas will seldom be used for special events, however smaller (or private) dining areas may occasionally be used for such events.

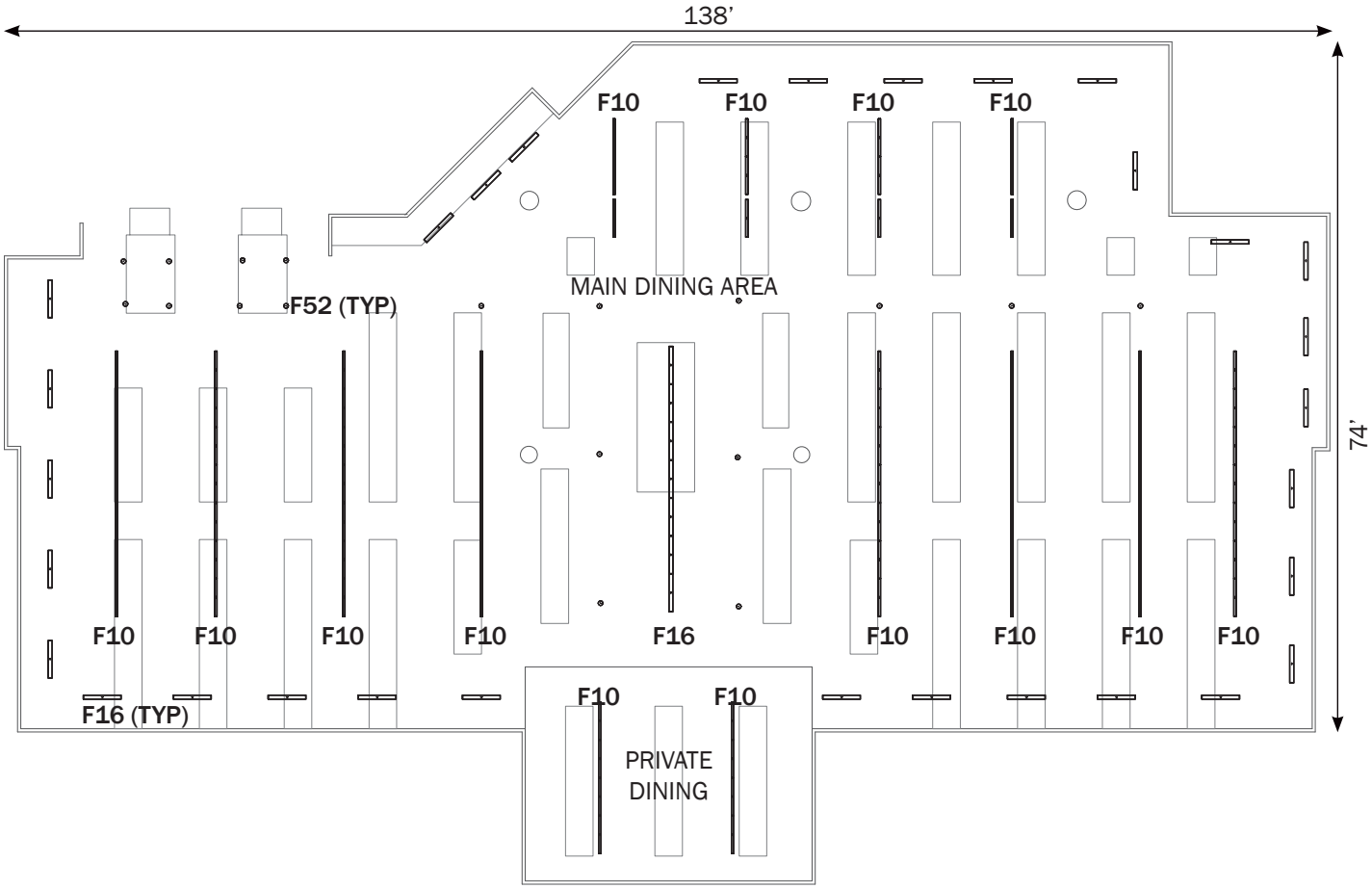
CONSIDERATIONS
High color rendering lighting is recommended for appealing food appearance. Lighting on the tables should be 20 fc in dining areas per TB MED 530 (for reference, the IESNA level is 10 fc). Furniture arrangement in these areas is subject to change so lighting should be independent of furniture layout. Dining areas are often expansive with relatively low ceilings with architectural features to break up the space into smaller sections. Lighting uniformity is not a priority on the table surfaces.

LIGHTING APPROACH
Use high color rendering (85+ CRI) sources distributed relatively evenly throughout the space. Use some semi-decorative high efficiency luminaires to add visual interest. Use linear fluorescent luminaires for general lighting; use T8U or long twin tube lamps when linear lamps are not appropriate. Minimize the use of recessed downlights, consider LEDs when recessed downlights must be used. An independent zone of lighting in the daylight zone (approximately two times the window height) may be switched or dimmed based on available daylight. Select luminaires, lamps, and ballast factor combinations appropriately to provide sufficient illuminance without over-lighting.

CONTROLS
Lighting should be controlled with occupancy sensors and building time-clock. Large sections of lighting should be zoned together, and controlled by occupancy sensors. Critical zones, those near primary entrances and exits can be left on to encourage seating in these areas, with other zones left off – only turning on when occupants move into that zone. Daylight sensors (switching or multi-level) should be used in areas in the daylight zone.

DINING

SAMPLE LAYOUT



SAMPLE SCHEMATIC LIGHTING LAYOUT (NOT TO SCALE)

COMMENTS

LPD = 0.59 W/ft^2
Maintained illuminance = 24 fc
Ceiling height = 10'-0"
F10 and F16 mounted at 8'-6" AFF

TYPE KEY

F10: (1) lamp cross-section F32WT8, suspended linear indirect, 1.18 BF
F16: (1) lamp cross-section F32WT8, suspended linear direct, 0.88 BF
F52: 25W recessed LED downlight, lensed

DISHWASHING / TRAY RETURN

Target Illuminance	Target LPD
50 fc	0.65 W/ft^2

Lighting Technologies

LAMP
L01 Fluor 32WT8

BALLAST
B03 Instant Start

LUMINAIRE
F01 Lensed Troffer

CONTROLS
C01 IR Occ/Vac Sensor

SPACE DESCRIPTION
The primary task in dishwashing areas is loading and unloading industrial dishwashers with dishes and utensils as well as inspecting items for cleanliness.

CONSIDERATIONS
High illuminance of 50 fc or more at equipment or utensil washing work areas (per TB MED 530, the IESNA level is also 50 fc). Luminaires need to be sealed and gasketed to withstand spray down at low pressure.

LIGHTING APPROACH
Use high color rendering (85+ CRI), high efficacy sources located near/above task surfaces. Do not add additional lighting over circulation areas or directly above large dishwashing machines (that do not have work surfaces above them). Use sealed and gasketed linear fluorescent luminaires. Select luminaires, lamps, and ballast factor combinations appropriately to provide sufficient illuminance without over-lighting.

CONTROLS
Lighting should be controlled primarily via building time-clock. All lighting, including equipment integrated lighting, should be switched off at closing time (with a warning flash for to allow the occupant to override). During operating hours, occupancy sensors can be used to turn the luminaires to a reduced power level when vacancy is detected.

KITCHEN / FOOD PREP / DRIVE-THRU

Target Illuminance	Target LPD
50 fc	0.65 W/ft^2

Lighting Technologies

LAMP
L01 Fluor 32WT8

BALLAST
B03 Instant Start

LUMINAIRE
F01 Lensed Troffer

CONTROLS
C01 IR Occ/Vac Sensor

SPACE DESCRIPTION
Low contrast and potentially dangerous tasks are performed in kitchen and food preparation area. Kitchen staff must be able to properly inspect food items and use sharp kitchen utensils and equipment accurately at a fast pace. Equipment is typically washed down with a low-pressure wash.

CONSIDERATIONS
High color rendering sources are strongly desired for food appearance. High illuminance of 50 fc or more on the food preparation surfaces is required by TB MED 530 (for reference the IESNA level is also 50 fc). Lamps must be shielded, coated or otherwise shatter resistant (TB MED 530). Luminaires need to be sealed and gasketed to withstand spray down at low pressure. Many of the kitchen appliances will come with integrated lighting. Circulation areas do not require high light levels.

LIGHTING APPROACH
Use high color rendering (85+ CRI) sources located near/above task surfaces. Do not add additional lighting over circulation areas. Use sealed and gasketed linear fluorescent luminaires. Linear fluorescent lamps should have a long rated life to minimize maintenance over food service areas. Select luminaires, lamps, and ballast factor combinations appropriately to provide sufficient illuminance without over-lighting.

CONTROLS
Lighting should be controlled via building time-clock. All lighting, including equipment integrated lighting, should be switched off at closing time (with warning flash for override). Using a long occupancy sensor time-out period, such as 30 minutes or more, will help prevent luminaires being turned off when the space is occupied.

LIVING QUARTERS

Target Illuminance	Target LPD
5 - 30 fc	0.60 W/ft^2

Lighting Technologies

LAMP
L01 Fluor 32WT8
L02 Fluor 32WT8U
L04 CFL 26W/42W Triple Tube
L05 CFL GU24 Integrated Ballast
L07 Fluor 17WT8

BALLAST
B04 Program Start

LUMINAIRE
F02 Wallbracket Direct/Indirect
F05 Furniture Integrated
F07 Narrow Lensed Wrap
F08 Wide Lensed Wrap
F09 or F51 Task
F12 Wallwash
F13 Strip
F14 Vanity
F30 Table Lamp

CONTROLS
C04 Wallbox Occ/Vac Sensor
C05 Integrated Occ Sensor

SPACE DESCRIPTION
Living quarters are similar to a small apartment or dorm suite. Most contain a bathroom, lavatory, an eat-in kitchen, and two private bedrooms each with a bed, night stand, desk, dresser and a closet. Bedrooms typically are against an exterior wall with a window to outdoors. Kitchens have a refrigerator, oven and range, counter top space, and may be equipped with a microwave and toaster.

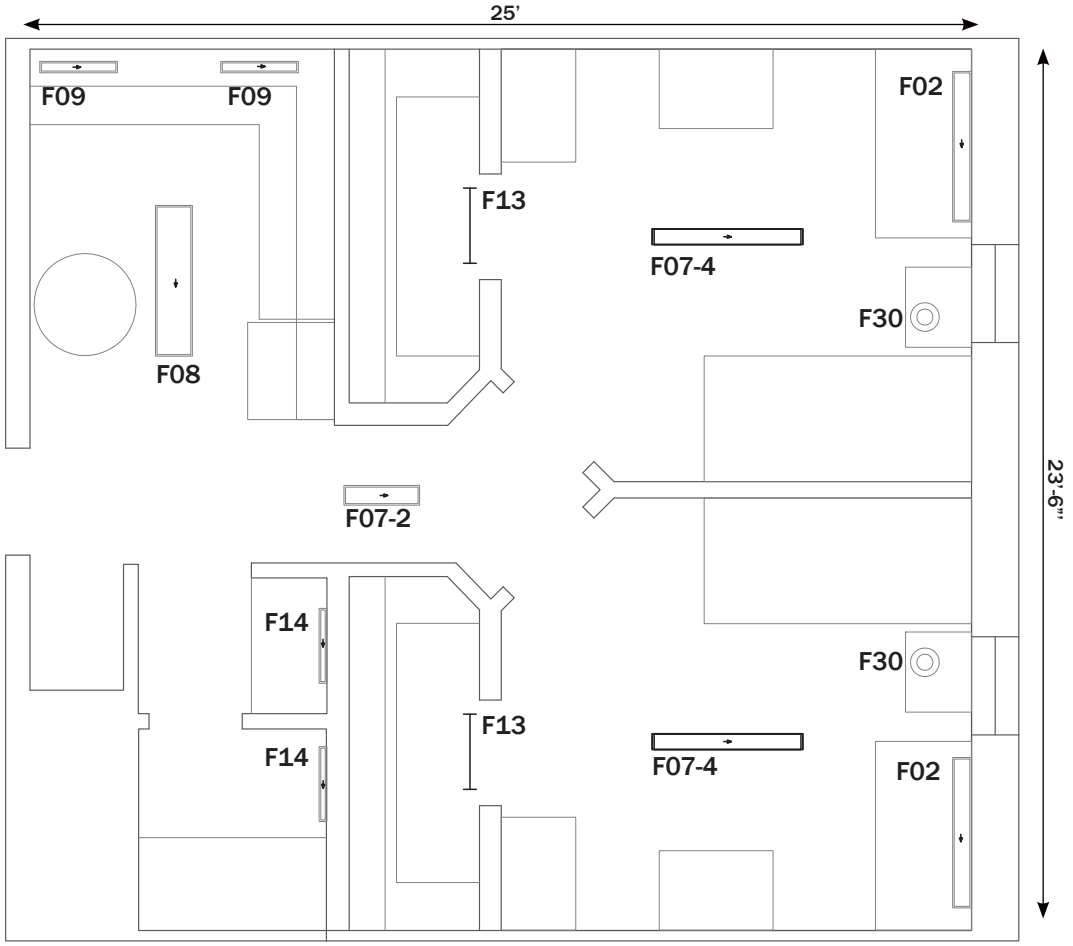
CONSIDERATIONS
Reading and food preparation areas require higher illuminance than other areas in the space. Low illuminance is sufficient away from counter and desk tops, 5 to 10 fc is sufficient for most areas. Visually comfortable, effective, permanently installed lighting should be used to prevent the use of uncontrolled plug load lighting. Luminaires may be unintentionally left on when spaces are unoccupied if they are not automatically controlled. Spaces within the living quarters along the core wall can become extremely dim at night time, which may result in some occupants leaving lights on as night lights for wayfinding purposes.

LIGHTING APPROACH
Use highly efficient surface mounted luminaires with appropriate lamps and ballasts to provide sufficient illuminance for localized tasks without over-lighting. For areas that have low light level requirements, this can be achieved by using one lamp luminaires or low ballast factors or both. Provide task lighting at desk with a wall mounted or furniture integrated luminaire. Provide a reading light on the night stand with a socket specific for compact fluorescent lamps. Low energy LED nightlights should be provided in rooms without exterior windows.

CONTROLS
Vacancy sensors should be used in each sub-space including bedrooms, bathrooms, kitchens and other areas. Luminaire integrated occupancy sensors may be appropriate in closets. Some electrical outlets in bedrooms, vanities, and bathrooms should be controlled by vacancy sensor switch.

LIVING QUARTERS

SAMPLE LAYOUT



SAMPLE SCHEMATIC LIGHTING LAYOUT (NOT TO SCALE)

COMMENTS

LPD = 0.50 W/ft^2

Maintained illuminance at work-surfaces = 30 - 40fc

TYPE KEY

F02: (1) lamp F32WT8, 4' wallbracket direct/indirect, 0.88 BF, wall mount
F07-2: (1) lamp F32WT8. 2' narrow lensed wrap, 0.77 BF
F07-4: (1) lamp F32WT8, 4' narrow lensed wrap, 0.73 BF
F08: (2) lamp F32WT8, 4' wide lensed wrap, 0.88 BF
F09: (1) lamp F17WT8, 2' undercabinet task, 0.77 BF
F13: (1) lamp F17WT8, 2' strip light, 1.00 BF, wall-mount above door
F14: (2) lamp F17WT8, 2' vanity wrap, 0.73 BF
F30: (1) lamp CF13W/GU24, table lamp with dedicated CFL socket

MECHANICAL / ELECTRICAL

Target Illuminance	Target LPD
30 fc	0.70 W/ft^2

Lighting Technologies

LAMP
L01 Fluor 32WT8

BALLAST
B04 Program Start

LUMINAIRE
F07 Narrow Lensed Wrap
F13 Strip

CONTROLS
C02 Ultra Sonic Occ/Vac Sensor

SPACE DESCRIPTION
Mechanical and electrical rooms contain equipment that may include motors, pumps, air handlers, boilers, transformers, lighting controls, circuit breakers, and other similar devices required for building operation. These spaces are typically only occupied by maintenance staff in time of repair or routine maintenance.

CONSIDERATIONS
Facilities personnel must be able read small print on the surfaces of equipment and perform routine maintenance tasks. Lighting should be provided primarily for the working surfaces of the equipment. Task areas such as the face of a circuit breaker or name plates should be lighted to 30 fc, spaces in between tasks areas should be lighted to 5 fc or more as in corridor spaces.

LIGHTING APPROACH
Use high efficacy sources located near/above task surfaces arranged to light critical task surfaces. Do not add additional lighting over circulation areas. Use linear fluorescent strip or wrap luminaires on chain mounts. Select luminaires, lamps, and ballast factor combinations appropriately to provide sufficient illuminance without over-lighting.

CONTROLS
Ultrasonic occupancy sensors may be used in these areas, but should be placed and commissioned with care to prevent false vacancy readings. Due to obstructions and the typical lack of daylight in these spaces, using a long time-out period, such as 60 minutes, will also help prevent luminaires being turned off when the space is occupied.

OFFICE (OPEN)

Target Illuminance	Target LPD
30 - 50 fc	0.70 W/ft^2

Lighting Technologies

LAMP
L01 Fluor 32WT8
L06 20/39W Ceramic Metal Halide

BALLAST
B01 Multi-Level
B02 Dimming
B04 Program Start

LUMINAIRE
F03 Non-Planar Lensed Troffer
F04 Suspended Direct/Indirect
F05 Furniture Integrated
F09 or F51 Task
F12 Wallwash
F40 or F50 Adjustable Accent

CONTROLS
C03 Dual Tech Occ/Vac Sensor
C07 Dimming Photosensor
C08 Switching Photosensor

SPACE DESCRIPTION
Open offices are designed to accommodate multiple individual work areas, typically separated by movable partitions and circulation areas. Individual work areas typically contain a computer, telephone, personal storage, and desk space for reading and writing. Furniture locations are not permanent and may change with needs and staffing. Open offices typically have one or more perimeter window walls which can provide views to the outdoors and usable daylight.

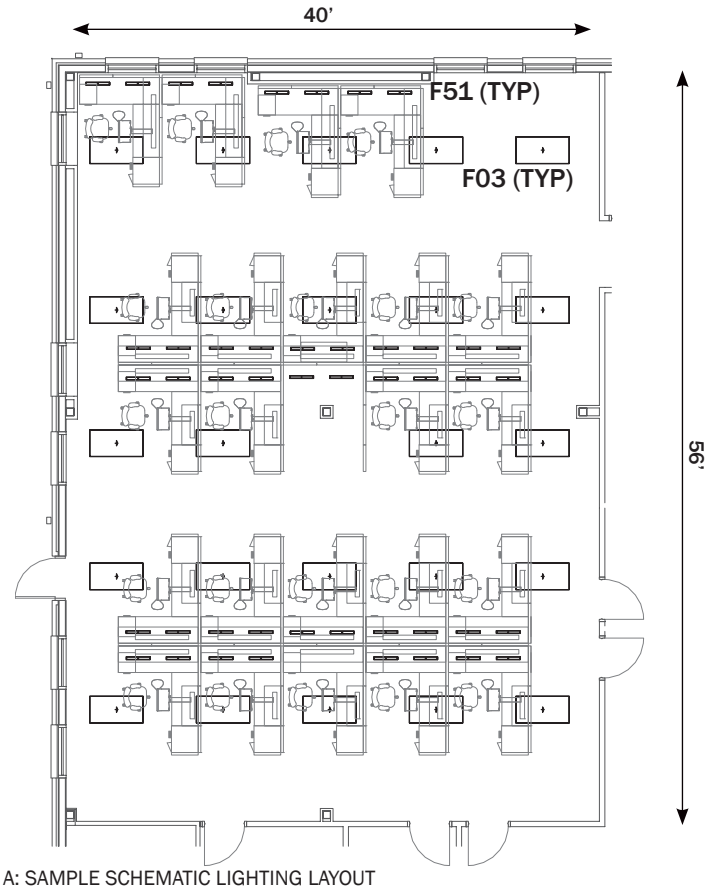
CONSIDERATIONS
Users' age, job function, and occupancy varies in each open office area. Work plane illuminance, as suggested by the IESNA, ranges from 30 fc to 50 fc for most office reading tasks. The visual needs of an older occupant in one work area may be different than that of a younger occupant. In most cases, the circulation space between work areas requires little if any lighting in addition to that provided for work areas. It is typical to find some work areas occupied and some vacant throughout the work day. Direct and reflected glare should be considered. Direct sunlight on work surfaces can contribute to glare and make it difficult to perform work. Lighting in the daylight zone (approximately twice the window height) can often be turned off or reduced to a low power setting during the day.

LIGHTING APPROACH
The lighting system in these spaces should be easily adaptable to suit the needs of occupants. Providing a task/ambient solution is an effective way to minimize energy use while providing sufficient lighting for the occupants. This can be achieved by providing a 15 to 25 fc of ambient (furniture-mounted or overhead) lighting – enough for computer use, facial recognition, and circulation – supplemented by individually controlled task lighting at each workstation. The lack of full height partitions and low-level ambient lighting may leave the space feeling dim in some cases. To avoid this perception, interior full height partitions should be lighted with wall washers or similar. This is especially effective when lighting the wall opposite the window wall in deeper spaces to balance vertical brightness in the field of view.

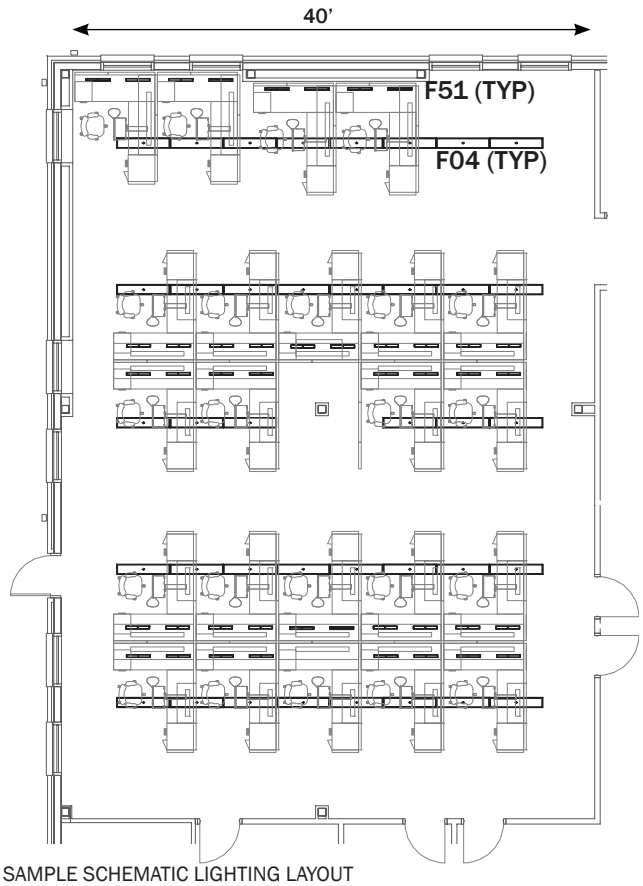
CONTROLS
Occupancy sensors may be used in open offices, but should be zoned and commissioned to prevent false triggers from the signal being blocked by partitions. All task lighting should be controlled by independent vacancy sensors at each workstation. Lighting specifically for interior perimeter walls may be controlled with an occupancy sensor or controlled only by a time-clock. Daylight responsive lighting controls should be used in areas with sufficient access to daylight.

OFFICE (OPEN)

SAMPLE LAYOUTS



A: SAMPLE SCHEMATIC LIGHTING LAYOUT
FOR CEILING HEIGHTS AT OR BELOW 9'-0" (NOT TO SCALE)



B: SAMPLE SCHEMATIC LIGHTING LAYOUT
FOR CEILING HEIGHTS ABOVE 9'-0" (NOT TO SCALE)

COMMENTS

LPD with task lights = 0.77 W/ft^2
LPD without task lights = 0.61 W/ft^2
Maintained task illuminance = 40 - 54 fc
Maintained ambient illuminance = 27 - 50 fc

TYPE KEY

F03: (1) lamp F32WT8. non-planar lensed troffer, 1.15 BF
F52: 6W Undercabinet LED task light (furniture mounted)

COMMENTS

LPD with task lights = 0.72 W/ft^2
LPD without task lights = 0.56 W/ft^2
Maintained task illuminance = 37 - 53fc
Maintained ambient illuminance = 20 - 45fc

TYPE KEY

F04: (1) lamp F32WT8, suspended direct/indirect, 1.00 BF
F52: 6W undercabinet LED task light (furniture mounted)

OFFICE (ENCLOSED)

Target Illuminance	Target LPD
30 - 50 fc	0.80 W/ft^2

Lighting Technologies

LAMP
L01 Fluor 32WT8

BALLAST
B01 Multi-Level
B01 Program Start

LUMINAIRE
F03 Non-Planar Lensed Troffer
F04 Suspended Direct/Indirect
F05 Furniture Integrated
F09 or F51 Task

CONTROLS
C01 IR Occ/Vac Sensor

SPACE DESCRIPTION
Enclosed offices are typically intended for use by one person, though some enclosed offices may be used by two people. A typical enclosed office contains a computer, telephone, personal storage, desk space for reading and writing and may contain an additional seating area.

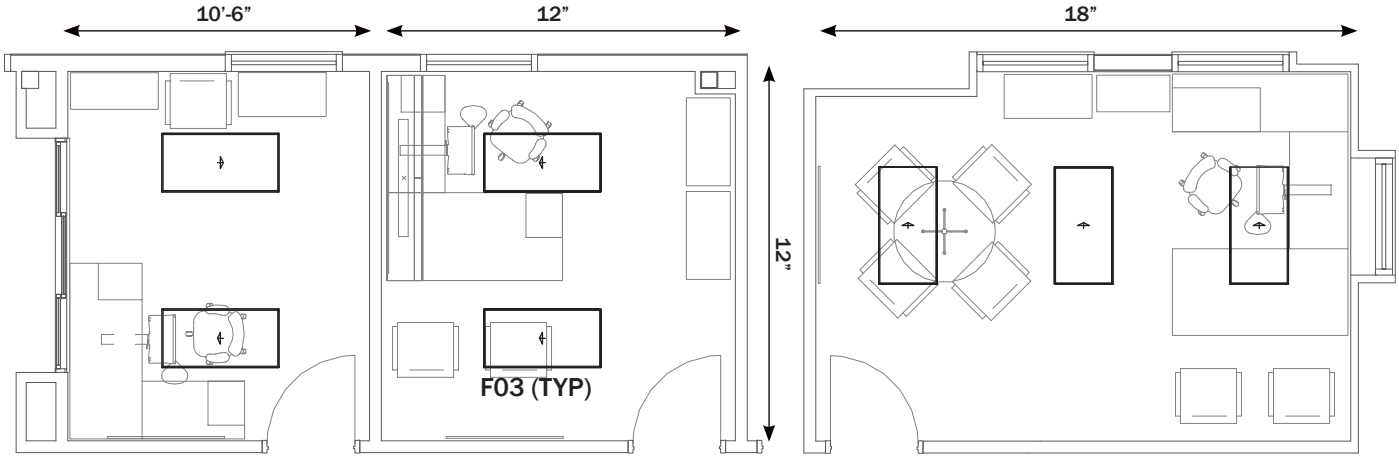
CONSIDERATIONS
Users of private offices vary by age and job function. Work plane illuminance, as suggested by the IESNA, ranges from 30 fc to 50 fc for most office reading tasks. The visual needs of an older occupant in one office may be much different than that of a younger occupant in another. Private offices often have a window to the outdoors and are frequently unoccupied.

LIGHTING APPROACH
The lighting system in these spaces should be easily adaptable to suit the needs of occupants. Providing a task/ambient solution is an effective way to minimize energy use, while providing sufficient lighting for the occupants. This is achieved by providing 15 to 25 fc ambient lighting – enough for computer use, facial recognition, and circulation – supplemented by individually controlled task lighting at each workstation. Alternatively, a bi-level overhead lighting system can provide similar savings as many occupants may choose the lower lighting level.

CONTROLS
Vacancy sensors should be used in offices with daylight access. For interior private offices, occupancy sensors that activate a low light output should be used. All task lighting should be controlled by independent vacancy sensor.

OFFICE (ENCLOSED)

SAMPLE LAYOUTS



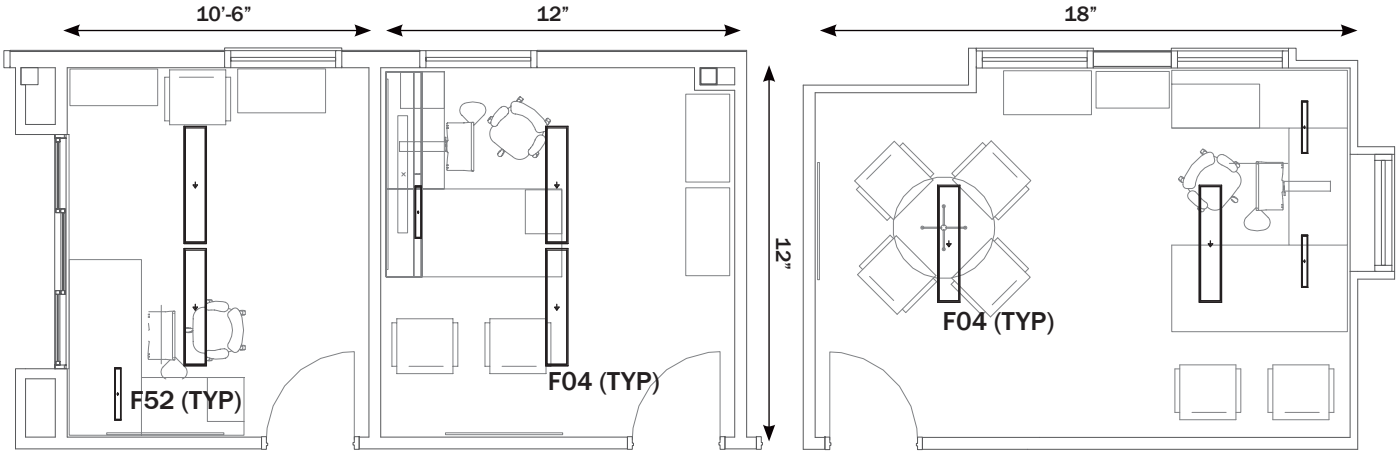
A: SAMPLE SCHEMATIC LIGHTING LAYOUT FOR CEILING HEIGHTS AT OR BELOW 9'-0" (NOT TO SCALE)

COMMENTS

LPD (average) = 0.75 W/ft^2
Task illuminance at full output = 34 - 58 fc
Task illuminance at half output = 11 - 20 fc

TYPE KEY

F03: (1) lamp F32WT8. non-planar troffer, 0.88 BF Bi-level ballast
F52: 6W Undercabinet LED task light (furniture mounted)



B: SAMPLE SCHEMATIC LIGHTING LAYOUT FOR CEILING HEIGHTS ABOVE 9'-0" (NOT TO SCALE)

COMMENTS

LPD with task lights = 0.77 W/ft^2
LPD without task lights = 0.70 W/ft^2
Maintained task illuminance = 37 - 65 fc
Maintained ambient illuminance = 20 - 40 fc

TYPE KEY

F04: (1) lamp F32WT8, suspended direct/indirect, 1.00 BF
F52: 6W Undercabinet LED task light (furniture mounted)

READINESS BAY

Target Illuminance	Target LPD
40 fc	0.75 W/ft^2

Lighting Technologies

LAMP
L01 Fluor 32WT8

BALLAST
B01 Program Start

LUMINAIRE
F01 Lensed Troffer
F08 Wide Lensed Wrap
F11 High Bay

CONTROLS
C02 Ultra Sonic Occ/Vac Sensor
C08 Switching Photosensor

SPACE DESCRIPTION
Readiness bays provide accommodation for individual combat equipment lockers and an area for equipment maintenance, training, and pre-deployment preparations. Readiness bays are typically designed to provide daylight in most of the space.

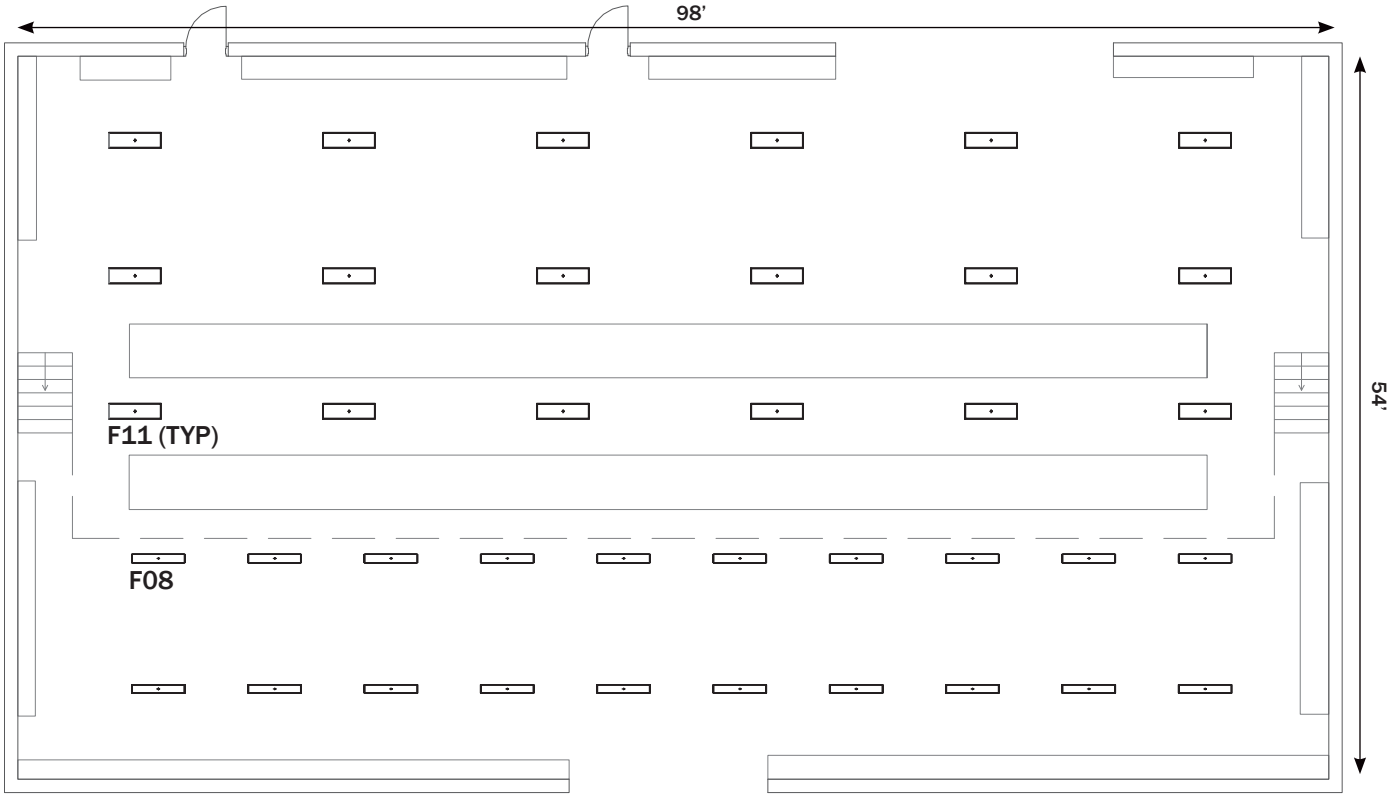
CONSIDERATIONS
Personnel must be able to identify stored objects and quickly load and unload combat equipment lockers. Lighting should be provided to light the vertical surface of the locker faces. The visual task in the interior equipment maintenance area varies but is primarily on the floor and requires uniform lighting. These spaces are intermittently occupied.

LIGHTING APPROACH
Provide surface mounted or recessed linear fluorescent luminaires along each row of lockers in areas with ceiling heights below 15'-0" AFF and evenly spaced linear fluorescent high bay luminaires in areas with higher ceilings. These luminaires should provide 10 fc on the vertical surface of the lockers 12" above the floor. Luminaires with ballasts wired for multi-level operation should provide 40 fc and 20 fc of uniform illuminance on the floor of the interior equipment maintenance area.

CONTROLS
Ultrasonic vacancy sensors should be used in these spaces to prevent false vacancy readings which may occur with infrared sensors due to signal blocking by the lockers. Luminaires in daylight zones should be wired for multiple circuits to allow for multi-level daylight switching. Locker lighting and equipment maintenance area lighting should be zoned separately.

READINESS BAY

SAMPLE LAYOUT



SAMPLE SCHEMATIC LIGHTING LAYOUT (NOT TO SCALE)

COMMENTS

LPD = 0.75 W/ft^2
Horizontal illuminance = 34 - 50 fc
Minimum vertical illuminance on locker = 10 fc
F11 mounted at 19' AFF

TYPE KEY

F08: (2) lamp F32WT8, narrow lensed wrap, 1.0 BF, bi-level circuiting
F11: (4) lamp F32WT8, open high bay, 1.15 BF, bi-level circuiting

REPAIR BAY / VEHICLE CORRIDOR

Target Illuminance	Target LPD
50 fc	0.85 W/ft^2

Lighting Technologies

LAMP
L01 Fluorescent 32WT8

BALLAST
B01 Multi-Level
B03 Instant Start

LUMINAIRE
F11 High Bay

CONTROLS
C01 IR Occ/Vac Sensor
C08 Switching Photosensor

SPACE DESCRIPTION
Each Tactical Equipment Maintenance Facility consists of two or more 32' x 96' structural bays with high ceilings. Each repair bay consists of four 16' x 32' repair work areas, and a 32' wide central vehicle corridor dividing them crosswise. The vehicle corridor extends into the rest of the building, and contains two 16' x 32' maintenance areas down the length of the corridor. Large bay doors surround each repair bay so that vehicles can easily drive in an out of the space. Repair bays are equipped with large overhead lifts which may be either 20 or 25' high. These spaces are used for the maintenance and repair of wheeled vehicles, tracked vehicles, missile launchers, and self-propelled artillery among other types of equipment. There are designated areas for specific functions such as welding, tire changing, and washing or steam cleaning.

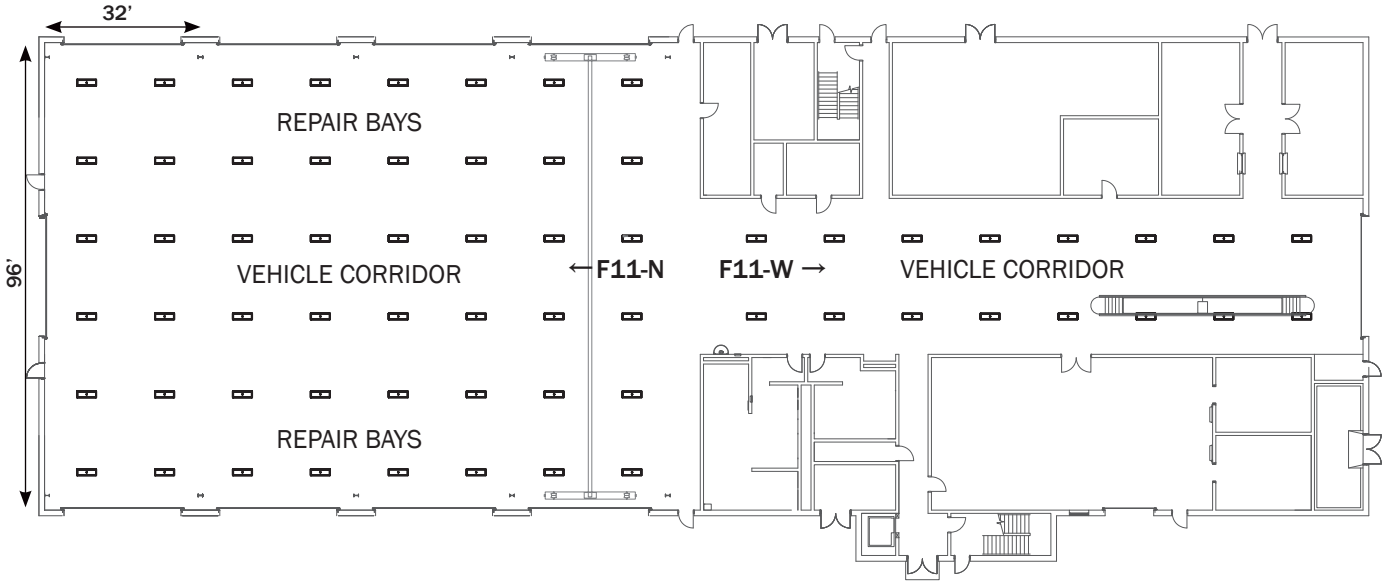
CONSIDERATIONS
Luminaire mounting locations are limited by the path of the over head bridge cranes. Overhead lighting should provide 50 fc on the floor. Additional lighting may be needed in some work areas. Abundant usable daylight may be available for much of the workday.

LIGHTING APPROACH
Locate suspended linear fluorescent high bay luminaires above the highest point of the overhead lift equipment. Arrange and zone luminaires to correspond with repair bay orientation and work areas and in areas to minimize light blocking by the overhead crane in its most common positions. Use narrow distribution luminaires mounted above 25' and wide distribution for those mounted below 25' above the finished floor. Use multi-step ballasts or multi-circuit luminaires coupled with occupancy sensors and photo sensors for maximum energy savings.

CONTROLS
Provide one occupancy sensor control zone per two repair/maintenance areas (one per 1,024 ft2). Use one open loop photosensor for all repair bay overhead lighting. Ensure that photosensor and vacancy sensor system malfunctions do not leave space in complete darkness by always leaving some lamps powered during occupied hours.

REPAIR BAY / VEHICLE CORRIDOR

SAMPLE LAYOUT



SAMPLE SCHEMATIC LIGHTING LAYOUT (NOT TO SCALE)

COMMENTS

LPD = 0.80 W/ft^2
Maintained Illuminance = 47 fc
F11-W mounted at 14'-0" AFF
F11-N mounted at 28'-0" AFF
Luminaires spaced on 16'-0"centers

TYPE KEY

F11-W: (6) lamp 32WT8, wide distribution high bay, 1.00 BF
F11-N: (6) lamp 32WT8, narrow distribution high bay, 1.15 BF

RESTROOM / SHOWER

Target Illuminance	Target LPD
20 fc	0.80 W/ft^2

Lighting Technologies

LAMP
L01 Fluor 32WT8

BALLAST
B04 Program Start

LUMINAIRE
F01 Lensed Troffer
F06 Perimeter
F14 Vanity
F31 or F52 Downlight

CONTROLS
C02 Ultra Sonic Occ/Vac Sensor
C04 Wallbox Occ/Vac Sensor

SPACE DESCRIPTION
Restrooms include one or more toilets and lavatories with a mirror for grooming. Some restrooms include showers and changing facilities.

CONSIDERATIONS
Restrooms are intermittently occupied and used for short durations. The primary visual task is hand washing and grooming. The IESNA illuminance this space is 5 fc, though lighting the walls and providing illuminances in the range of 10 fc to 20 fc near the sinks and toilets can help make the space feel brighter which may promote cleanliness. The illuminance provided between the sink and toilets is non-critical and may be as low as 5 fc. Luminaires in the shower areas need to be rated for wet locations.

LIGHTING APPROACH
Provide overhead perimeter lighting above the sinks and along the toilet wall. Some restrooms may require an additional luminaire near the room entry, though often the perimeter luminaires are all that is necessary. Luminaires with one lamp may and a low ballast factor should be considered. Overhead lighting provided above the showers and near the locker areas is often all that is required in these areas.

CONTROLS
Ultrasonic occupancy sensors should be used in these spaces to prevent false vacancy readings which may occur with infrared sensors due to interior partitions. These systems should be automatic-on, automatic-off.

SERVER ROOM

Target Illuminance	Target LPD
30 fc	0.85 W/ft^2

Lighting Technologies

LAMP
L01 Fluor 32WT8

BALLAST
B04 Program Start

LUMINAIRE
F01 Lensed Troffer
F07 Narrow Lensed Wrap

CONTROLS
C02 Ultra Sonic Occ/Vac Sensor
C04 Wallbox Occ/Vac Sensor

SPACE DESCRIPTION
Server rooms house semi-permanently installed computer equipment in racks, typically arranged in rows to allow for easy access to the front and back of server equipment.

CONSIDERATIONS
IT personnel must be able to identify computer equipment, data connections and cables and install components with small fasteners. Lighting should be provided to illuminate the vertical faces of each server rack. These spaces are frequently unoccupied and seldom have access to daylight.

LIGHTING APPROACH
Locate and specify highly efficient luminaires between server racks to light vertical surfaces to 30 fc.

CONTROLS
Ultrasonic occupancy sensors should be used in these areas. Multiple sensors and zones may be required for larger spaces with several server racks. Sensors integrated into wall switches should be used in small areas.

SERVING AREA

Target Illuminance	Target LPD
50 fc	0.70 W/ft^2

Lighting Technologies

LAMP
L01 Fluorescent 32WT8
L06 20/39W Ceramic Metal Halide

BALLAST
B03 Instant Start
B05 Electronic CMH

LUMINAIRE
F01 Lensed Troffer
F16 Suspended Direct
F40 Adjustable Accent
F31 or F52 Downlight

CONTROLS
C03 Dual Tech Occ/Vac Sensor
C08 Switching Photosensor

SPACE DESCRIPTION
The serving area is in buffet format with food serving areas arranged around the perimeter of the space with a central island with circulation space in between. The space behind the food serving areas is used for light food preparation and storage.

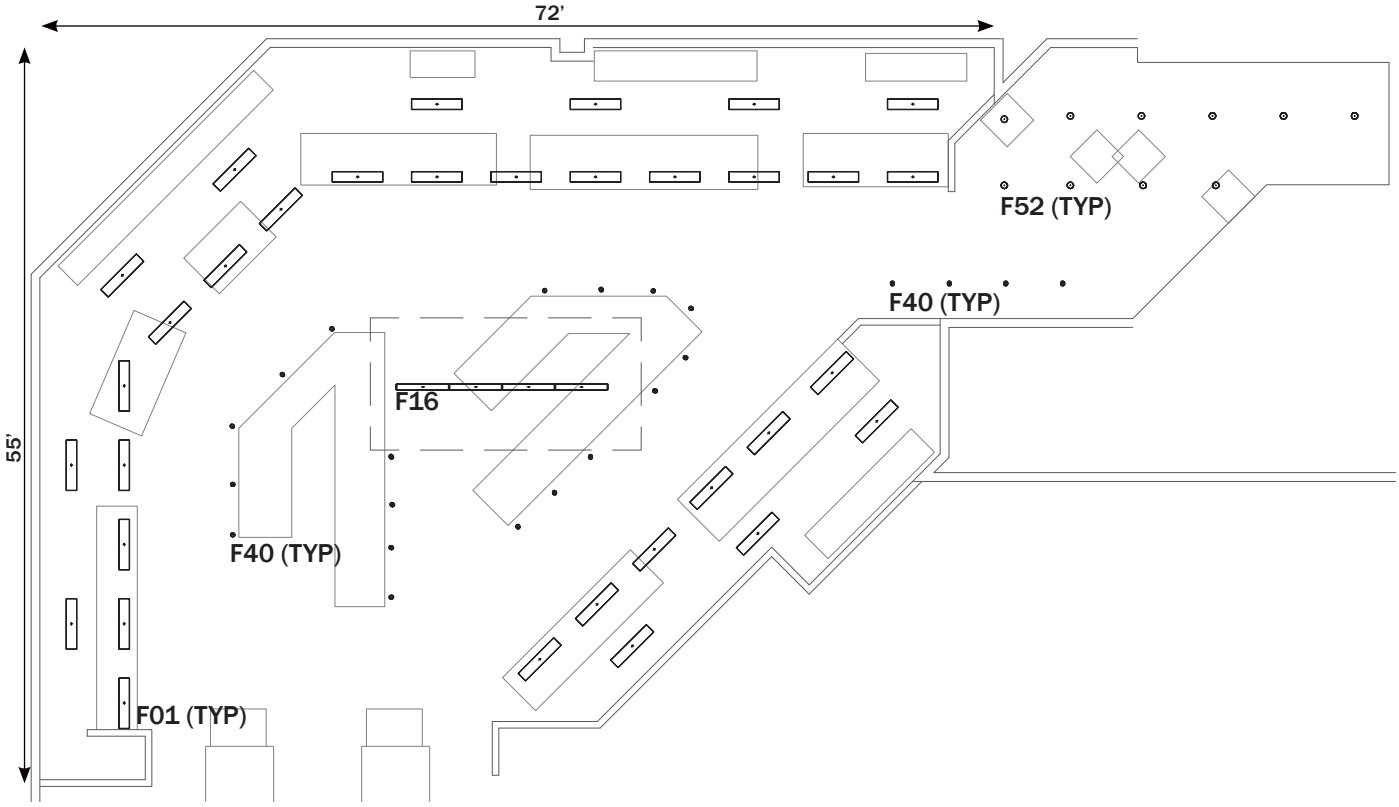
CONSIDERATIONS
High color rendering lighting is recommended for appealing food appearance. Lighting on work surface and food presentation areas should be 50 fc. Spill light from lighting the food displays will often be enough to light the circulation areas. Lensed luminaires are required

LIGHTING APPROACH
Use high color rendering (85+ CRI) sources. Use linear fluorescent lensed troffers for lighting larger food displays and work areas. Use ceramic metal halide accent luminaires to highlight special food display areas or those in a center island, for example. Minimize the use of recessed downlights, consider LEDs when recessed downlights are be used.

CONTROLS
Lighting should be controlled with a building time-clock. All luminaires, including equipment integrated lighting, should be switched off at closing time. Occupancy sensors may also be used in these areas for further energy savings.

SERVING AREA

SAMPLE LAYOUT



SAMPLE SCHEMATIC LIGHTING LAYOUT (NOT TO SCALE)

TYPE KEY

LPD = 0.58 W/ft^2
Illuminance on food displays = 39-54 fc
Illuminance in circulation area = 11-33 fc

TYPE KEY

F01: (1) lamp F32WT8, 1'x4' recessed lensed troffer, 1.18 BF
F16: (2) lamp F32WT8, suspended linear direct, 0.88 BF
F40: (1) lamp 39W CMH, adjustable accent, 1.0 BF
F52: 25W recessed LED downlight, lensed

STAIR

Target Illuminance	Target LPD
10 fc	0.50 W/ft^2

Lighting Technologies

LAMP
L01 Fluor 32WT8

BALLAST
B01 Multi-Level

LUMINAIRE
F07 Narrow Lensed Wrap
F15 Bi-level Occ Sens Wrap

CONTROLS
C05 Integrated Occ Sensor

SPACE DESCRIPTION
Stairwells are typically enclosed and often contain a landing between two building floors. These spaces are used for daily circulation as well as for egress in the case of emergency.

CONSIDERATIONS
Many stairways are critical exit paths in the case of an emergency. These spaces are intermittently occupied, and some stairwells are used only in the case of an emergency. There are conflicting code requirements that stipulate minimum illuminance on stair treads. Code requires some light in stairwells even when unoccupied.

LIGHTING APPROACH
Use luminaires only at landings where possible while meeting applicable safety code requirements.

CONTROLS
Use luminaire integrated occupancy sensors to reduce luminaire to low light output, low power setting when vacancy is detected.

STORAGE (DRY FOOD)

Target Illuminance	Target LPD
10 fc	0.70 W/ft^2

Lighting Technologies

LAMP
L01 Fluor 32WT8

BALLAST
B04 Program Start

LUMINAIRE
F01 Lensed Troffer

CONTROLS
C02 Ultra Sonic Occ/Vac Sensor

SPACE DESCRIPTION
Dry food storage area used to store food and contain movable shelving. Kitchen staff must be able to identify labels and textures of stored food items.

CONSIDERATIONS
Relatively low light levels are required, 10 fc (per TB MED 530, the IESNA level is 5 fc). Lighting on vertical surfaces is critical as items are typically stored on shelving. If movable shelving units are used, lighting should be sufficient on shelf surfaces for all typical storage positions. Lamps need to be shielded if storage areas will contain open packages or other exposed food.

LIGHTING APPROACH
Use high efficacy sources located near/above task surfaces arranged to accommodate movable storage units if in use. Do not add additional lighting over circulation areas. Use sealed and gasketed linear fluorescent luminaires. Select luminaires, lamps, and ballast factor combinations appropriately to provide sufficient illuminance without over- lighting.

CONTROLS
Lighting should be controlled with a occupancy sensor.

STORAGE (GENERAL)

Target Illuminance	Target LPD
10 fc	0.50 W/ft^2

Lighting Technologies

LAMP
L01 Fluor 32WT8

BALLAST
B04 Program Start

LUMINAIRE
F01 Lensed Troffer
F13 Strip

CONTROLS
C01 IR Occ/Vac Sensor
C02 Ultra Sonic Occ/Vac Sensor
C04 Wallbox Occ/Vac Sensor

SPACE DESCRIPTION
Storage areas typically contain shelving to store items vertically. These spaces are typically occupied for brief periods to store or retrieve items.

CONSIDERATIONS
Occupants must be able to identify stored objects and read labels. Lighting should be provided to light the faces of stored items. Lighting the top of shelves is not useful while light on the front face of shelving will allow for quick identification of items.

LIGHTING APPROACH
Use high efficacy sources located near/above task surfaces arranged to light critical task surfaces to 10 fc. Do not add additional lighting over circulation areas or directly above shelving units. Use linear fluorescent strip or wrap luminaires. Select luminaires, lamps, and ballast factor combinations appropriately to provide sufficient illuminance without over-lighting.

CONTROLS
IR and/or ultrasonic occupancy sensors should be used in these areas depending on shelving and other obstructions. Sensors integrated into wall switches should be used in small storage areas.

TELECOM / SIPRNET

Target Illuminance	Target LPD
50 fc	1.20 W/ft^2

Lighting Technologies

LAMP
L01 Fluor 32WT8

BALLAST
B04 Program Start

LUMINAIRE
F01 Lensed Troffer
F07 Narrow Lensed Wrap

CONTROLS
C02 Ultra Sonic Occ/Vac Sensor
C04 Wallbox Occ/Vac Sensor

SPACE DESCRIPTION
Telecom and SIPRNET rooms house semi-permanently installed computer and telecommunications equipment arranged in racks or against walls.

CONSIDERATIONS
Personnel must be able to identify computer equipment, data connections and cables and install components with small fasteners. Lighting should be provided to illuminate the vertical faces of equipment. These spaces are frequently unoccupied and seldom have access to daylight.

LIGHTING APPROACH
Locate and specify highly efficient luminaires to light critical surfaces to 50 fc, avoid locating luminaires directly above or behind equipment to maximize the light falling on critical surfaces.

CONTROLS
Ultrasonic occupancy sensors should be used in these areas. Multiple sensors and zones may be required for larger spaces. Sensors integrated into wall switches should be used in small areas.

VAULT

Target Illuminance	Target LPD
40 fc	0.70 W/ft^2

Lighting Technologies

LAMP
L01 Fluor 32WT8

BALLAST
B04 Program Start

LUMINAIRE
F01 Lensed Troffer
F09 or F51 Task

CONTROLS
C01 IR Occ/Vac Sensor

SPACE DESCRIPTION
Vaults are secure spaces used to temporarily store sensitive items, such as weapons and ammunition, non-sensitive items with high value, serial numbered items, or secure telecommunication items. Typically there is an administrative workstation and in some cases a workbench area in each vault.

CONSIDERATIONS
Personnel must be able to identify stored objects and read serial numbers with fine print. Lighting should be provided to light the faces of stored items and the workbench and desk area.

LIGHTING APPROACH
Use high efficacy sources located near/above task surfaces arranged to light critical task surfaces to 40 fc. Do not add additional lighting over circulation areas. Use linear fluorescent strip or wrap luminaires. Select luminaires, lamps, and ballast factor combinations appropriately to provide sufficient illuminance without over-lighting.

CONTROLS
IR occupancy sensors should be used in these areas.

GLOSSARY

ballast factor (BF): The ratio of a lamp's lumen output on a particular ballast to the lamp's rated lumens in the testing environment. Allows for the prediction of actual lamp light output for commercially available lamp-ballast combinations.

brightness: The attribute used to describe perceived luminous flux per unit area. Cannot be measured or quantified.

color rendering index (CRI): A measurement which describes how similar objects' colors appear under a specific light source as compared to a reference source of like color temperature.

daylight zone: An area within a space with enough exposure to daylight that electric lighting may be turned off or dimmed for a portion of the day. For spaces that are primarily sidelighted with daylight, this area extended two times the window height into the spaces.

efficacy: A measure of a lamp's effectiveness in converting electrical energy in to light. Expressed in units of lumens/Watt [lm/W].

energy: The generation or use of electric power over a period of time. Expressed in units of kilowatt-hours.

glare: An unpleasant or disabling visual sensation stimulated by luminances in the field of view that are significantly higher than the adaptation level of the visual system.

illuminance: Measures light incident on a point or surface, defined as luminous flux per unit area incident on a point or surface. Expressed in units of footcandles [fc] or [lm/ft^2] and lux [lm/m^2].

lamp lumen depreciation (LLD): Describes the decrease in lumen output of a lamp during its operable life. Usually expressed as the percentage of initial light output that a lamp emits at 40% of its rated lamp life.

luminaire efficiency: The ratio of lumens that exit a luminaire to the lumens that are emitted by the lamp(s) contained within.

luminance: The magnitude of light energy propagating in a specific direction from an area. Expressed in units of candela/m^2.

luminous flux: The time rate flow of light energy. Used to describe the total light output of lamps. Expressed in units of lumens.

luminous intensity: The magnitude of light energy propagating in a specific direction from a point. Expressed in units of candelas.

power: The amount of work done by an electric current in a unit time. Expressed in Watts or Kilowatts.

rated lamp life: Time, in hours, after which half of a statistically large group of lamps are still in operation, under specific operating conditions.

reflectance: The ratio of luminous flux reflected off of a surface to the incident luminous flux. Usually expressed as a percentage.

COOPER LIGHTING - METALUX®

energy solutions

DESCRIPTION

GC8 is a premium grade specification lensed troffer series. This innovative, high quality luminaire is dedicated to the latest T8 lamp and micro electronic ballast technology for optimal performance and energy efficiency. The GC8 is compatible with all of today's popular ceiling systems and is available with a number of options and accessories for application versatility.

The GC8 Series features efficiency, quality and performance. The series is an excellent choice for commercial office spaces, schools, hospitals or retail merchandising areas.

Catalog #		Type
Project		
Comments		Date
Prepared by		

SPECIFICATION FEATURES

A ··· Construction

Rigid housing is die formed of code gauge prime cold rolled steel and features full length die-formed stiffeners for added strength. Side flanges are hemmed. Innovative design provides superior lens brightness uniformity and visual comfort. Micro ballast cover*** reduces ballst shadow for superior lens brightness uniformity and is easily removed without tools. Die formed captive lampholder brackets fully enclose lampholder wiring permitting easy lampholder replacement. Heavy endplates are securely attached with interlocking tabs and screws. Four auxiliary fixture end suspension points provided. KOs for continuous row wiring. Endplates have integral Grid-lock feature for safety and convenience.

B ··· Electrical

Ballasts are CBM/ETL Class "P" and are positively secured by mounting bolts. Roto-lock lampholders ensure positive lamp retention. UL/CUL listed. Suitable for damp locations.**

C ··· Finish

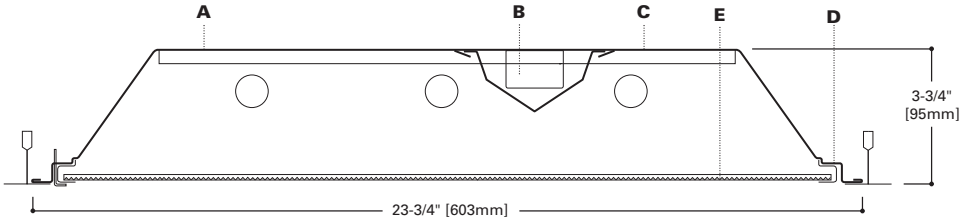
Multistage, iron phosphate pretreatment ensures maximum bonding and rust inhibition. Housing and ballast cover finished with new 90% reflective white enamel for superior performance. "PAF" Painted After Fabrication option also available.

D ··· Hinging/Latching

Positive cam action spring loaded steel latches with baked white enamel finish. Safety-lock T-hinges allow hinging and latching either side.

E ··· Frame/Shielding

Die formed, heavy gauge, flat steel door with reinforced mitered corners and baked white enamel finish. Flat and regressed aluminum doors also available. Positive light seals. Light stabilized 100% virgin acrylic prismatic lens. Standard #12 pattern. Numerous additional shielding options available.



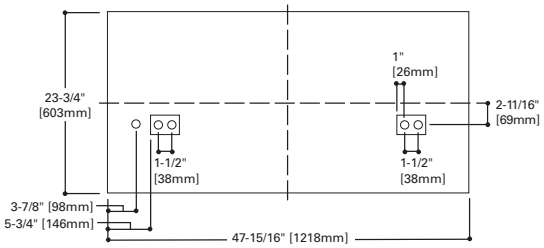
†maximum overall nominal depth

2GC8
328T8
332

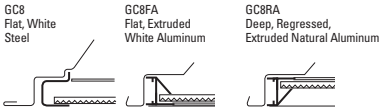
2' X 4' TROFFER
3 T8 LAMPS

Specification T8 Troffer

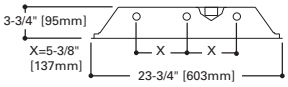
MOUNTING DATA



DOOR FRAMES

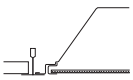


LAMP CONFIGURATIONS

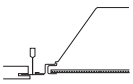


CEILING COMPATIBILITY

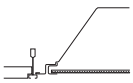
G
Grid/Lay-in
Standard



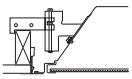
G
Concealed T



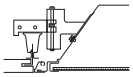
G
Slot Grid



F
Flange Trim
With Supporting
Swing Gates



C
Modular Trim
With Supporting
Swing Gates



Ceiling Type	Trim Type
Exposed Grid	G
Concealed T	G
Slot Grid	G
Flange	F
Metal Pan	C

(Verify compatibility/ consult factory.)

ENERGY DATA

Input Watts:
EB Ballast & STD Lamps
328T8 (67)
332 (91)

Luminaire Efficacy Rating
LER = FL-69
Catalog Number: 2GC8-332A

Yearly Cost of 1000 lumens, 3000 hrs at .08 KWH = $3.46

*Reference the lamp/ballast data in the Technical Section for specific lamp/ballast requirements.

**Consult Pre Sales Technical Support.

***Full sized ballast cover for biaxial lamps and emergency option.

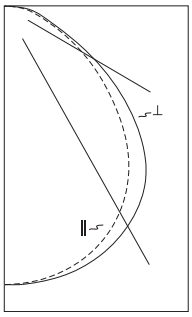
LAMPS CONTAIN MERCURY. DISPOSE ACCORDING TO LOCAL, STATE OR FEDERAL LAWS

LINEAR DISCONNECT
Safe and convenient means of disconnecting power.

ADF031997

COOPER LIGHTING

PHOTOMETRICS



2GC8-332A
Electronic Ballast

(3) F32T8 lamps 2750 lumens per Lamp

Spacing criterion: (II) 1.3 x mounting height, (⊥) 1.4 x mounting height

Efficiency 86.2%

Test Report: 233P137

LER = FL-69

Yearly Cost of 1000 lumens, 3000 hrs at .08 KWH = $3.46

Candela

Angle	Along II	45°	Across
0	2742	2742	2742
5	2726	2734	2743
10	2695	2711	2729
15	2637	2670	2701
20	2556	2606	2649
25	2446	2512	2566
30	2301	2386	2461
35	2123	2221	2327
40	1900	2004	2153
45	1629	1747	1916
50	1339	1484	1623
55	1079	1202	1293
60	840	884	968
65	631	587	693
70	464	369	507
75	338	261	397
80	250	212	305
85	142	131	183
90	23	31	43

Coefficients of Utilization

Effective floor cavity reflectance 20%

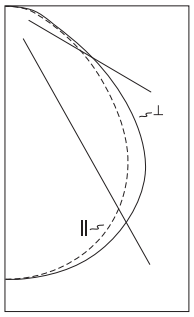
rc	80%				70%				50%			30%			10%			0%
rw	70	50	30	10	70	50	30	10	50	30	10	50	30	10	50	30	10	0
RCR																		
0	103	103	103	103	100	100	100	100	96	96	96	92	92	92	88	88	88	86
1	94	90	87	84	92	88	85	82	85	82	80	81	79	77	78	77	75	73
2	86	80	74	69	84	78	73	68	75	71	67	72	68	65	69	67	64	62
3	79	70	64	58	77	69	63	58	67	61	57	64	60	56	62	58	55	53
4	73	63	56	50	71	62	55	50	60	54	49	58	52	48	56	51	48	46
5	67	56	49	43	65	55	48	43	54	47	43	52	47	42	50	46	42	40
6	62	51	44	38	60	50	43	38	49	42	38	47	42	37	46	41	37	35
7	58	46	39	34	56	46	39	34	44	38	33	43	37	33	42	37	33	31
8	54	42	35	30	52	42	35	30	41	34	30	40	34	30	39	33	30	28
9	50	39	32	27	49	38	32	27	37	31	27	37	31	27	36	31	27	25
10	47	36	29	25	46	35	29	25	35	29	25	34	28	25	33	28	24	23

Zonal Lumen Summary

Zone	Lumens	%Lamp	%Fixture
0-30	2169	26.3	30.5
0-40	3555	43.1	50.0
0-60	5967	72.3	83.9
0-90	7103	86.1	99.9
0-180	7108	86.1	100.0

Luminance Data

Angle in Deg	Average 0-Deg cd/sm	Average 45-Deg cd/sm	Average 90-Deg cd/sm
45	3627	3890	4266
55	2962	3299	3549
65	2351	2187	2582
75	2056	1588	2415
85	2565	2366	3306



2GC8-332A187
Electronic Ballast

(3) FO32/35K lamps 2750 lumens per Lamp

Spacing criterion: (II) 1.3 x mounting height, (⊥) 1.4 x mounting height

Efficiency 70.6%

Test Report: 107P148

LER = FL-57

Yearly Cost of 1000 lumens, 3000 hrs at .08 KWH = $3.46

Candela

Angle	Along II	45°	Across 0
0	2428	2428	2428
5	2412	2423	2435
10	2383	2407	2431
15	2333	2376	2416
20	2260	2331	2392
25	2165	2271	2355
30	2046	2192	2303
35	1903	2083	2226
40	1721	1919	2054
45	1466	1563	1703
50	1135	1040	1245
55	801	747	835
60	533	572	540
65	385	379	388
70	317	285	319
75	265	270	260
80	179	182	181
85	95	96	108
90	0	0	0

Coefficients of Utilization

Effective floor cavity reflectance 20%

rc	80%				70%				50%			30%			10%			0%
rw	70	50	30	10	70	50	30	10	50	30	10	50	30	10	50	30	10	0
RCR																		
0	84	84	84	84	82	82	82	82	78	78	78	75	75	75	72	72	72	71
1	78	75	72	69	76	73	70	68	70	68	66	67	66	64	65	63	62	61
2	71	66	62	58	70	65	61	57	62	59	56	60	57	55	58	56	54	52
3	66	59	54	49	64	58	53	49	56	52	48	54	50	47	52	49	47	45
4	61	53	47	43	59	52	47	42	50	46	42	49	45	41	47	44	41	39
5	56	48	42	37	55	47	41	37	45	41	37	44	40	36	43	39	36	35
6	52	43	37	33	51	43	37	33	41	36	33	40	36	32	39	35	32	31
7	48	39	34	29	47	39	33	29	38	33	29	37	32	29	36	32	29	27
8	45	36	30	26	44	36	30	26	35	30	26	34	29	26	33	29	26	25
9	42	33	28	24	41	33	27	24	32	27	24	31	27	24	31	26	23	22
10	40	31	25	22	39	30	25	22	30	25	22	29	25	21	28	24	21	20

Zonal Lumen Summary

Zone	Lumens	%Lamp	%Fixture
0-30	1947	23.2	32.8
0-40	3239	38.6	54.6
0-60	5145	61.2	86.8
0-90	5928	70.6	100.0
0-180	5928	70.6	100.0

Luminance Data

Angle in Deg	Average 0-Deg cd/sm	Average 45-Deg cd/sm	Average 90-Deg cd/sm
45	3269	3485	3798
55	2202	2054	2296
65	1436	1414	1448
75	1614	1645	1584
85	1719	1737	1954

ORDERING INFORMATION

SAMPLE NUMBER: 2GC8-332A-120V-EB81-U

Rating
Blank=Standard
NY=New York City Rated (20 Gauge Riveted End Plates)

Width
2=**2'** Width

Trim Type
G=Grid/Lay-in (Standard)[1]
G=Concealed T
G=Slot Grid
F=Flange Trim
C=Modular Trim

Series
C8=Specification T8 Troffer

Door Frame
Standard=Flat White Steel Door (Leave Blank)
FA=Flush White Extruded Aluminum c/w Spring Latch
RA=Regressed White Extruded Aluminum
FAN=Flush Natural Anodized Extruded Aluminum
RAN=Regressed Natural Anodized Extruded Aluminum
FAB=Flush Black Extruded Aluminum
RAB=Regressed Black Extruded Aluminum

Number of Lamps[2]
3 Lamps
(Not included)

Wattage (Length)
28T8=28W T8 (48")
32=32W T8 (48")

A=#12 Pattern Acrylic
A125=#12 Pattern Acrylic (.125" Thick)
A19/156=#19 Pattern Acrylic (.156" Thick)
IMA 48=Injection Molded Acrylic (.150" Thick)
PB1S=Silver Parabolic Louver (1/2" x 1/2" x 1/2")
DA=Dropped Dish - Matte White Acrylic (Additional Shielding Media Available. See Accessory Section.)

Voltage[3]
120V=120 Volt
277V=277 Volt
347V=347 Volt
UNV=Universal Voltage 120-277[4]

Options
GL=Single Element Fuse
GM=Double Element Fuse
Lamps=Lamps Installed
Flex=Flex Installed
EL=Emergency Installed

Options
PAF=Painted After Fabrication
MEP=Modified End Plate/ For End Filler Applications
(See options & accessories)

Packaging
U=Unit Pack
PAL=Job Pack, out of carton
PALC=Job Pack, in carton

Ballast Type[3]
EB8_=T8 Electronic Instant Start. Total Harmonic Distortion < 10%
No. of Ballast 1, 2 or 3
EB8_/PLUS=T8 Electronic Instant Start. High Ballast Factor >1.13. Total Harmonic Distortion < 10%
No. of Ballast 1, 2 or 3
ER8_=T8 Electronic Program Rapid Start. Total Harmonic Distortion < 10%
No. of Ballast 1, 2 or 3
ER8_/PLUS=T8 Electronic Program Start. High Ballast Factor >1.13. Total Harmonic Distortion < 10%
No. of Ballast 1, 2 or 3

HPT8 Ballast
HB8_L=T8 Electronic Instant Start. Low Ballast Factor .77
HB8_=T8 Electronic Instant Start. Ballast Factor .88
HB8_N=T8 Electronic Instant Start. Normal Ballast Factor 1.0
HB8_H=T8 Electronic Instant Start. High Ballast Factor 1.15-1.2
HR8_DIM=T8 Electronic Program Start Step Dimming. Ballast Factor .88
HR8_L=T8 Electronic Program Start. Low Ballast Factor .77
HR8_=T8 Electronic Program Start. Ballast Factor .88
HR8_H=T8 Electronic Program Start. High Ballast Factor 1.15-1.2

ACCESSORIES

EQ-CLIP-U=T-BAR Safety Earthquake Clips[1]

SHIPPING INFORMATION

Catalog No.	Wt.
2GC8-328T8A	31 lbs.
2GC8-332A	31 lbs.

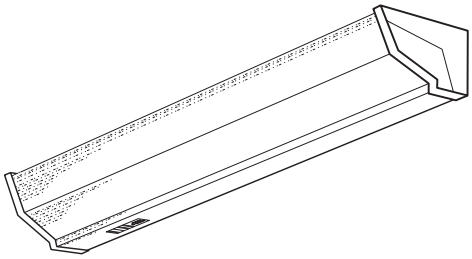
NOTES: [1]An EQ Grid Clip is recommended for all 9/16" ceiling systems. [2]Standard off-center ballast compartment on 3-lamp fixtures. [3]Products also available in non-US voltages and frequencies for international markets. [4]Not available when specifying emergencies, voltage must be specific.

Specifications & dimensions subject to change without notice. Consult your Cooper Lighting Representative for availability and ordering information.

Columbia
LIGHTING

SA2-1, SA3-1, SA4-1

2', 3', or 4' Wall Mount Light / 1-Lamp T8



PROJECT INFORMATION

Project Name _____ **Type** _____

Catalog No. _____ **Date** _____

FEATURES

- Designed for uplight, downlight and frontlight
- One piece shielding assembly easily removable for cleaning
- No hardware
- Heavy gauge steel housing
- Rotary lock lampholders for positive lamp contact
- A grounded convenience outlet and an on/off push-button switch are standard equipment (120V fixtures only)
- An optional pull chain switch is available

BALLASTS
Energy efficient ballasts are thermally protected, automatic resetting. Class P, sound rated A, UL listed. 20 watt ballasts are Trigger Start, Class P, UL listed.

FINISH
White painted parts are treated with a five stage phosphate bonding process and finished after fabrication with a minimum 90% reflective gloss baked enamel.

SHIELDING
A one piece clear prismatic acrylic diffuser with white injection molded ends solvent welded to form a rigid enclosure. Removes easily from the front with no hardware.

CERTIFICATION
All luminaires are built to UL 1598 standards and bear appropriate UL and cUL or CSA labels. Damp location labeling is standard. Emergency-equipped fixtures labeled UL 924.

ORDERING INFORMATION

EXAMPLE SA4-132-E120-PAF

SA – **1** – **E** –

MODEL	SIZE	NO. OF LAMPS	LAMP TYPE	BALLAST	VOLTAGE	OPTIONS
SA Wall Mount Light	**2** 2'	**1** One	**17** 2', T8: 17 Watt	**E** Electronic Instant Start (Std.)	**120** 120V	**GLR** Fast Blow Fuse
	3 3'		**25** 3', T8: 25 Watt		**277** 277V	**EL** Emergency Battery Pack
	4 4'		**32** 4', T8: 32 Watt		**347** 347V	**PAF** Paint After Fabrication
						LSW Less Switch
						LCO Less Grounded Convenience Outlet
						OFP Low Brightness Opal Front Panel
						PSW Pull Chain Switch (120V only)

Note: SA fixture includes push-button switch (120V only).

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701 Millennium Blvd. Greenville, SC 29607 / Tel **864.678.1000** / Tech Support **864.678.1668** / Website **www.columbialighting.com**

Hubbell Lighting, Inc.

PHOTOMETRIC DATA

Test **8969** Test Date **1/8/03**

LUMINAIRE DATA

Luminaire	**SA4-140-LE** **SA/SAM Surface Mounted 4' Single Lamp Wraparound Wall Mount Luminaire**
Ballast	**412-L-SLH-TC-P**
Ballast Factor	**0.95**
Lamp	**F40CW**
Lumens per Lamp	**3150**
Watts	**45**
Shielding Angle	**N/A**
Spacing Criterion	**0° = N/A 90° = N/A**
Luminous Opening in Feet	**Length: 4.00** **Width: 0.33** **Height: 0.00**

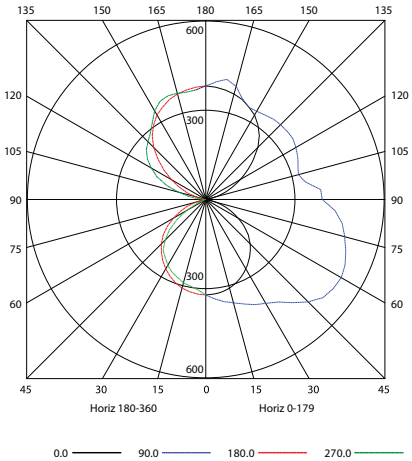
ZONAL LUMEN SUMMARY

Zone	Lumens	Lamp	Fixt.
0-30	262	8.3	9.8
0-40	444	14.1	16.6
0-60	874	27.8	32.7
0-90	1339	42.5	50.0
90-120	421	13.4	15.7
90-130	628	19.9	23.5
90-150	1036	32.9	38.7
90-180	1339	42.5	50.0
0-180	2678	85.0	100.0

ENERGY DATA

Total Luminaire Efficiency	**85.0%**
Luminaire Efficacy Rating (LER)	**57**
IESNA RP-1-1993 Compliance	**Non-Compliant**
Comparative Yearly Lighting Energy Cost per 1000 Lumens	**$4.21 based on 3000 hrs. and $0.08 per KWH**

INDOOR CANDELA PLOT



AVG. LUMINANCE (Candela/Sq. M.)

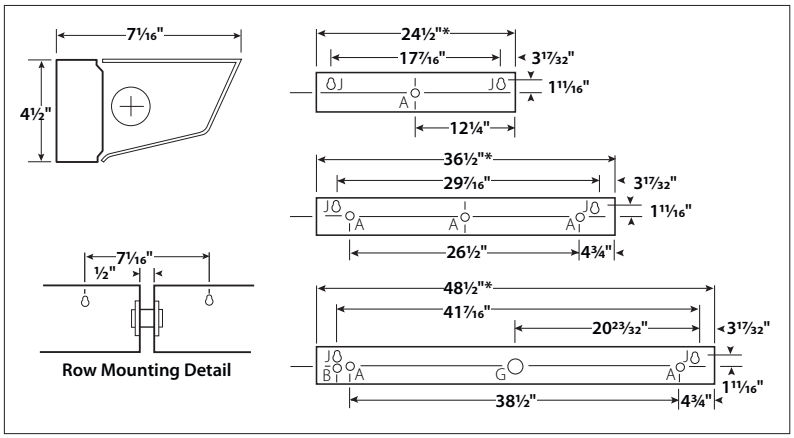
Average Luminance Angle	0.0	90.0	180.0	270.0	360.0
0	2618	2618	2618	2618	2618
30	2533	3795	2533	2410	2533
40	2470	4822	2470	2374	2470
45	2433	5616	2433	2226	2433
50	2372	6521	2372	2030	2372
55	2246	7435	2246	1692	2246
60	2055	8579	2055	1207	2055
65	1814	9976	1814	617	1814
70	1550	11945	1550	238	1550
75	1071	15249	1071	95	1071
80	704	21884	704	141	704
85	374	40888	374	187	374

COEFFICIENTS OF UTILIZATION (%)

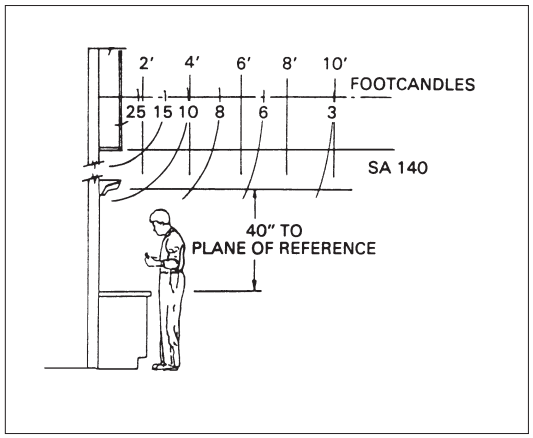
RCR	RC	80				70				50			0
	RW	70	50	30	10	70	50	30	10	50	30	10	0
	1	81	77	73	69	75	71	67	64	60	57	55	32
	2	73	66	60	55	67	61	56	51	51	47	44	26
	3	66	58	51	45	61	53	47	42	44	40	36	21
	4	61	51	43	38	55	47	40	35	39	34	30	17
	5	55	45	37	32	51	41	35	30	35	30	26	15
	6	51	40	33	27	46	37	30	25	31	26	22	13
	7	47	36	29	24	43	33	27	22	28	23	19	11
	8	43	32	25	21	40	30	24	19	25	20	17	10
	9	40	29	23	18	37	27	21	17	23	18	15	9
	10	38	27	20	16	34	25	19	15	21	17	13	8

RCR = Room Cavity Ratio
RC = Effective Ceiling Cavity Reflectance **RW** = Wall Reflectance

DIMENSIONAL DATA



FOOTCANDLES



NOTE: All dimensions are in inches; dimensions and specifications are subject to change without notice. Please consult factory or check sample for verification.

*Overall fixture length with shielding installed.

A: ⅞" Diameter Knockout
B: .570" × .656" Strain Relief Knockout
G: 3¼" Diameter Knockout
J: ½" Diameter × 13/16" Long Keyslot—dimension is to center line of mounting screw.

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Hubbell Lighting, Inc.

FINELITE

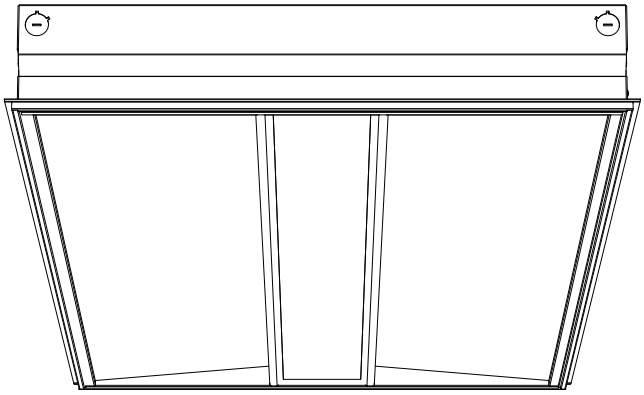
High Performance Recessed (HPR) 2x4

Project_____

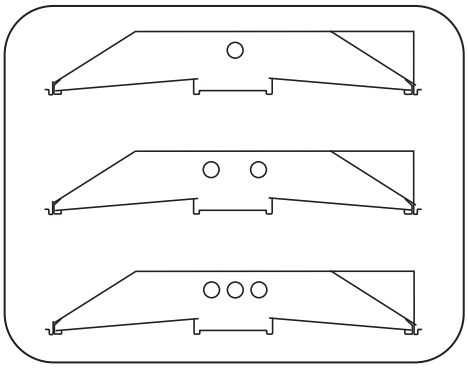
Firm Name_____

Date_____ Type_____

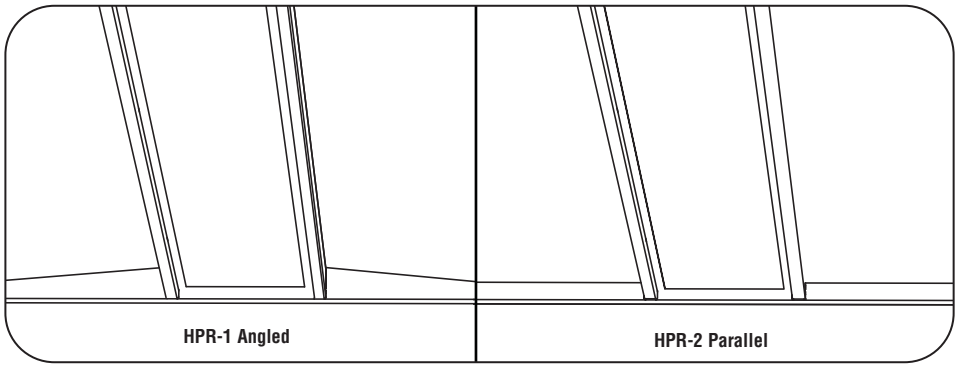
HPR is a highly effective recessed luminaire delivering excellent visual comfort and outstanding performance for offices, schools, healthcare, and retail applications. Advanced optical designs make HPR a powerful solution for low-ceiling applications and eliminate the shadows common to other recessed products.



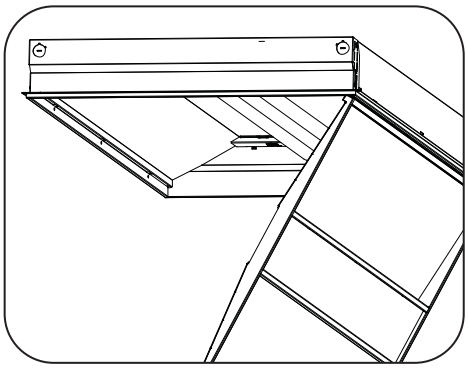
FEATURES



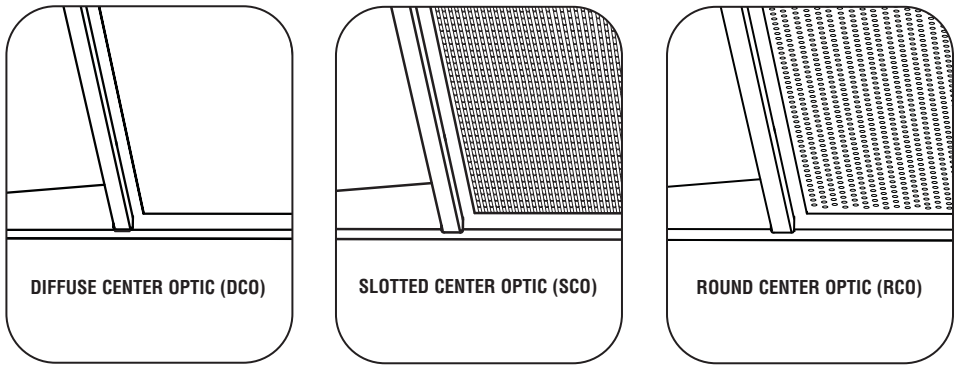
LAMP OPTIONS:
Available in 1, 2, or 3 T8, T5, or T5HO lamp cross sections.



LUMINAIRE STYLES:
HPR-1 features lenses angled toward the center-shielding element. HPR-2 features lenses parallel to the ceiling plane.



HINGED DOOR ASSEMBLY:
The hinged door assembly makes relamping and maintenance fast and easy.



CENTER SHIELDING OPTIONS:
HPR is available with three different center-shielding options: a diffuse center optic, a slotted center optic, and a round center optic.

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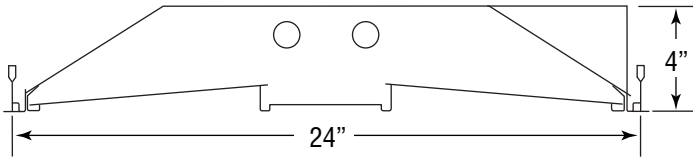
FINELITE

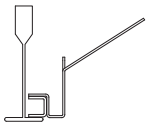
High Performance Recessed (HPR) 2x4

DIMENSIONS

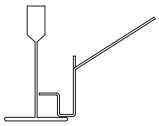


CEILING SYSTEM INFORMATION

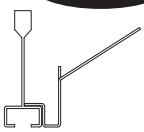
IC - RATED



9/16” T-Bar

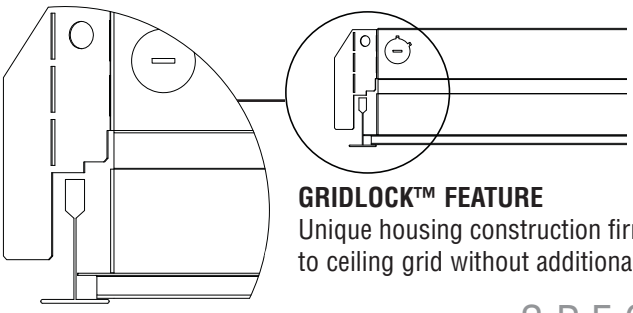


15/16” T-Bar

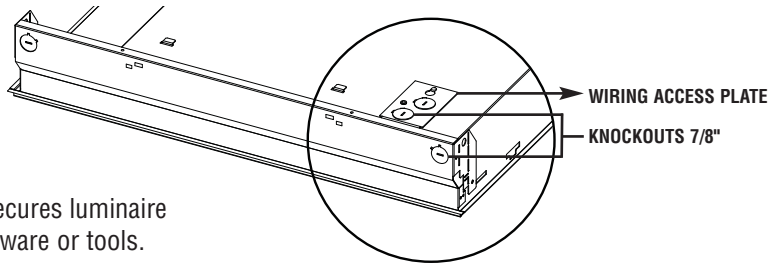


Screw Slot T-Bar

CEILING SYSTEMS DETAIL



WIRING ACCESS DETAIL



GRIDLOCK™ FEATURE
Unique housing construction firmly secures luminaire to ceiling grid without additional hardware or tools.

SPECIFICATIONS

CONSTRUCTION:
Fixture assembly constructed using die-formed 20-gauge cold-rolled steel housing and ends. All components are hard-tooled to tolerances of 0.010". Ballast compartment is accessible from below. Optical system retained using hinged door frame assembly to provide easy access to ballast compartment and for re-lamping from below without the need of tools. Seismic brackets are integrated into the fixture assembly. Additional wire entrances are positioned on the ends of the housing to allow easy wiring access for the installer.

REFLECTORS:
Die-formed 20-gauge cold-rolled steel reflectors are finished in 96 LG high reflectance matte white powder coat paint.

OPTICAL SYSTEM:
Optical system components include side lens panels and a center optic element held in place with a frame constructed from die-formed cold-rolled steel. The side lenses are UV-stabilized and impact-resistant frosted virgin acrylic, 0.080” thick. They are either angled toward the center optic or parallel to the ceiling plane.

Available options for the center optic elements:

Diffuse Center Optic: UV-stabilized and impact-resistant frosted virgin acrylic. Optional Soft Glow Optic (SGO) available for T8 only.

Slotted Center Optic: Die-formed cold-rolled steel panel with 1/16" x 1/2" rectangular hole pattern. Virgin acrylic overlay.

Round Center Optic: Die-formed cold-rolled steel panel with precision-punched 3/32” round hole pattern arranged in staggered formation. Virgin acrylic overlay.

LAMPING:
Available in 1, 2, or 3 T8, T5, or T5HO lamp cross sections.

BALLAST:
UL listed Class P. Electronic instant-start ballast <10% THD, 0.88 BF standard for T8 lamps. Electronic program-start ballasts <10% THD, 1.0 BF standard for T5/T5HO lamps. Contact factory for available BF’s. Optional adders: program-start ballasts (standard for T5/T5HO), 347V, emergency battery packs, dimming or bi-level ballasts (controls by others).

ELECTRICAL:
Fixtures and electrical components are ETL listed conforming to UL1598 in the USA, and Canada and ETL listed certified to CAN/CSA C22.2 No. 250.0. In accordance with NEC code 410.73 (G) this luminaire contains an internal ballast disconnect. IC-Rated for all lamping except 3 T5HO. Optional Chicago Plenum available. Contact factory.

Daylight Sensor Occupancy Sensor

ON-BOARD CONTROLS:
Refer to Occupancy Sensor and Daylight Sensor tech sheets for more info.

MOUNTING:
Standard flange design works with most lay-in ceiling types. Integral pryout tabs secure luminaire to ceiling grid from above. Fixture offers tie-in locations for tie-wire on all corners. Consult local code for appropriate tie-wire recommendations. Drywall Kit available. Surface mount version available; refer to separate tech sheet.

AIR RETURN:
Refer to the 2x4, or 2x2 Air Return tech sheets for more information.

FEED:
18-gauge wire standard.

FINISH:
Housing and door assembly painted with 96 LG high reflectance matte white powder coat paint. Available in matte white only.

WIRING:
Master / Satellite wiring available. Contact factory for configuration options. Optional whips (with flex connectors) supplied in a max. of 11’ lengths.

WEIGHT:
Maximum weight: 2x4 - 33 lbs.

ORDERING GUIDE

HPR - 2 - 2X4 - DCO - 1 T8 - 277 - SC - C1 - IS.88 - OBO

Finelite Series **HPR**
Luminaire Styles (1-Angled, 2-Parallel)
Size (2x4)
Center Optic (DCO-Diffuse, SCO-Slotted, RCO-Round)
Lamp Type (1, 2 or 3 T8, T5 or T5HO)
Voltage (120, 277, 347V)
Circuiting (SC-Single Circuit, DC-Dual Circuit, SD-Step Dimming)
Mounting (C1-1" T-Bar, C2-9/16" T-Bar, C3-Screw Slot, DW-Drywall Kit, SM-Surface Mount)
Ballast (IS-Instant Start, PS-Program Start, BL-Bi-level, DI-Dimming, and specify BF*)
On-Board Controls (OBD-Daylight, OBO-Occupancy, OBB-Both)

** Standard 0.88 for T8 lamps, 1.0 for T5 or T5HO. Contact factory for available BF’s*
Contact factory for Master/Satellite and factory-supplied whip options.

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FINELITE

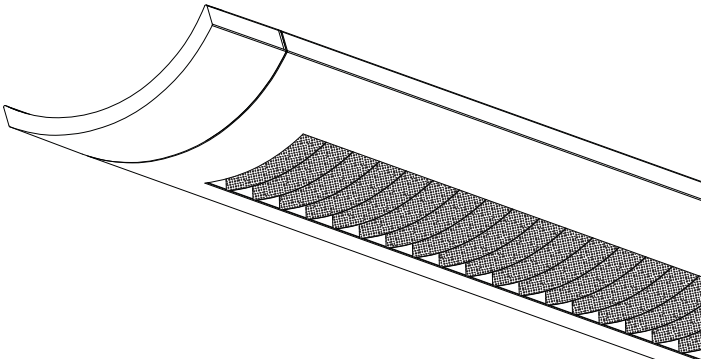
Series 12-ID Technical Sheet

Project _____

Firm Name _____

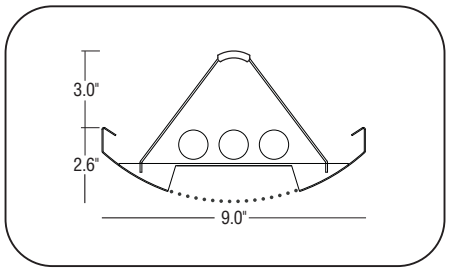
Date _____ Type _____

Series 12-ID is an indirect/direct luminaire with downlight shielding and optical choices that extends the Series 12 family to new levels of light distribution. Series 12-ID uses sophisticated designs and manufacturing techniques to produce a product that is as affordable as it is beautiful. Available in 1, 2, or 3 T8, T5 or T5HO lamps in 4' and 8' lengths. Choose from White Cross Blade perforated baffle or semi-specular Parabolic Louver, and 3 choices to control downlight distribution. Available with standard flat or optional curved die-cast endcaps. Companion wall mount also available.

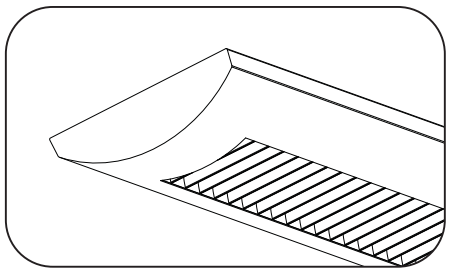


Series 12-ID with WCB white cross blade and optional die-cast curved endcap.

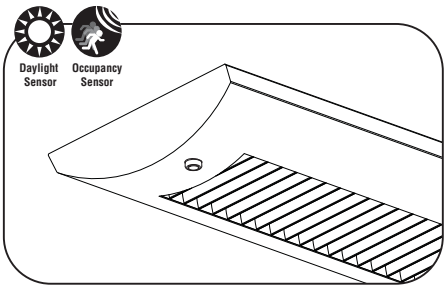
FEATURES



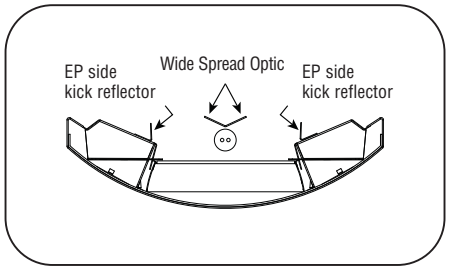
LAMPING
Available in 1, 2 or 3 T8, T5 or T5HO lamp cross sections.



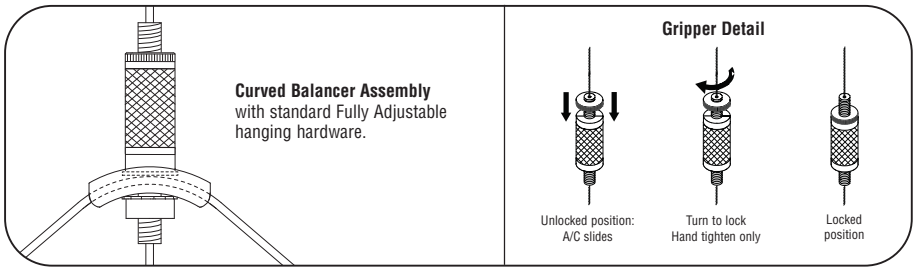
SHIELDING
Optional semi-specular Parabolic Louver PLV shielding. Shown here with the standard flat endcap.



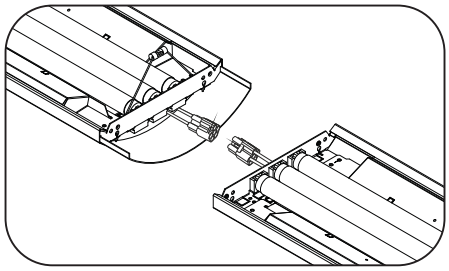
INTEGRATED SENSORS
Series 12-ID can be specified with integrated daylight or occupancy sensors.



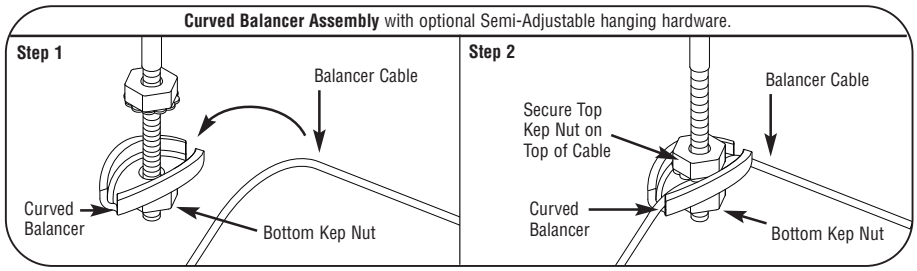
WSO-WIDE SPREAD OPTICS
Special wide spread reflector gives extended distribution and is especially effective in low ceiling areas.



STANDARD FIXTURE SUPPORT
The Curved Balancer improves the strength of the hardware connection and improves installation. The balancer arrives attached to the fully adjustable hanging hardware. Simply adjust the bottom nut to the desired height, secure it to the balancer cable, adjust the side-to-side level, and secure the top nut. Install safety stop into fixture body.



PLUG-TOGETHER WIRING
Standard plug-together wiring and die-formed aligner plate come factory installed for smooth joints with no light leaks.



OPTIONAL SEMI-ADJUSTABLE CABLE SUPPORT
Optional Semi-Adjustable aircraft cable, (AC) ± 0.5" in lengths of 12", 15", 18", 21", 24", 27", 30", 36". Aircraft cable assembly screws into the balancer. Attach Curved Balancer in the same way as Fully Adjustable assembly.

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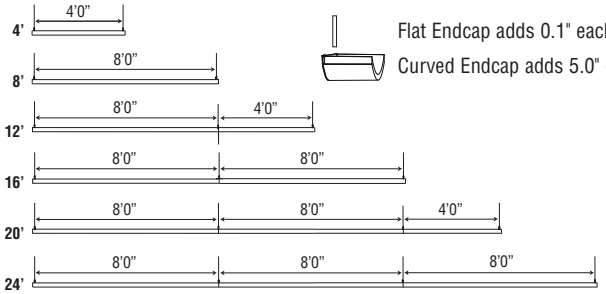
FINELITE

Series 12-ID Technical Sheet

Series 12-ID is available in the lengths shown below.



Flat Endcap adds 0.1" each end.

Curved Endcap adds 5.0" each end.

Modular section lengths offer standard 4'0" and 8'0" support spacing that aligns with grid ceiling systems.

Additional 4' or 8' segments can be added to create runs as long as required.

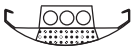
CONTROLLED CENTER OPTICS

Controlled Center Optics (CCO) covers the center lamp—100% direct. Use dual switching for bi-directional control. Turn side lamps off for tightly controlled centered downlight, or turn side lamps on and center off for indirect/direct. Especially suitable for classrooms and energy conscious areas.

SOFT TOP OPTICS

Soft Top Optics (STO) diffuses and softens the uplight with a perforated covering above the lamps. STO is helpful in applications where less light is desired on the ceiling and more direct downlight is needed.

TOTALLY DIRECT OPTICS



With Totally Direct Optics (TDO), a covering over the lamps makes all the light reflect downward for a 100% direct fixture.

SPECIFICATIONS

CONSTRUCTION: Body is 20-gauge die-formed steel with 18-gauge die-formed internal joiner system, plug-together wiring standard. All components are hard-tooled to tolerances of 0.010".

ENDCAPS: (FE) Flat Endcap standard, 20-gauge die-formed steel, adds 0.1" at each end.

Optional: (CE) Curved Endcap, aluminum die-cast endcap with 0.100" reveal, adds 5.0" at each end.

REFLECTORS: Standard (91W) 91 White: Die-formed pre-painted aluminum, 91% reflective white. Virgin acrylic-UV-stabilized lens diffuser over perforations is standard. Optional Extended Performance (EP) reflector system for T5HO. (WSO) Wide Spread Optic system for 1 T5HO.

UPLIGHT OPTICAL OPTIONS:

Open	No optical control.
CCO	Controlled Center Optics, covers center lamp, 100% downlight (center only).
STO	Soft Top Optic, perforations cover the surface.
TDO	Totally Direct Optic, solid top above lamps.

DOWNLIGHT SHIELDING OPTIONS:

WCB	White Cross Blade baffle, white cross blades with straight edges spaced approximately 1" apart.
PLV	Parabolic Louver, semi-specular louvers with straight edges, spaced approximately 1" apart.

ACCESSORY: Optional Dust Cover, clear acrylic, T8 lamps only. NOTE: Will significantly impact light level performance. Contact Factory.

ELECTRICAL: 120 or 277V prewired. Fixture and electrical components are UL/C-UL listed and fixture will bear UL/C-UL labels. Optional Adders: Low profile 347V ballast, prewired dual circuit, emergency circuits, low profile emergency battery packs. Contact factory.

INTEGRATED SENSORS: Series 12-ID can be specified with integrated sensors from Wattstopper, Philips, and Lutron. **Daylight Sensors:** Wattstopper sensors can be supplied with either a closed loop 0-10v dimming (handheld remote supplied) or closed loop single zone switching system. The Lutron sensor is directional and for use with Ecosystem ballasts. The Philips sensor is a closed loop 0-10v sensor for use with Advance Mark 7 ballasts. **Occupancy Sensor:** Wattstopper occupancy sensor is a PIR sensor with additional hold-off daylight feature.

LAMPING: Available in 1, 2 or 3 T8, T5 or T5HO lamp cross sections.

BALLAST: Electronic instant-start ballast <10% THD, .88 BF standard for T8 lamps. Electronic rapid-start ballasts <10% THD, 1.0 BF standard for T5/T5HO lamps. Optional adders: rapid-start ballasts (standard for T5/T5HO), 347V, emergency battery packs, dimming ballasts (controls by others). Requires low-profile ballasts and battery packs. Contact factory for multiple ballast factors in one luminaire.

MOUNTING OPTIONS: Standard (FA) fully adjustable aircraft cable with safety stop in lengths up to 150". Mounting connects to fixture with factory-installed Level and Lock Assembly™, which allows side-to-side fixture leveling and locks into place. NOTE: Curved balancer assembly is 3" above top of fixture. Optional (AC) semi-adjustable aircraft cable (± 0.5") in lengths of 12", 15", 18", 21", 24", 27", 30", and 36".

Optional: (AC) Semi-adjustable aircraft cable (± 0.5) in lengths of 12 , 15 , 18 , 21 , 24 , 27 , 30 , 36 .

SUPPORT CABLES: Plated steel cable and hardware.

FEED: 18 gauge straight cord. 14 gauge feed cord used when fixture current exceeds 6 amps. Optional Adders: Coil Cord Feed.

FINISHES: Finelite Signal White standard. Optional Adders: 185 colors available from Tiger Drylac's RAL color chart.

LENGTHS: 4' and 8' section lengths can be combined to make longer runs. Contact factory for additional lengths.

WEIGHT: Fixture weight = 2.6 to 3.6 lb/ft. with curved endcaps. Fixture weight 2.0 lb/ft. with flat endcaps.

WALL MOUNT: Complementary wall mount available.

ORDERING GUIDE **S12-ID - WCB - 32' - 2T8 - SC - 91W - OPEN - 277 - FA - FE - C1 - .88 - OBO**

Finelite **Series 12-ID (Indirect/Direct)**
Shielding (WCB, PLV)
Run length (4', 8' multiples standard)
Number of lamps in cross section (1, 2, 3, T8, T5 or T5HO)
Circuiting (SC-single circuit, DC-dual circuit, CRD-center row dimming)
Reflector system (91W, EP, WSO)
Uplight optical options (Open, CCO, STO, TDO)
Voltage (120, 277, 347V)
Mounting (AC/FA)
Endcap FE (flat), CE (curved)
Ceiling type (C1-1" T-bar, C2-9/16" T-bar, C3-Slot Grid, C4-Hard Ceiling)
Ballast factor (Standard .88 for T8 lamps, 1.0 for T5 or T5HO)
Integrated Sensors / On-Board Controls (OBD-Daylight, OBO-Occupancy, OBB-Both)

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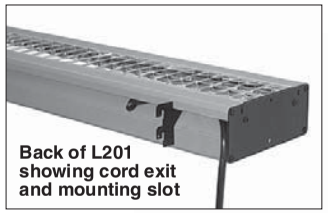
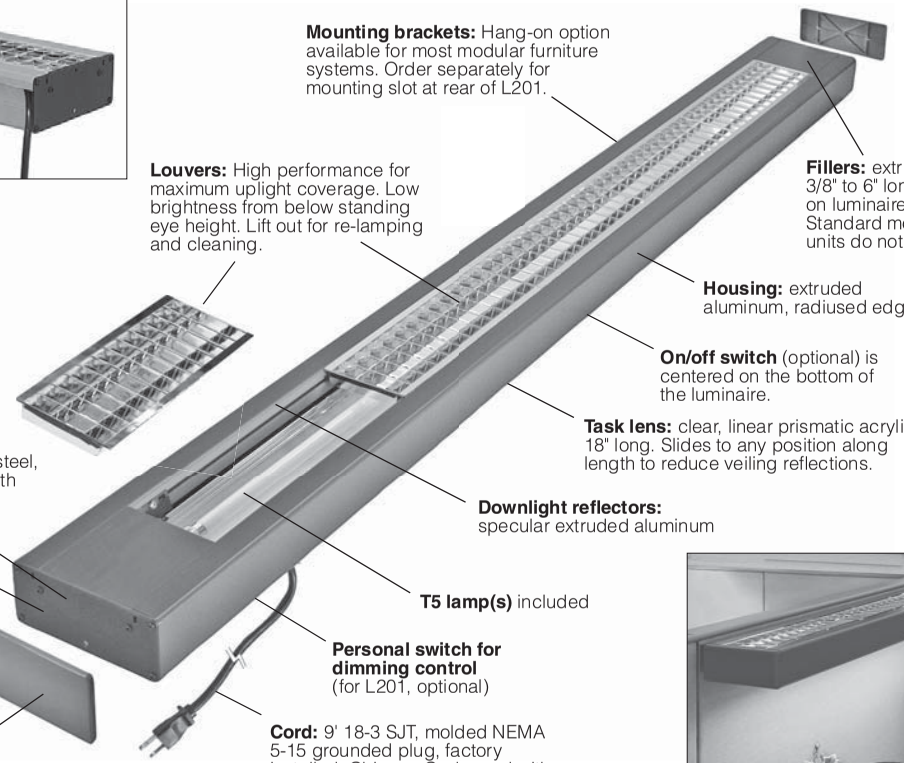
Task Ambient, Linear T5 Lamp

T5 Fluorescent

Styles L201, L202



Back of L201 showing cord exit and mounting slot



Features

- *Task and ambient lighting from a single T5 lamp*
- *Typical energy consumption is 0.6 W/sf or less*
- *Integrates with embedded wireless controls (consult factory)*
- *Low profile; integrates with open plan office furniture systems*
- *Portable; may be reconfigured along with the furniture*
- *Reduces glare, eyestrain and visual distraction*

TA 1.0

Specifications

Finish:

Painted housing, fillers, decorative end plates, and mounting accessories (panel hooks, end mount rails, stanchions).

Painted surfaces – environmentally friendly 6-stage pretreatment and electrostatically applied thermoset powder coat provides a long lasting, scratch resistant finish. Choice of standard colors. RAL and computer matched colors available on request.

Reflector – extruded aluminum, chemically brightened and clear anodized.

Louver tiles – specular vacuum metalized polycarbonate with clear polymer topcoat for easy cleaning.

Mounting:

L201 has a continuous mounting slot along the rear of the unit, and can be mounted to a wall, furniture panel, or desk clamp stanchion. L201 cords are routed along the mounting slot and can be specified for right- or left-hand exit.

L202 has a smooth back surface for mounting with end mount rails (for 24" wide end panels) or with desk clamp stanchions. L202 cord exits are specified left or right, rear or bottom of unit, depending on mounting method. Stanchions feature a cord management slot.

Electrical:

Integral electronic ballast is HPF thermally protected class P, 120 volt. BF > 0.98. Programmed start maximizes lamp life and minimizes energy use.

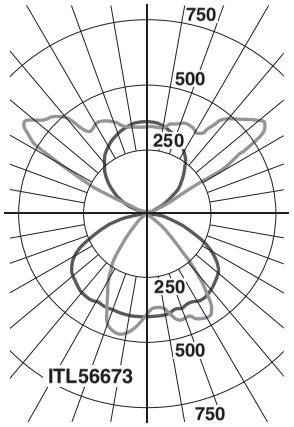
Cord – 9' 18-3 SJT, molded NEMA 5-15 grounded plug, factory installed. Chicago Code cord with integral circuit breaker available. Low profile grounded plug with 45° rotation is standard. Black is standard; gray and beige cords are available at additional cost.

Standard output T5 lamps are included. Choose from 3000K, 3500K and 4100K lamps.

Standard:

UL listed or CSA certified.

Performance



Lighter curve at left shows 180° to 0°. Darker curve shows 90° to 270°.

High lamp height position, see website for alternate positions. Illuminance based on a minimum of ten workstations. Light levels will be 5-10% greater in large rooms with more workstations. Ballast factor 0.98, input watts 52, maximum candlepower at 140° is 629 cd.

*For complete photometrics, see **thelightingquotient.com**.*

tambient
Green in any color™

To Order

Styles L201, L202

Project: _____ Type: _____

Sample number: L201-71S6-M-EL15-1-1R-0S-35

L	2	0		–		–		–		–				–		–	
Style				Length/Lamp(s) Code		Optic		Finish		Electrical	Cord	Cord Exit		Options		Lamp Color	

Style

L201 Task ambient luminaire with integral hang-on mounting channel

L202 Task ambient luminaire with smooth back panel

Length/Lamps

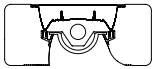
Code	Length (mm)	Lamp(s)	Input
24S2	24" (610)	1xF14T5	14W
36S3	35-3/4" (910)	1xF21T5	27W
48S4	47-1/2" (1205)	1xF28T5	33W
60S5	59" (1500)	1xF35T5	41W
71S6	70-3/4" (1800)	2xF21T5	49W
83S7	82-1/2" (2095)	1xF21T5 + 1xF28T5	60W
95S8	94-1/4" (2395)	2xF28T5	66W

Other lengths and lamping are available; consult factory.

TA 1.1

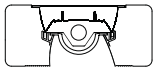
Optic

L Low-mount (L202 shown)



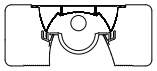
For low-mount IES information, consult factory.

M Mid-mount (L202 shown)



Download IES file.

H High-mount (L202 shown)



Download IES file.

Mounting Height	Worksurface Depth	
	24"	30"
48" – 50"	Low	Low
51" – 52"	Mid	Low
53" – 57"	Mid	Mid
58" – 61"	High	Mid
62" – 63"	High/(1)	High
64" – 66"	(1)	High

(1) Consult factory. Notation for height 62" – 63" is for L202.

To avoid glare, do not install below 48" or above 66".

Finish

EL02 Eggshell white
EL06 Dark bronze
EL07 Silver
EL08 Semi-gloss black
EL12 British racing green
EL15 Warm metallic
TASL Semi-gloss slate
XXXX Custom color (specify or submit sample)
or 4-digit RAL color code (color chart available)

Electrical

120 V only

1 Electronic ballast

T Dimming ballast for personal dimming control option (L201 only, specify with option **0D**). For other dimming applications, consult factory.

Cord

90° SW rotation plug, 9 feet:

1 Black
3 Gray
5 Beige
7 Chicago cord, integral circuit breaker, black

Straight plug, 9 feet (L202 only):

2 Black
4 Gray
6 Beige
8 Chicago cord, integral circuit breaker, black

Cord Exit

R Right rear (L201, L202)
L Left rear (L201, L202)
E Right bottom (L202 only)
W Left bottom (L202 only)

For L202, **R** and **L** are on dual stanchion only. **E** and **W** exits (L202) are 1-1/2" from end of luminaire.

Options

00 None
0S On/off switch
0D Dimming switch (L201, for use with dimming ballast only)
X0 Dual stanchion pre-drill (L202)
XS Dual stanchion pre-drill and integral on/off switch (L202)
XX Custom modification (specify)

Lamp Color

30 3000K, 85 CRI
35 3500K, 85 CRI
41 4100K, 85 CRI

Mounting Accessories

*For compatible furniture systems, see website.

TPH Panel Hooks, pair (L201)
TPR End Mount Rail Kit (L202)

T	P				–	
			System*			Finish (at left)

TPH Panel Hooks mount to slotted panel frame. Stamped and formed CRS, pair. **TPR End Mount Rails** (for 24" wide end panels) mount to slotted panel frames. Several models are available to interface with a variety of panel systems. Pair of rails, includes pair of black interface plates.

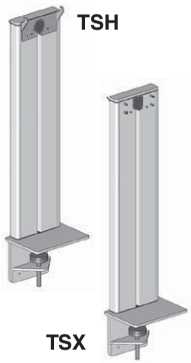
TPE End Mount Brackets, pair (P202)

Support the ends of the luminaire, black, pair.

TMHDW Wall Brackets, pair (L201)

T	M	H	D	W	–	E	L	0	0

TMHDW Wall Brackets mount to stud framed walls, millwork, and other solid surfaces. Stamped and formed CRS, black, pair.



TSH Desk Clamp Stanchion (L201)
TSX Desk Clamp Stanchion (L202)

T	S				–	
			Height			Finish (at left)

Desk Clamp Stanchions mount to edge of worksurface – 1/2" to 3-1/4" thick. Extruded aluminum post. Resilient pads resist slippage, protect surfaces. Integral cord management. **TSH19-/TSX19-** places top of luminaire 19-1/2" above worksurface. Sold individually; some luminaires require two stanchions.

L202 with TSX stanchion, back view

tambient
Green in any color™

tambient *from* **The Lighting Quotient**
114 Boston Post Road, West Haven, Connecticut 06516, USA
Voice 203.931.4455 • Fax 203.931.4464 • **thelightingquotient.com**

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DESCRIPTION

Parabolic Baffle and/or Bold Baffle Series 76 are staggered lamp perimeter lighting systems providing a shadowless wall wash configuration of uninterrupted light. The lighting is continuous and unbroken, utilizing one or two lamp staggered. Runs and patterns are field adjusted. There are no blank filler sections, visible joints, mullions, or hardware. The floating wall angle and ceiling trim with heavy extruded aluminum, rigid, straight and true with a 3/8" regress soft lit edge.

Features: PentaFlex (TM) reflector system, continuous and seamless up to 40'.

Catalog #		Type
Project		
Comments		Date
Prepared by		

SPECIFICATION FEATURES

A ... Construction
20-gauge steel housing.

B ... Shielding
White bold baffle. Semi-specular aluminum parabolic baffle.

C ... Electrical
120, 277, 347 or Universal Voltage electronic ballast. Fixtures and electrical components certified to UL and CUL standards.

Mounting
Recessed.

D ... Finish
Durable, low gloss, white, powder coated acrylic finish.

E ... Staggered Lamps
T8=3", T5=6"

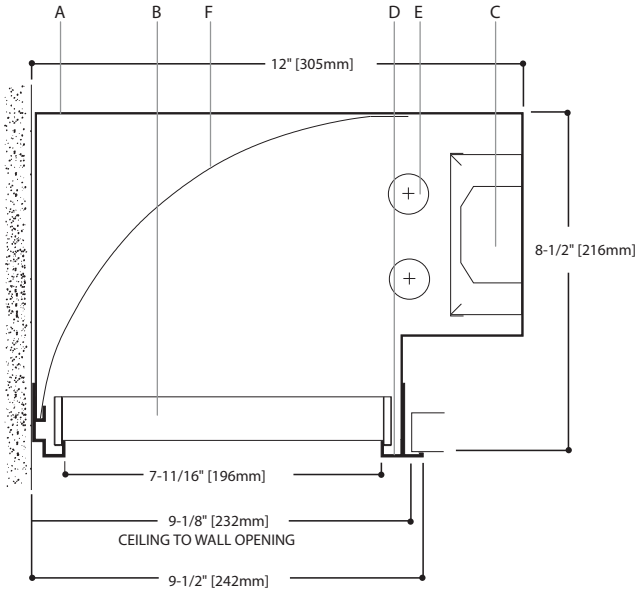
F ... Reflector
Pentaflex(TM) continuous white reflector is seamless up to 40'.

Series 76PF with PentaFlex

1 & 2T8
1 & 2T5
1 & 2T5HO

Perimeter
Recessed Direct
Wall Wash

Light Distribution:
Indirect - 0.0%
Direct - 100.0%



ORDERING INFORMATION

Sample Number: S76PF-1T8-30-1EB-SI-S72

Series
76PF= Perimeter with Pentaflex

Number of Lamps
1= 1 Lamp
2= 2 Lamps

Lamp Type
T8= T8
T5= T5
T5HO= T5HO

Run Length
Overall Nominal Run Length __ ft.

Voltage [1]
1= 120V
2= 277V
3= 347V

Ballast
EB= Electronic Ballast
DB= Dimming Ballast

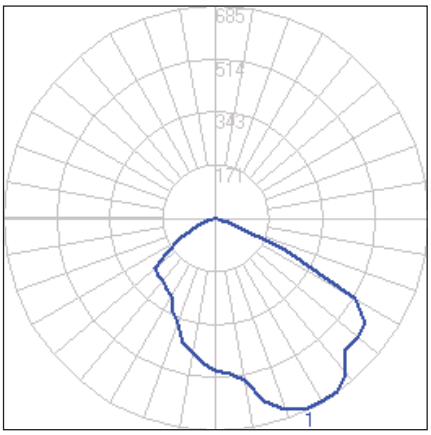
Switching Options
SI= Single Switching
DU= Double Switching

Emergency
EM= Emergency Pack

Fusing
GLR= GLR
GMF= GMF

Shielding Options
S58= KSH-12 Acrylic Lens
S72= Bold Baffle
S79= Parabolic Baffle

Notes: 1 Not all options available. Please consult your Cooper Lighting Representative for availability.



76PF
(1) F32T8/835
2950 Lumens

Efficiency 42.60%

Test Report
#14779.0

Coefficients of Utilization

Effective floor cavity reflectance											20%
RC	80				70			50			
RW	70	50	30	10	50	30	10	50	30	10	
0	51	51	51	51	47	47	47	45	45	45	
1	47	45	44	43	43	42	41	41	40	39	
2	43	40	38	36	38	36	34	37	35	34	
3	40	36	33	30	34	32	30	33	31	29	
4	37	32	29	26	30	28	25	29	27	25	
5	34	29	25	23	33	28	25	27	24	22	
6	31	26	22	20	30	26	22	24	21	19	
7	29	24	20	18	28	23	20	22	19	17	
8	27	21	18	16	26	21	18	20	17	15	
9	25	20	16	14	25	19	16	19	16	14	
10	24	18	15	13	23	18	15	17	15	13	

Zonal Lumen Summary

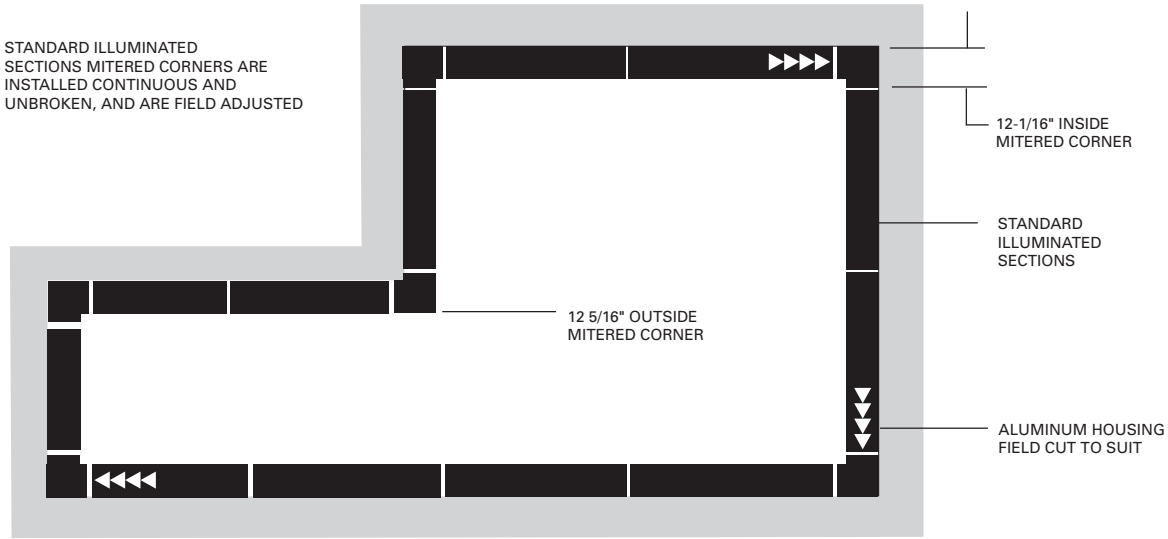
Zone	Lumens	%Lamp	%Fixt
0-30	394.46	13.40	31.40
0-40	655.45	22.20	52.20
0-60	1137.62	38.60	90.60
0-90	1255.88	42.60	100.00
90-180	0.00	0.00	0.00
0-180	1255.88	42.60	100.00

Total Luminaire Efficiency = 42.60%

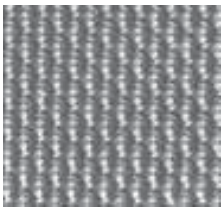
Candela

Angle	Along II	45°	Across ⊠
0	492	492	492
5	502	499	490
10	529	502	486
15	610	535	482
20	658	547	415
25	683	579	421
30	680	588	381
35	685	584	363
40	653	545	311
45	595	485	248
50	597	448	201
55	588	368	133
60	521	251	61
65	246	125	26
70	43	25	16
75	21	16	10
80	7	7	5
85	3	3	1
90	0	0	0

RUNS AND PATTERNS



SHIELDING INFORMATION



S58 Acrylic Lens
1/8" thick, clear acrylic prismatic lens.

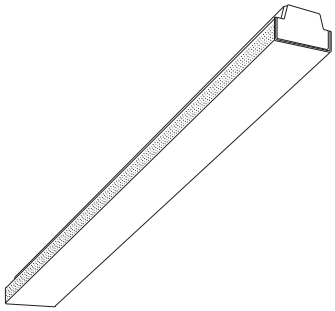
S72 Bold Baffle
1" high x 1.2"o.c., 3/16" thick aluminum baffle, continuous and unbroken, no visible joints.

S79 Parabolic Baffle
1-1/4" high blades. 2.4" o.c., semi-specular lo-brightness Pearlescent Aluminum baffle. Continuous and unbroken, no visible joints.

Columbia
LIGHTING

PT

Premium Corridor Wraparound / 1 or 2-Lamp T5, T5HO, T8



PROJECT INFORMATION

Project Name

Type

Catalog No.

Date

FEATURES

- Matches the WC Series in appearance
- Clear acrylic prismatic diffuser, flat bottom with vertical sides and injection molded ends sonically welded to the prismatic extrusion
- Injection molded white plastic decorative ends are removable for continuous row mounting
- Heavy gauge steel housing die embossed for maximum rigidity. Sturdy metal end pieces provide overall strength to the fixture

ELECTRICAL
Standard class "P", thermally protected, auto-resetting HPF ballast, sound rated A. All ballast leads extend a minimum of 6" through access location. NEC/CEC-compliant ballast disconnect is standard.

FINISH
White painted parts are treated with a five stage phosphate bonding process and finished after fabrication with a minimum 90% reflective gloss baked enamel.

SHIELDING
100% clear prismatic acrylic.

CERTIFICATION
All luminaires are built to UL 1598 standards and bear appropriate UL and cUL or CSA labels. Damp location labeling is standard. Emergency-equipped fixtures labeled UL 924.

ORDERING INFORMATION

EXAMPLE PT4-132-EU

PT – – –

MODEL
- **PT** Premium Corridor Wraparound

LENGTH
- **2** 2'
- **4** 4'
- **8** 8'

NO. OF LAMPS
- **1** One
- **2** Two

LAMP TYPE
- **14** 2', T5: 14 Watt
- **17** 2', T8: 17 Watt
- **24** 2', T5HO: 24 Watt
- **28** 4', T5: 28 Watt
- **32** 4', T8: 32, 30, 28 or 25 Watt
- **54** 4', T5HO: 54 or 51 Watt

BALLAST
- **E** Electronic T8, Instant Start
- **4E** 4-Lamp Electronic T8, Instant Start
- **EP** Electronic T5 or T8, Programmed Start
- **4EP** 4-Lamp Electronic T5HO (N/A 347V) or T8, Programmed Start

For a specific ballast vendor show as option.

VOLTAGE
- **U** 120V-277V
- **347** 347V

OPTIONS
- **GLR** Fast Blow Fuse
- **EL** Emergency Battery Pack
- **PAF** Paint After Fabrication

ACCESSORIES (ORDER SEPARATELY)
- **ITB4** T-Bar Hanger
- **S18** 18" Stem, Canopy
- **SS18** 18" Swivel Stem-45° Swivel

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Hubbell Lighting, Inc.

PHOTOMETRIC DATA

LUMINAIRE DATA

Luminaire	**PT4-132-E PT Wraparound 7" × 48" 1-Lamp with wraparound acrylic prismed lens**
Ballast	**B232I120**
Ballast Factor	**0.96**
Lamp	**FO32**
Lumens per Lamp	**2900**
Watts	**30**
Shielding Angle	**N/A**
Spacing Criterion	**0° = 1.27 90° = 1.53**
Luminous Opening in Feet	**Length: 4.00 Width: 0.56 Height: 0.25**

AVG. LUMINANCE (Candela/Sq. M.)

Average Luminance Angle	0.0	22.5	45.0	67.5	90.0
0	2816	2816	2816	2816	2816
30	2683	2686	2793	2823	2837
40	2593	2658	2679	2521	2483
45	2494	2522	2384	2143	2110
50	2268	2221	1952	1810	1820
55	1869	1756	1538	1590	1632
60	1492	1336	1314	1440	1485
65	1233	1091	1207	1351	1394
70	1019	984	1116	1310	1426
75	903	922	1078	1505	1755
80	797	868	1165	1999	2327
85	643	809	1553	2643	2945

ZONAL LUMEN SUMMARY

Zone	Lumens	Lamp	Fixt.
0-30	499	17.2	19.8
0-40	853	29.4	33.8
0-60	1462	50.4	57.9
0-90	1989	68.6	78.7
90-120	429	14.8	17.0
90-130	469	16.2	18.6
90-150	518	17.9	20.5
90-180	537	18.5	21.3
0-180	2526	87.1	100.0

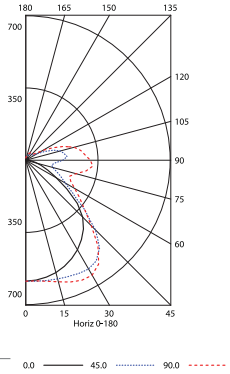
COEFFICIENTS OF UTILIZATION (%)

Test **10324** Test Date **1/8/03**

RCR	RC 80				70				50			0
RW	70	50	30	10	70	50	30	10	50	30	10	0
1	89	84	80	76	84	80	76	73	73	70	67	54
2	81	73	67	61	76	70	64	59	64	59	55	44
3	73	64	57	51	70	61	55	49	56	51	46	37
4	67	57	49	43	64	54	47	42	50	44	39	32
5	62	51	43	37	59	49	41	36	45	39	34	28
6	57	46	38	32	54	44	37	31	40	34	30	24
7	53	41	34	28	50	40	33	28	37	31	26	21
8	49	37	30	25	47	36	29	25	33	28	23	19
9	46	34	27	23	44	33	26	22	31	25	21	17
10	43	32	25	20	41	30	24	20	28	23	19	15

RCR = Room Cavity Ratio
RC = Effective Ceiling Cavity Reflectance **RW** = Wall Reflectance

INDOOR CANDELA PLOT



ENERGY DATA

Total Luminaire Efficiency	**87.1%**
Luminaire Efficacy Rating (LER)	**81**
ANSI/IESNA RP-1-2004 Compliance	**Noncompliant**
Comparative Yearly Lighting Energy Cost per 1000 Lumens	**$2.96 based on 3000 hrs. and $0.08 per KWH**

LUMINAIRE DATA

Luminaire	**PT4-232-E PT Wraparound 7" × 48" 2-Lamp with wraparound acrylic prismed lens**
Ballast	**B232I120RH**
Ballast Factor	**0.88**
Lamp	**FO32/741**
Lumens per Lamp	**2900**
Watts	**55**
Shielding Angle	**N/A**
Spacing Criterion	**0° = 1.26 90° = 1.44**
Luminous Opening in Feet	**Length: 4.00 Width: 0.56 Height: 0.25**

AVG. LUMINANCE (Candela/Sq. M.)

Average Luminance Angle	0.0	22.5	45.0	67.5	90.0
0	6084	6084	6084	6084	6084
30	5779	5642	5711	5589	5559
40	5543	5395	5213	5000	4933
45	5328	5000	4643	4239	4120
50	4863	4301	3736	3438	3382
55	3884	3291	2961	2890	2870
60	2914	2506	2498	2518	2542
65	2256	2091	2156	2332	2480
70	1787	1855	1985	2473	2941
75	1551	1763	2060	3129	3712
80	1512	1796	2384	3918	4490
85	1447	1801	3170	4862	5367

ZONAL LUMEN SUMMARY

Zone	Lumens	Lamp	Fixt.
0-30	1055	18.2	21.4
0-40	1769	30.5	35.8
0-60	2950	50.9	59.7
0-90	3947	68.1	79.9
90-120	709	12.2	14.4
90-130	830	14.3	16.8
90-150	950	16.4	19.2
90-180	994	17.1	20.1
0-180	4942	85.2	100.0

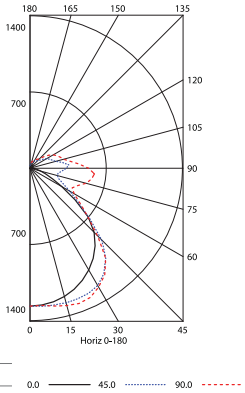
COEFFICIENTS OF UTILIZATION (%)

Test **11013** Test Date **1/8/03**

RCR	RC 80				70				50			0
RW	70	50	30	10	70	50	30	10	50	30	10	0
1	87	83	78	75	83	79	75	72	72	69	67	54
2	79	72	66	61	75	69	63	59	63	59	55	45
3	72	63	56	51	69	61	54	49	56	50	46	38
4	66	56	49	43	63	54	47	42	50	44	39	32
5	61	50	43	37	58	48	41	36	45	39	34	28
6	56	45	38	32	54	44	37	32	40	34	30	25
7	52	41	34	29	50	40	33	28	37	31	27	22
8	49	37	30	25	46	36	29	25	34	28	24	20
9	45	34	27	23	43	33	27	22	31	25	21	18
10	43	32	25	21	41	31	24	20	29	23	19	16

RCR = Room Cavity Ratio
RC = Effective Ceiling Cavity Reflectance **RW** = Wall Reflectance

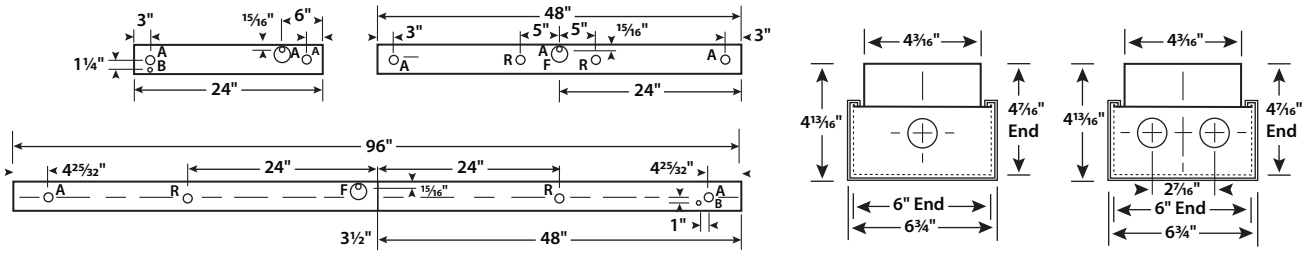
INDOOR CANDELA PLOT



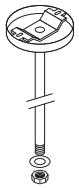
ENERGY DATA

Total Luminaire Efficiency	**85.2%**
Luminaire Efficacy Rating (LER)	**79**
ANSI/IESNA RP-1-2004 Compliance	**Noncompliant**
Comparative Yearly Lighting Energy Cost per 1000 Lumens	**$3.04 based on 3000 hrs. and $0.08 per KWH**

DIMENSIONAL DATA

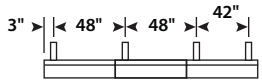


A: ⅞" Diameter Knockout B: .570" × .656" Strain Relief Knockout F: 2" Diameter Knockout R: 11/16" Diameter Knockout

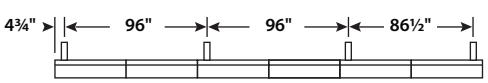


S18 Stem Hanger

Recommended Stem Hanging Arrangements



4' Fixtures



8' Fixtures

NOTE: All dimensions are in inches; dimensions and specifications are subject to change without notice. Please consult factory or check sample for verification.

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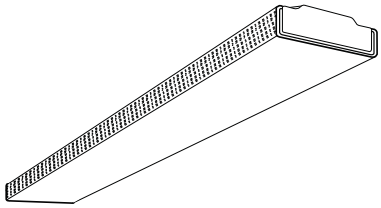
Hubbell Lighting, Inc.

Columbia
LIGHTING

WC

10" Wide Specification Grade Wraparound / 2-Lamp T5, T5HO, T8



PROJECT INFORMATION

Project Name _____ Type _____

Catalog No. _____ Date _____

FEATURES

- Clear acrylic prismatic diffuser. Hinges from either side. Flat bottom and vertical sides
- Linear side prisms control visual brightness and direct light onto adjacent ceiling area
- Injection molded decorative glow ends on diffuser baskets.
- Heavy gauge steel housing, die embossed for maximum rigidity
- Heat sink embossments and levelling projections allow direct mounting of HPF fixtures on combustible low density cellulose fiberboard ceilings

FINISH
All parts pre-painted with high gloss baked white enamel, minimum reflectance 86%, applied over iron phosphate pre-treatment for maximum adhesion and rust resistance.

ELECTRICAL
Standard class "P", thermally protected, auto-resetting HPF ballast, sound rated A. All ballast leads extend a minimum of 6" through access location. NEC/CEC-compliant ballast disconnect is standard.

SHIELDING
100% clear prismatic acrylic. 50% DR acrylic lens available as an option.

CERTIFICATION
All luminaires are built to UL 1598 standards and bear appropriate UL and cUL or CSA labels. Damp location labeling is standard. Emergency-equipped fixtures labeled UL 924.

ORDERING INFORMATION

EXAMPLE WC4-232-EU

WC – 2 – – –

MODEL
- **WC** 10" Wide Specification Grade Wraparound

NO. OF LAMPS
- **2** Two

LENS
- **Blank** Clear Prismatic Acrylic
- **DR** 50% DR content, Clear Prismatic Acrylic

VOLTAGE
- **U** 120V-277V
- **347** 347V

OPTIONS
- **GLR** Fast Blow Fuse
- **EL** Emergency Battery Pack
- **PAF** Paint After Fabrication
- **NYC** NYC Compliant
- **NYCU** NYC Compliant, Union Labeled

SIZE
- **2** 2'
- **4** 4'
- **8** 8'

LAMP TYPE
- **14** 2', T5: 14 Watt
- **17** 2', T8: 17 Watt
- **24** 2', T5HO: 24 Watt
- **28** 4', T5: 28 Watt
- **32** 4', T8: 32, 30, 28 or 25 Watt
- **54** 4', T5HO: 54 or 51 Watt

BALLAST
- **E** Electronic T8, Instant Start
- **4E** 4-Lamp Electronic T8, Instant Start
- **EP** Electronic T5, T5HO, or T8, Programmed Start
- **4EP** 4-Lamp Electronic T5 or T8, Programmed Start

ACCESSORIES (ORDER SEPARATELY)
- **ITB4** T-Bar Hanger
- **S18** 18" Stem, Canopy
- **SS18** 18" Swivel Stem - 45° Swivel

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PHOTOMETRIC DATA

Test **L11152** Test Date **1/8/03**

LUMINAIRE DATA

Luminaire	**WC4-232-EB8-PAF** **10" × 48" White Painted Interior with Wraparound Prismed Lens**
Ballast	**B232I120RH**
Ballast Factor	**0.88**
Lamp	**FO32/31K**
Lumens per Lamp	**2900**
Watts	**59**
Shielding Angle	**N/A**
Spacing Criterion	**0º = 1.27 90º = 1.31**
Luminous Opening in Feet	**Length: 4.00** **Width: 0.82** **Height: 0.08**

ZONAL LUMEN SUMMARY

Zone	Lumens	% Lamp	% Fixt.
0-30	1208	20.8	27.1
0-40	1980	34.1	44.4
0-60	3114	53.7	69.8
0-90	3861	66.6	86.5
90-120	422	7.3	9.5
90-130	481	8.3	10.8
90-150	569	9.8	12.7
90-180	601	10.4	13.5
0-180	4463	76.9	100.0

ENERGY DATA

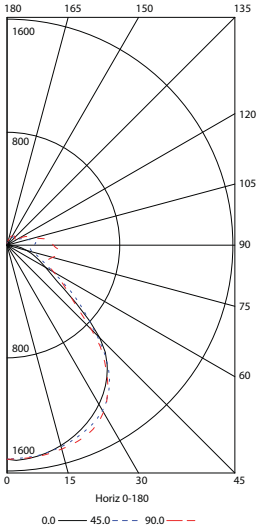
Total Luminaire Efficiency	**76.9%**
Luminaire Efficacy Rating (LER)	**67**
IESNA RP-1-1993 Compliance	**Non-Compliant**
Comparative Yearly Lighting Energy Cost per 1000 Lumens	**$3.58 based on 3000 hrs. and $0.08 per KWH**

COEFFICIENTS OF UTILIZATION (%)

RC	80				70				50			0
RW	70	50	30	10	70	50	30	10	50	30	10	0
RCR 1	81	77	74	71	78	74	71	69	69	67	65	55
2	74	68	63	58	71	66	61	57	61	57	54	47
3	68	60	54	49	65	58	53	48	54	50	46	40
4	63	54	47	42	60	52	46	42	49	44	40	35
5	58	48	42	37	55	47	41	36	44	39	35	31
6	54	44	37	33	51	42	36	32	40	35	31	27
7	50	40	33	29	48	39	33	28	37	31	28	24
8	46	36	30	26	45	35	30	26	34	28	25	22
9	43	33	27	23	42	33	27	23	31	26	22	20
10	41	31	25	21	39	30	25	21	29	24	20	18

RCR = Room Cavity Ratio
RC = Effective Ceiling Cavity Reflectance **RW** = Wall Reflectance

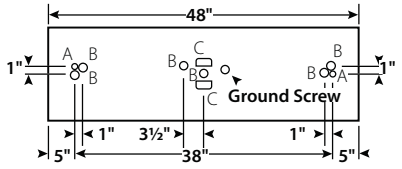
INDOOR CANDELA PLOT



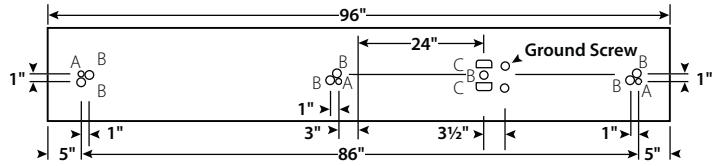
AVG. LUMINANCE (Candela/Sq. M.)

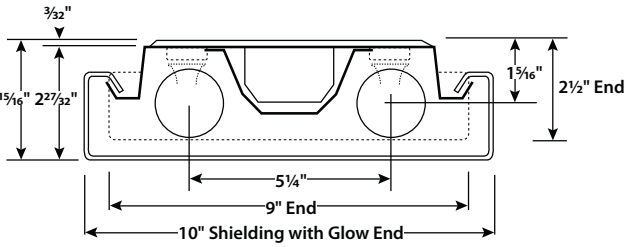
Average Luminance Angle	0.0	22.5	45.0	67.5	90.0
0	4975	4975	4975	4975	4975
30	4870	4824	4885	4864	4900
40	4647	4522	4441	4292	4261
45	4222	4079	3839	3623	3577
50	3186	3399	3242	2826	2790
55	2308	2814	2675	2385	2451
60	1998	2382	2157	2178	2156
65	1869	2067	1891	2099	2029
70	1764	1830	1804	2224	2323
75	1699	1679	1829	2731	3114
80	1680	1780	2158	3781	4477
85	1532	1908	3244	5672	6551

DIMENSIONAL DATA

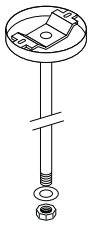


A - 5⁄16" Dia. Mounting Holes
B - 7⁄8" Dia. K.O.
C - 1⅛" × 2" "Butterfly" K.O.

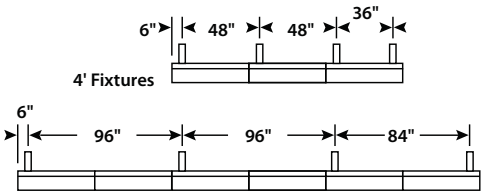




STEM MOUNTING



S18 Stem Hanger



8' Fixtures
Recommended Stem Hanging Arrangements

NOTE: All dimensions are in inches; dimensions and specifications are subject to change without notice. Please consult factory or check sample for verification.

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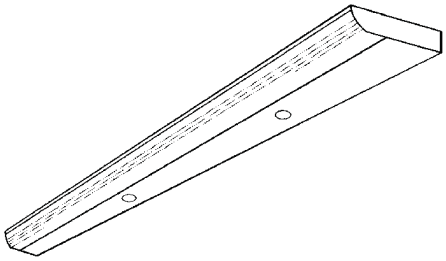
DoD Lighting Design Guide

F08



PROJECT INFORMATION

Project Name _____ Type _____

Catalog No. _____ Date _____

FEATURES

- Baked white enamel finish, painted after fabrication
- Standard T8 fluorescent design
- Diffuser easily removable for lamp access and cleaning
- Heavy gauge steel housing
- Optional grounded convenience outlet

FINISH
Painted parts are treated with a five stage phosphate bonding process and finished with a high reflectance baked white enamel.

ELECTRICAL
Standard class "P", thermally protected, auto-resetting HPF ballast, sound rated A. All ballast leads extend a minimum of 6" through access location. NEC/CEC-compliant ballast disconnect is standard.

CERTIFICATION
All luminaires are built to UL 1598 standards and bear appropriate UL and cUL or CSA labels. Damp location labeling is standard.

ORDERING INFORMATION

EXAMPLE UC18-115-LU-GC0

UC – **1** – **U** –

MODEL	SIZE	NO. OF LAMPS	LAMP TYPE	BALLAST	VOLTAGE	OPTIONS
UC Undercabinet	**18** 18" long	**1** One	**15** 18", T12: 15 Watt	**Blank** HPF, Non-energy Saving	**U** 120V-277V	**F0735** 35K, 75CRI, T8 Lamps Installed
	24 24" long		**17** 24", T8: 17 Watt	**L** Low Power Factor		**WSW** On-Off Rocker Switch (120V only)
	36 36" long		**20** 24", T12: 20 Watt	**E** Electronic T8, Instant Start		**GC0** Grounded Convenience Outlet (120V only)
	48 48" long		**25** 36", T8: 25 Watt			**GLR** Fast Blow Fuse
			30 36", T12: 30 Watt			
			32 48", T8: 32 Watt			

Fixtures without switches or grounded convenience outlets have knockouts for both for field installation.

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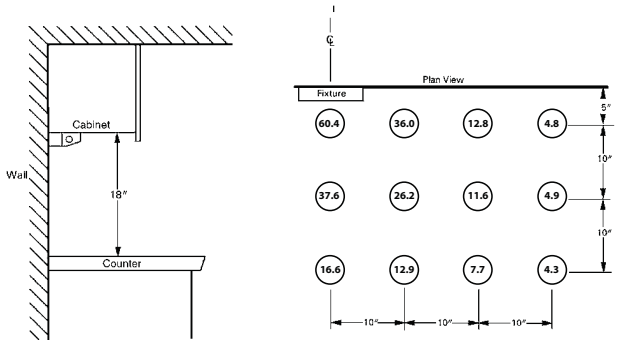
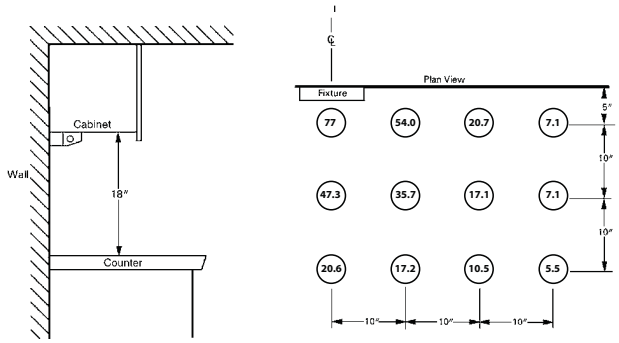
PHOTOMETRIC DATA

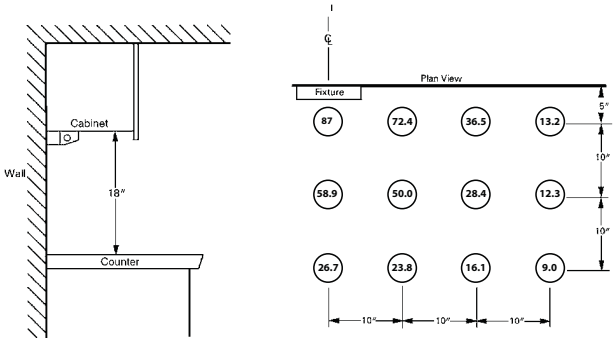
18" 15 Watt T-12 Lamp



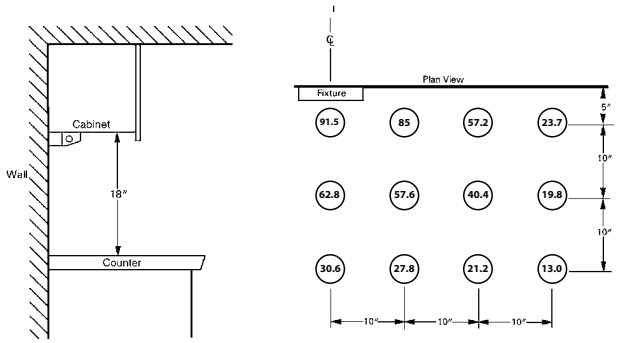
24" 17 Watt T8 Lamp



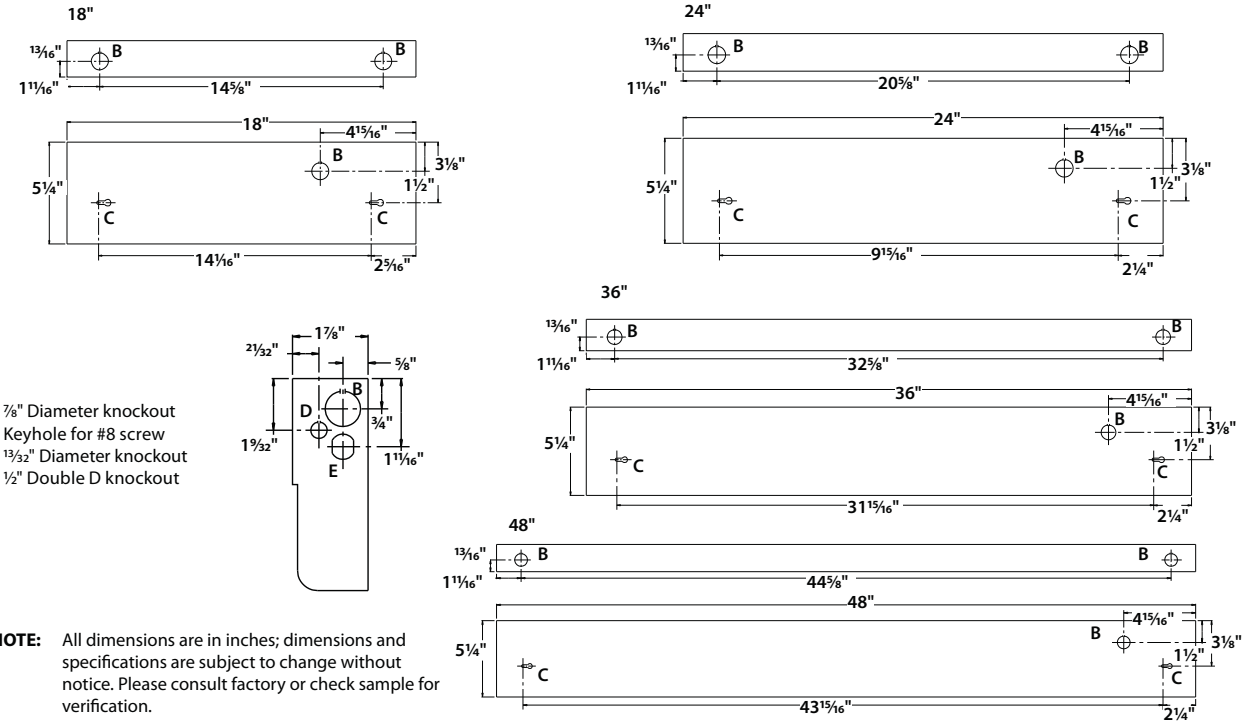
36" 25 Watt T8 Lamp



48" 32 Watt T8 Lamp



DIMENSIONAL DATA



B: 7/8" Diameter knockout
C: Keyhole for #8 screw
D: 13/32" Diameter knockout
E: 1/2" Double D knockout

NOTE: All dimensions are in inches; dimensions and specifications are subject to change without notice. Please consult factory or check sample for verification.

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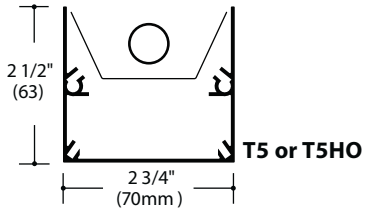
LITECONTROL

Fixture Type:
Project name:



LCS™ Control Solutions available

Mod-22xa™

P-I-0200

Pendant-Mounted Indirect

Product Description

Small-scale indirect extruded aluminum luminaire. UL Listed. Cradle to Cradle Certified.CM

Ordering Guide

Product, Lamping, & Length

P -	I -	02	2	8	T5HO-
Mounting	Distribution	Series	Lamp Count	Nominal Length (ft)	Lamp Type
P Pendant-mounted	**I** Indirect	**02**	**1 →**	**3**	**T5**
			1 →	**4**	**T5HO**
			2 →	**6**	**T8**
			2 →	**8**	
			3 →	**12**	
			see **notes**		

Mounting
- add to end of catalog number
Aircraft cables
☑ **FAI/ACC** (field adjustable)
standard

Options

TCWM-	LP/ELB-	F-	120
Finishes	Ballasts	Other Options	Volts
CAA (clear anodized aluminum) **TCWM** (textured matte white) are standard see **LiteColors™** in for other finishes	**ELB10** is standard for T8 **LP/ELB** is standard for T5 & T5HO **DA/MK7** **DL/ECO** **DO/HEL** **LPD/CS/e** see **Ballast Options**	**F** **LP/EF** see **Other Options**	**120** **277**

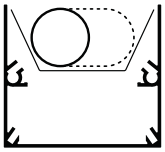
notes:
Lamp count = total number of lamps in the fixture
For ordering guide information in shaded areas, choose selection by reading ACROSS the shaded areas for correct specifications.

P-I-0228T5HO-TCWM-LP/ELB-F-120-FAI/ACC is the catalog number for a 2-lamp (1 lamp in cross-section) 8-foot long indirect high-output T5 fixture, textured matte white finish, with a low-profile electronic ballast, fuse, 120 volts, mounted with field adjustable aircraft cables.

Cross-section lamping

1-T5 or T5HO

1-T8



Finishes

TCWM Textured Matte White paint.
CAA Clear Anodized Aluminum.
For *LiteColors* or other finish choices, consult the Product Guide or litecontrol.com.

Ballast Options LCSe

Specify in place of ELB10 or LP/ELB, contact factory for availability:

DA/MK7 Advance Mark VII dimming ballast
DL/ECO Lutron ECO-10 dimming ballast
DO/HEL Osram Sylvania dimming ballast

To have the fixture enabled for Lutron EcoSystem compatibility:
LPD/CS/e EcoSystem low-profile dimming electronic ballasts installed at the factory, along with all required internal EcoSystem wiring. For other configurations of the Lutron EcoSystem components, including custom device connection feeds to enable connection to ceiling-mounted sensors and control devices, consult litecontrol.com/cs or contact the factory.

Other Options

F Fuse. Slow or fast blow, determined by Litecontrol.
LP/EF Low-profile Emergency Fluorescent Ballast. Battery-powered ballast from a UL Listed manufacturer will operate one lamp for 1 1/2 hours.

Questions to Ask

1. Row information, including desired fixture lengths?
2. Lamp type? **3.** Ballast options? **4.** White, *LiteColor*, or special color?
5. Controls solutions? **6.** Other options? **7.** 120 or 277 volt?

revised 7/12/2010

Click on **Quick Find 02**
litecontrol.com

Specifications

HOUSING. One-piece extruded aluminum. Standard finishes include Textured Matte White (**TCWM**) paint or Clear Anodized Aluminum (**CAA**).
END CAPS. Required at each end of row and at both ends of an individual fixture. Either painted steel or Clear Anodized Aluminum (**CAA**) with no holes or knockouts, finished to match housing.
REFLECTOR. Die-formed steel with high-reflectance white finish.
LAMPING. Available in one-lamp T8, T5, or T5HO. T8 lamp is diagonally positioned along length to clear suspension hardware at fixture ends for "on-module" suspensions, and provide symmetrical light distribution.
BALLAST. Electronic Ballast (**ELB10** for T8 lamping**)** or Low-profile Electronic Ballast (**LP/ELB** for T5 or T5HO lamping), high power factor, thermally protected Class P, Sound Rated A, manufactured by a UL-Listed manufacturer, as available, determined by Litecontrol. Ballasts with a voltage range of 120 to 277 will be used when fixture configuration and ballast availability allow. The minimum number of ballasts will be used.
CONTROLS. Available as an EcoSystem enabled fixture with factory installed daylight sensors. See Ballast and Control options for details.
PRE-WIRING. Fixtures are supplied with #12 AWG type THHN wire for branch circuits. One end will have factory installed push-in quick-connects. The other end will be stripped back 1/2" for quick connection in field. For fixtures to accommodate special circuits such as night light and emergency, etc., in-field wiring will be required.
BALLAST DISCONNECT. Fixture supplied with a ballast disconnect device to enable compliance with the NEC.
ROW JOINING. Support points are centered above the midpoint of joint "on seam" for aligned, symmetrical appearance. Fixture end headers are threaded in one location to allow easy row joining.
SUSPENSION Yoke with field adjustable aircraft cable attaches directly to the end header. Mounting points in rows are exactly "on module" at 36", 48", 72", 96", and 144", including at ends of rows.
CERTIFICATION. Fixture and electrical components shall be UL and/or CUL Listed and shall bear the I.B.E.W., A.F. of L. label. This fixture is Cradle to Cradle Certified[CM] Silver by MBDC.

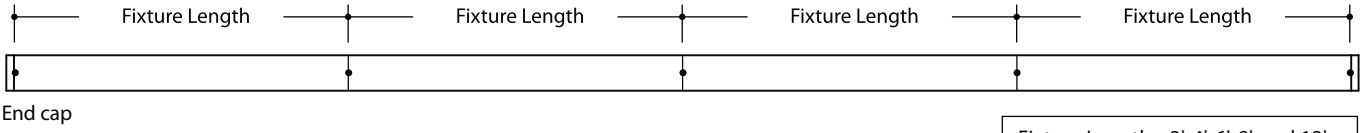
Note: Litecontrol reserves the right to change specifications without notice for product development and improvement.

Planning for installation

Suspension Assemblies
Provided with 3/64" diameter field adjustable aircraft cables (**FAI/ACC**) in 51" lengths (4' nominal). Longer length aircraft cables of 87" and 219" are available upon request. See Aircraft Cables sheets for further details.

Suspension mounting locations
Yoke with field adjustable aircraft cable attaches directly to end header. Mounting points in rows are exactly "on module" at 48" and 96", including at ends of rows.

Row diagram



Fixture Lengths: 3', 4', 6', 8', and 12'
• Indicates pendant locations

Cradle to Cradle Certified[CM] is a certification mark of MBDC.

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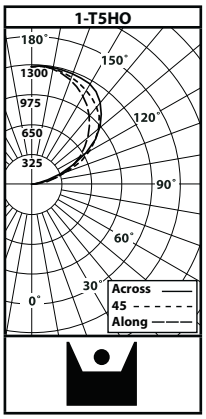
781 294 0100 f: 781 293 2849 litecontrol.com

CERTIFIED cradletocradle SILVER

Click on **Quick Find 02**
litecontrol.com

Photometric data T5HO and T8

1-T5HO



CANDLEPOWER SUMMARY

ANGLE	0	22.5	45	67.5	90
180	1268	1268	1268	1268	1268
175	1282	1273	1276	1283	1281
170	1268	1259	1270	1285	1280
165	1242	1241	1257	1276	1277
160	1207	1208	1237	1268	1273
155	1162	1168	1209	1256	1264
150	1107	1121	1177	1237	1254
145	1044	1066	1140	1210	1220
140	970	1004	1096	1153	1157
135	887	930	1037	1071	1069
130	800	858	949	967	970
125	707	783	846	853	846
120	612	705	733	716	685
115	509	607	601	536	504
110	403	484	437	366	336
105	288	347	268	207	184
100	174	191	125	94	87
95	59	58	41	36	35
90	1	4	2	6	4

P-I-0214T5HO 92.2 % Efficiency
Litecontrol Certified Test Report P-I-0214T5HO.IES

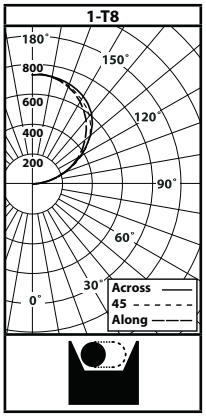
RCC	80				70				50			30			10			0
RW	70	50	30	10	70	50	30	10	50	30	10	50	30	10	50	30	10	0
RCR																		
0	88	88	88	88	75	75	75	75	51	51	51	29	29	29	9	9	9	0
1	80	76	73	70	68	65	63	60	45	43	42	26	25	24	8	8	8	0
2	73	66	61	57	62	57	53	49	39	36	34	22	21	20	7	7	7	0
3	66	58	52	47	56	50	45	41	34	31	29	20	18	17	6	6	6	0
4	60	51	45	40	51	44	39	34	30	27	24	18	16	14	6	5	5	0
5	55	45	39	34	47	39	33	29	27	23	21	16	14	12	5	4	4	0
6	51	40	34	29	43	35	29	25	24	20	18	14	12	11	4	4	3	0
7	47	36	29	25	40	31	26	22	22	18	15	12	11	9	4	3	3	0
8	43	33	26	22	37	28	23	19	19	16	13	11	9	8	4	3	3	0
9	40	29	23	19	34	25	20	16	18	14	12	10	8	7	3	3	2	0
10	37	27	21	17	31	23	18	14	16	13	10	9	7	6	3	2	2	0

Floor Cavity Reflectance .20

ZONAL LUMEN SUMMARY

ZONE	LUMENS	% LAMP	% LUMINAIRE
180-90˚	4149	92	100
90-0˚	0	0	0
180-0˚	4149	92	100

1-T8



CANDLEPOWER SUMMARY

ANGLE	0	22.5	45	67.5	90
180	725	725	725	725	725
175	732	727	727	728	729
170	723	718	722	728	726
165	710	707	713	719	718
160	690	688	697	707	709
155	665	664	676	691	693
150	633	635	652	670	675
145	598	601	624	645	648
140	556	563	591	610	612
135	509	519	550	565	566
130	460	474	501	507	507
125	408	425	445	440	438
120	353	374	381	373	369
115	296	317	310	300	297
110	237	253	238	231	230
105	173	178	167	164	162
100	109	105	103	101	101
95	45	44	44	44	43
90	3	4	6	7	6

P-I-0214T8 79.8 % Efficiency
Litecontrol Certified Test ReportP-I-0214T8.IES

RCC	80				70				50			30			10			0
RW	70	50	30	10	70	50	30	10	50	30	10	50	30	10	50	30	10	0
RCR																		
0	76	76	76	76	65	65	65	65	44	44	44	25	25	25	8	8	8	0
1	69	66	63	61	59	56	54	52	39	37	36	22	22	21	7	7	7	0
2	63	57	53	49	54	49	46	43	34	32	30	19	18	17	6	6	6	0
3	57	50	45	41	49	43	39	35	30	27	25	17	16	15	6	5	5	0
4	52	44	39	34	44	38	33	30	26	23	21	15	14	12	5	4	4	0
5	48	39	33	29	41	34	29	25	23	20	18	13	12	11	4	4	3	0
6	44	35	29	25	37	30	25	22	21	18	15	12	10	9	4	3	3	0
7	40	31	26	21	34	27	22	19	19	16	13	11	9	8	3	3	3	0
8	37	28	23	19	32	24	20	16	17	14	12	10	8	7	3	3	2	0
9	34	25	20	16	29	22	17	14	15	12	10	9	7	6	3	2	2	0
10	32	23	18	14	27	20	16	13	14	11	9	8	6	5	3	2	2	0

Floor Cavity Reflectance .20

ZONAL LUMEN SUMMARY

ZONE	LUMENS	% LAMP	% LUMINAIRE
180-90˚	2315	80	100
90-0˚	0	0	0
180-0˚	2315	80	100

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COOPER LIGHTING - METALUX®

DESCRIPTION

The HBI series is an outstanding solution for high mounting height industrial or retail applications. The HBI optic has been optimized to provide maximum performance from T8 lamps. Optional uplight component is provided to enable excellent ceiling uniformity. HBI's high lumen package allows the benefits of fluorescent to be applied at high mounting heights that were traditionally exclusive to H.I.D. The primary benefits include exceptional color rendering, high system efficacy, 95% lumen maintenance, long lamp life, instant on/instant re-strike, economical dimming, and uniform brightness control. Primary applications include retail, shopping malls, light industrial, gymnasiums and recreational environments.

Catalog #		Type
Project		
Comments		Date
Prepared by		

SPECIFICATION FEATURES

A···Construction

Full bodied steel housing with integral ballast channel adds strength, rigidity and structural protection for optical assembly.

B···Electrical

The HBI comes with a standard Class P electronic ballast and twistlock lampholders. UL/cUL listed for high ambient environments up to 55°C (131°F) for all lamps and ballast combinations when used in open uplight configurations. Suitable for damp locations. Optional modular power receptacle meets UL2459 and NEC 410.73 and is UL/cUL rated for make and break under load from outside the luminaire to speed maintenance.

C···Finish

White paint after fabrication enamel finish preceded by a multistage cleaning cycle, iron phosphate coating with rust inhibitor to protect against contaminants and oxidation.

D···Downlight/Uplight Optics

Die formed, segmented optical design optimizes performance across three distributions. Optical choices include a narrow distribution for aisles, medium distribution for assembly and loading areas, or wide distribution for general, open area lighting. An uplight option is offered to permit ceiling uniformity and allow for ample lamp and luminaire heat dissipation. Gasketed door frame & lens assembly is optional for more demanding environments.

Mounting

The HBI series is suited for suspension mounting with optional wire hook and chain set or cable mounting. Single monopoint mounting is available with SPM Tong Hanger.

Options

Integral Occupancy Sensor available and provides from 600 sq. ft. (MS) up to 1250 sq. ft. (MSO) of coverage in a maximum mounting height of 40' using interchangeable lens caps provided.

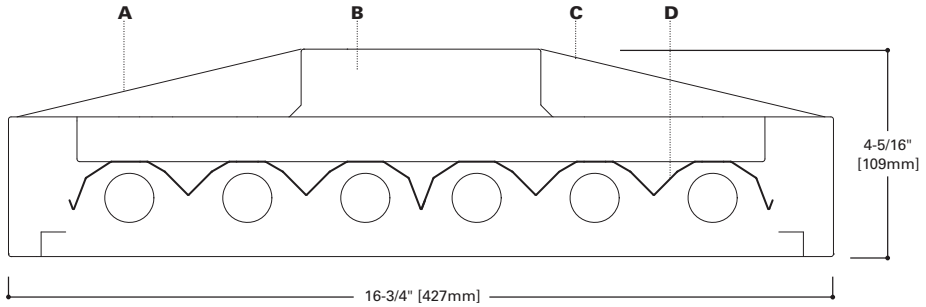
Warranty

When operated in high ambient conditions, the HBI is supported by a 5 yr/55°C and 3 yr/65°C ballast warranty when used with a high power factor ballast in open, uplight configurations. To maximize your warranty, the HBI should be ordered with a high power factor ballast in ambient environments that typically exceed 40°C (102°F).

HBI SERIES

HIGH-BAY INDUSTRIAL FLUORESCENT LUMINAIRE 6 T8 LAMPS

F-BAY™ FLUORESCENT HIGH-BAY



ENERGY DATA

Input Watts:

EB Ballast
632 = 169W

EB/Plus Ballast
632 = 218W

ER Ballast
632 = 169W

ER/Plus Ballast
632 = 218W

Luminaire Efficacy Rating
LER = FL84 (Narrow Beam)
Catalog Number: HBI-632-N-UPL

Yearly Cost of 1000 Lumens, 3000 hrs. at .08 KWH = $ 2.85

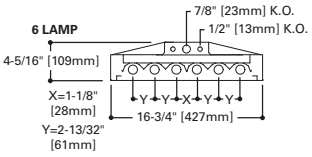
* Reference the lamp/ballast data in the Technical Section for specific lamp/ballast requirements

** Consult Pre Sales Technical Support.

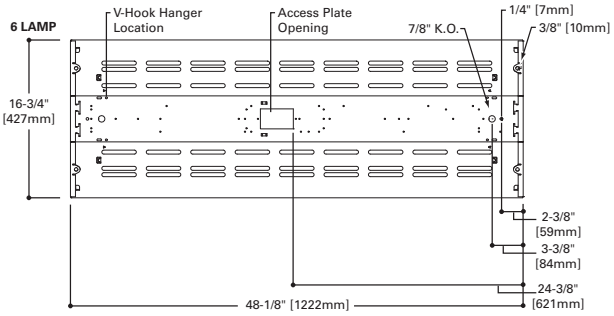
LAMPS CONTAIN MERCURY. DISPOSE ACCORDING TO LOCAL, STATE OR FEDERAL LAWS

LINEAR DISCONNECT
Safe and convenient means of disconnecting power.

LAMP CONFIGURATIONS



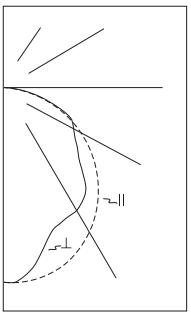
DIMENSION TOP VIEW



COOPER LIGHTING

ADF091043

PHOTOMETRICS



HBI-632-N-UNV-EB82
Electronic Ballasts
(6) 32W T8 Lamps
2850 lumens
Spacing criterion: (II) 1.3 x mounting height, (⊥) 1.1 x mounting height
Efficiency 91.3%
Test Report: HBI632.IES
LER =FL81
Yearly Cost of 1000 lumens, 3000 hrs at .08 KWH = $2.95

Candela

Angle	Along II	45°	Across ⊥
0	5981	5981	5981
5	6000	5958	5900
10	5959	5716	5516
15	5861	5330	4953
20	5702	4832	4572
25	5468	4418	4452
30	5189	4191	4398
35	4862	3996	4222
40	4491	3834	3894
45	4085	3563	3314
50	3649	3169	2953
55	3186	2598	2657
60	2699	2220	2469
65	2193	1914	2291
70	1668	1693	1766
75	1144	1291	1226
80	635	760	703
85	194	274	227
90	10	14	14

Coefficients of Utilization

Effective floor cavity reflectance 20%

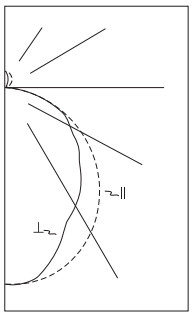
rc	80%				70%				50%			30%			10%			0%
rw	70	50	30	10	70	50	30	10	50	30	10	50	30	10	50	30	10	0
RCR																		
0	109	109	109	109	106	106	106	106	101	101	101	97	97	97	93	93	93	91
1	99	94	90	87	96	92	89	85	89	85	83	85	82	80	82	80	78	76
2	90	82	76	70	87	80	74	69	77	72	68	74	70	66	71	68	65	63
3	82	72	64	58	79	70	63	58	68	62	57	65	60	56	63	58	55	53
4	75	64	55	49	73	62	55	49	60	53	48	58	52	48	56	51	47	45
5	69	57	49	42	67	56	48	42	54	47	42	52	46	41	50	45	41	39
6	64	51	43	37	62	50	43	37	49	42	36	47	41	36	46	40	36	34
7	59	46	38	33	57	46	38	33	44	37	32	43	37	32	42	36	32	30
8	55	42	35	29	53	42	34	29	41	34	29	39	33	29	38	33	29	27
9	51	39	31	26	50	38	31	26	37	31	26	36	30	26	35	30	26	24
10	48	36	29	24	47	36	29	24	35	28	24	34	28	24	33	27	24	22

Zonal Lumen Summary

Zone	Lumens	%Lamp	%Fixture
0-30	4244	24.8	27.2
0-40	6874	40.2	44.0
0-60	12002	70.2	76.9
0-90	15606	91.3	100.0
0-180	15606	91.3	100.0

Luminance Data

Angle in Deg	Average 0-Deg cd/sm	Average 45-Deg cd/sm	Average 90-Deg cd/sm
45	12912	11262	10475
55	12415	10124	10353
65	11598	10122	12116
75	9879	11148	10587
85	4975	7027	5821



HBI-632-N-UNV-EBT2-UPL
Electronic Ballasts
(6) 32W T8 Lamps
2850 lumens
Spacing criterion: (II) 1.0 x mounting height, (⊥) 1.1 x mounting height
Efficiency 94.5%
Test Report: HBI632-UPL.IES
LER =FL84
Yearly Cost of 1000 lumens, 3000 hrs at .08 KWH = $2.85

Candela

Angle	Along II	45°	Across ⊥
0	6096	6096	6096
5	6103	6109	6097
10	6057	6018	5933
15	5952	5772	5528
20	5776	5383	5054
25	5542	4954	4556
30	5252	4442	4306
35	4916	4027	4025
40	4529	3719	3653
45	4117	3379	3251
50	3665	2969	2984
55	3186	2542	2597
60	2686	2231	2288
65	2169	1823	2045
70	1634	1539	1588
75	1105	1147	1089
80	602	660	616
85	174	218	158
90	5	6	7

Coefficients of Utilization

Effective floor cavity reflectance 20%

rc	80%				70%				50%			30%			10%			0%
rw	70	50	30	10	70	50	30	10	50	30	10	50	30	10	50	30	10	0
RCR																		
0	112	112	112	112	109	109	109	109	103	103	103	98	98	98	93	93	93	91
1	102	98	94	90	99	95	91	88	90	87	85	86	84	82	82	80	78	76
2	93	85	79	73	90	83	77	72	79	74	70	75	71	68	72	69	66	64
3	85	75	67	61	82	73	66	60	70	64	59	67	62	57	64	60	56	54
4	78	66	58	52	75	65	57	51	62	55	50	59	54	49	57	52	48	46
5	71	59	51	45	69	58	50	44	56	49	44	54	47	43	51	46	42	40
6	66	54	45	39	64	52	45	39	50	43	38	49	42	38	47	41	37	35
7	61	49	40	35	59	48	40	34	46	39	34	44	38	33	43	37	33	31
8	57	44	37	31	55	44	36	31	42	35	30	41	35	30	39	34	30	28
9	53	41	33	28	52	40	33	28	39	32	28	38	32	27	36	31	27	25
10	50	38	30	25	49	37	30	25	36	30	25	35	29	25	34	28	25	23

Zonal Lumen Summary

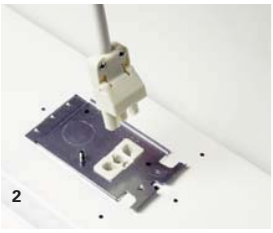
Zone	Lumens	%Lamp	%Fixture
0-30	4812	26.4	27.9
0-40	7183	42.0	44.5
0-60	12252	71.7	75.8
0-90	15556	91.0	96.3
0-180	16155	94.5	100.0

Luminance Data

Angle in Deg	Average 0-Deg cd/sm	Average 45-Deg cd/sm	Average 90-Deg cd/sm
45	13013	10680	10276
55	12415	9905	10120
65	11471	9641	10815
75	9542	9905	9404
85	4462	5590	4052

Modular F-Bay Power Supply Option

Cooper Lighting's F-Bay Modular Power Supply is standard on all F-Bay products. The modular power supply allows external fixture access for safe and easy servicing. There is no need to remove lamps or reflectors to disconnect fixture power with F-Bay Modular Power Supply. Access to the individual fixture's power supply allows servicing without turning off all the fixtures disrupting occupants. F-Bay Modular Power Supply is a time saver in installation – ***simply plug & power.***



1. Modular Power Supply Receptacle supplied mounted into fixture Access Plate
2. Modular Power Cord & Plugs in 120, 277, 347, & 480V configurations for easy plug & power into existing supply

No internal fixture access required for installation or disconnecting power

Modular Motion Sensor Option supplied with Mounting Box and Modular Power Supply Receptacle

Code Compliance

- UL/cUL Certified for Make/Break under load (UL2549)
- Meets NEC requirements for ballast disconnect (NEC 410.73G)
- Allows for addition of Occupancy Sensor without hard connections
- Receptacles complete with insulating/dust cap

ORDERING INFORMATION

SAMPLE NUMBER: HBI-632-N-UNV-EB82/PLUS-MP-UPL-U **Includes V Hangers for rapid installation[6]**

Series
HBI=High Bay Industrial

No. of Lamps
6=6 Lamps

Lamp Type
32=32W T8 Lamps (48")

Distribution
N=Narrow Beam (Standard)
M=Medium Beam
W=Wide Beam

Shielding
Blank=None
A=Prismatic Acrylic Lens & Doorframe
WG=Wireguard & Doorframe
A/WG=Acrylic Lens, Wireguard & Doorframe
CL=Clear Acrylic Lens & Doorframe
CL/WG=Clear Lens, Wireguard & Doorframe

Voltage[2]
UNV=Universal 120/277 Voltage
UNC=Universal 347/480 Voltage[5]
120V=120 Volt
277V=277 Volt
347V=347 Volt
480V=480 Volt

Options
Lamps Installed
L8830=T8 Lamp, 85CRI 3000K
L8835=T8 Lamp, 85CRI 3500K
L8841=T8 Lamp, 85CRI 4100K
L8850=T8 Lamp, 85CRI 5000K
HL=Add HL at end of lamp for high lumen lamps, T8 only
GL=Single Element Fuse
GM=Double Element Fuse
EL=Emergency Installed[2]

Ballast Type[3]
EB8_=T8 Electronic Instant Start. Total Harmonic Distortion < 10%
No. of Ballast 2 or 3
EB8_/PLUS=T8 Electronic Instant Start. High Ballast Factor >1.15. Total Harmonic Distortion < 10%
No. of Ballast 1, 2 or 3
ER8_=T8 Electronic Program Rapid Start.[9] Total Harmonic Distortion < 10%
No. of Ballast 2 or 3
ER8_/PLUS=T8 Electronic Program Start.[9] High Ballast Factor >1.15. Total Harmonic Distortion < 10%
No. of Ballast 2 or 3
DIM=Consult Factory[7]

Options
MP=Modular Power Receptacle (Used for all Cord or Cord and Plug options)[1], [10]
NUA=No uplight apertures in housing. (Cannot be combined w/UPL)
UPL=Uplight Apertures
MWS=Modular Wiring System[9]
MS=360° or 180° Motion Sensor, 120 through 347, or 480V[4]
G2=Gasketed Door (Requires Selection of Lensed Doorframe)
SDF=Slotted Doorframe (Requires Selection of Lensed Doorframe)

Packaging
U=Unit Pack
PALC=Palletized In Carton
PAL=Job Pack Out of Carton

Accessories (order separately)
HB-SPM=Single Monopoint Hanger w/Hub
RH-1=Retrofit Hanger
FH-1=Fixture Hook
FL-1=Fixture Loop
Y-TOGGLE-=Y Mounting Toggle, #2 Cable[8] (Specify 10' or 30', requires 2 per fixture)
HBAYC-CHAIN/SET/U=(2) V-Hook Hangers, 36" Chain Sets w/S-Hooks
MC3=3' Modular Power Cord
MPC3=3' Modular Power Cord & Plug (Specify Voltage)
MC6=6' Modular Power Cord
MPC6=6' Modular Power Cord & Plug (Specify Voltage)
MMS=360° or 180° Aisle Motion Sensor with Modular Power Receptacle (120-277V)[1]
MDS6=6' Modular Power Cord with MWS 27DS18/2G06MP Connector[10]
SWG=Heavy Duty Wireguard for Field Installation

NOTES: [1]Requires use of MC_ or MPC_cord accessories, specify voltage for plugs. [2]Voltage must be specified when ordered with plugs or emergency ballasts. [3]ER8 and EB8 ballast systems suitable for operation in ambient environments up to 122°F (50°C) in open uplight configuration. [4]When ordering MS option, specify UNV (for 120 or 277V), 347 or 480V. [5]2/3 lamp ballast configurations in EB8/PLUS only for T8 UNC versions. [6]Can be used in high abuse applications such as gymnasiums. [7]Dimming ballast must be specified at time of order. [8]Two required. [9]Cannot be combined with Modular Power Receptacle (MP). [10] For MWS with MP, choose MP in fixture logic and then choose MWS accessory such as MDS6.

Quick Ship
Made To Order

Quick Ship Ordering Information **Sample Number: HBI632-MP-UPL-L5**

Quick Ship orders ship in 5 days in order quantities not to exceed 200 pieces. **Includes V Hangers for rapid installation[6]**

NOTE: Orders received after noon are entered on the following day.

Family
HBI

Lamp Qty
6=6 Lamps

Lamp Type
32=32W T8 Lamps (48")

Distribution
Blank=Narrow Beam
W=Wide Beam

Ballast Type
Blank=(2) 120/277V 4L and 2L High Ballast Factor > 1.15 T8 Instant Start Electronic
PS=(2) 120/277V 4L and 2L High Ballast Factor > 1.15 T8 Electronic Program Rapid Start[9]

Power Receptacle
Blank=Standard Wiring to Access Plate
MP=Modular Power Receptacle[10]

Uplight
Blank=No Uplight
UPL=Uplight

Lamping
Blank=No Lamps
L4=Lamps Installed 85+CRI 4100K[11]
L5=Lamps Installed 85+CRI 5000K
L5HL=Lamps Installed 85+CRI 5000K, High Lumen

NOTES: [9]Recommended when utilizing Motion Sensor option. [10]Requires use of Modular cord and plug accessories. [11]High lumen (3100 initial) lamps supplied for 4100K.

SHIPPING INFORMATION

Catalog No.	Wt.
HBI-632-UPL	lbs.

Visit our web site at www.cooperlighting.com
COOPER Lighting
Customer First Center 1121 Highway 74 South Peachtree City, GA 30269 770.486.4800 **FAX** 770.486.4801 7/10 ADF091043

DESCRIPTION

The Metalux Horizon Recessed Wall Wash Series features recessed aesthetics and the latest in Energy Efficient Technology. The clean architectural design incorporates precision-formed aluminum reflector features that produces efficient, uniform and continuous vertical wall illumination.
The Horizon Recessed Wall Wash Series is specifically designed for effective use in various retail, merchandising and commercial wall washing environments. Horizon is ideal for retail displays, showrooms, corridor walls, art lighting and the elimination of the "Cave Effect" in office lighting applications.

Catalog #		Type
Project		
Comments		Date
Prepared by		

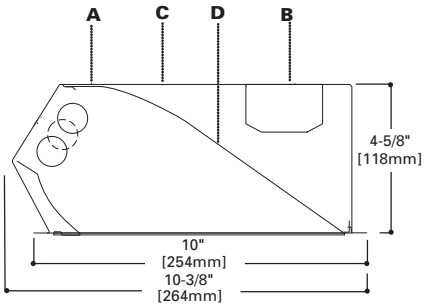
SPECIFICATION FEATURES

A ... Construction
Nominal 4-1/2" deep 10"x4' housing designed for use with T8 and biaxial lamps. The housing is constructed of die formed code gauge prime cold rolled steel. Housing incorporates a longitudinal flange for grid installation or ceiling tile support. KO's for continuous row mounting.

B ... Electrical*
Ballasts are CBM/ETL Class "P" and are positively secured. Biax models use 2G11 base lampholders with double-edge wiping action pressure lock contacts and lamp support clips. T8 models use pressure-lock lampholders. UL/CUL listed. Suitable for damp locations.

C ... Finish
Electrostatically applied baked white polyester powder enamel finish. Multistage cleaning cycle, iron phosphate coating with rust inhibitor. Conveyorized application and baking timing accurately controlled at an elevated temperature.

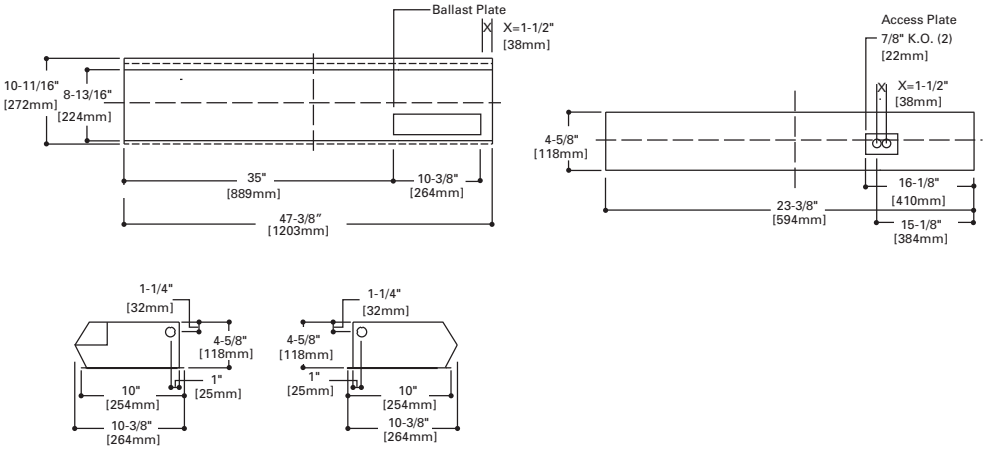
D ... Reflector Optical Assembly
The internal aluminum reflector optical assembly incorporates an upper "Scoop" and lower "Kick" reflector design. This design produces uniform even illumination on vertical surfaces. Continuous illumination is maintained to the junction of the wall and the ceiling. Reflectors are precision manufactured from specular low iridescent aluminum in a computer-controlled operation.



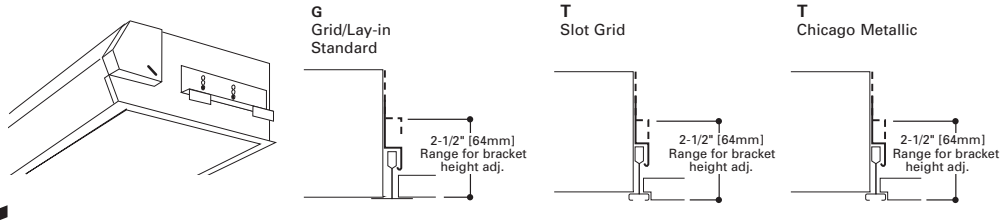
RWW
132
232
T1BX40

1' X 4'
RECESSED
WALL WASH
Vertical Illumination
Luminaire
T8 or Biaxial Lamps

MOUNTING DATA



INSTALLATION DATA



HORIZON™

ENERGY DATA
Input Watts:
Electronic Ballast & STD Lamps
132 (32)
232 (58)
T1BX40 (71)
T1BX50 (106)
T1BX55 (117)
ES Ballast & STD Lamps
132 (30)
232 (55)
1BX50 (54 Watts)
T2BX50 (106 Watts)
STD Ballast & STD Lamps
T1BX40 (77)

*Reference the lamp/ballast data in the Technical Section for specific lamp/ballast requirements.

LAMPS CONTAIN MERCURY. DISPOSE ACCORDING TO LOCAL, STATE OR FEDERAL LAWS

LINEAR DISCONNECT
Safe and convenient means of disconnecting power

COOPER Lighting
www.cooperlighting.com

Specifications and Dimensions subject to change without notice.
Consult your representative for additional options and finishes.

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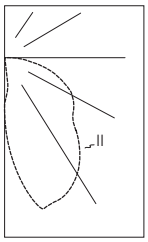


RWW-232MI
Electronic Ballast
F32T8/835 Lamps
2800 Lumens
Efficiency 69.7%
Test Report:
RWW232MI.IES

Zonal Lumen Summary

Zone	Lumens	%Lamp	%Fixture
0-30	959	17.1	24.6
0-40	1640	29.3	42.0
0-60	2973	53.1	76.2
0-90	3902	69.7	100.0
0-180	3902	69.7	100.0

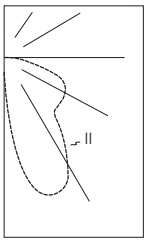
Candela

Angle	Along ∥	45°	Across ⊥
0	943	943	943
5	1435	1319	940
10	2087	1803	930
15	2601	2227	910
20	2656	2529	880
25	2595	2556	839
30	2479	2436	791
35	2332	2317	736
40	2136	2155	675
45	1817	1961	607
50	1667	1737	532
55	1554	1442	454
60	1416	1258	379
65	1197	1111	305
70	938	912	234
75	663	657	166
80	422	406	110
85	184	166	59
90	0	0	0

Coefficients of Utilization

Effective floor cavity reflectance 20%

rc	80%				70%				50%			30%			10%			0%
rw	70	50	30	10	70	50	30	10	50	30	10	50	30	10	50	30	10	0
RCR																		
0	83	83	83	83	81	81	81	81	77	77	77	74	74	74	71	71	71	70
1	76	73	70	67	74	71	68	66	68	66	64	65	64	62	63	61	60	59
2	69	63	59	55	67	62	58	54	60	56	53	57	54	52	55	53	51	49
3	63	56	50	46	61	55	50	45	53	48	45	51	47	44	49	46	43	42
4	58	49	43	39	56	49	43	38	47	42	38	45	41	37	44	40	37	35
5	53	43	37	32	51	43	37	32	41	36	32	40	35	32	39	34	31	30
6	48	39	32	28	47	38	32	28	37	31	27	36	31	27	35	30	27	26
7	44	35	28	24	43	34	28	24	33	28	24	32	27	24	31	27	23	22
8	41	31	25	21	40	30	25	21	30	24	20	29	24	20	28	23	20	19
9	37	28	22	18	36	27	22	18	26	21	18	26	21	17	25	21	17	16
10	35	25	19	15	34	25	19	15	24	19	15	23	19	15	23	18	15	14



RWW-T1BX40
Electronic Ballast
F40BX/835/RS Lamps
3150 Lumens
Efficiency 79.9%
Test Report:
RWWT1BX40MI.IES

Zonal Lumen Summary

Zone	Lumens	%Lamp	%Fixture
0-30	1095	17.4	21.8
0-40	1998	31.7	39.7
0-60	3648	57.9	72.5
0-90	5031	79.9	100.0
0-180	5031	79.9	100.0

Candela

Angle	Along ∥	45°	Across ⊥
0	419	419	419
5	931	826	423
10	2342	1586	419
15	3471	2733	412
20	3766	3408	403
25	3847	3601	389
30	3629	3573	371
35	3145	3500	349
40	2378	3154	328
45	2092	2635	306
50	2014	1960	283
55	2006	1721	260
60	1961	1593	236
65	1899	1514	219
70	1631	1382	209
75	1099	1146	203
80	675	653	191
85	405	326	99
90	0	0	0

Coefficients of Utilization

Effective floor cavity reflectance 20%

rc	80%				70%				50%			30%			10%			0%
rw	70	50	30	10	70	50	30	10	50	30	10	50	30	10	50	30	10	0
RCR																		
0	95	95	95	95	93	93	93	93	89	89	89	85	85	85	81	81	81	80
1	86	82	79	76	84	81	77	74	77	74	72	74	72	70	71	69	68	66
2	78	71	66	61	76	70	65	60	67	63	59	64	61	57	62	59	56	54
3	71	62	56	50	69	61	55	50	59	53	49	57	52	48	54	51	47	45
4	65	55	48	42	63	54	47	42	52	46	41	50	45	41	48	44	40	38
5	59	48	41	35	57	47	40	35	45	39	34	44	38	34	42	38	34	32
6	54	43	35	30	52	42	35	30	40	34	29	39	33	29	38	33	29	27
7	50	38	31	26	48	37	30	25	36	30	25	35	29	25	34	29	25	23
8	45	34	27	22	44	33	26	22	32	26	22	31	26	21	30	25	21	20
9	42	30	23	18	40	30	23	18	29	23	18	28	22	18	27	22	18	16
10	39	27	20	16	37	27	20	16	26	20	16	25	20	16	24	19	16	14

Wall Illuminance

Individual Unit*

Ceiling	0'	1'	2'	3'	4'	5'	6'	7'	8'
8'	65	59	42	24	13	7	4	2	2
7'	82	74	56	35	20	11	7	4	3
6'	64	59	47	33	21	13	8	5	3
5'	50	46	38	28	19	13	8	6	4
4'	35	33	29	23	17	12	8	6	4
3'	25	24	21	18	14	10	8	6	4
2'	18	18	16	14	11	9	7	5	4
1'	14	14	13	11	10	8	6	5	4
Floor									

*Units located 3' from wall. Data provided for RWW-232MI Unit

Multiple Units*

8'

Ceiling	0'	1'	2'	3'	4'	5'	6'	7'	8'
8'	69	63	48	33	27	33	48	63	69
7'	88	81	65	49	42	49	65	81	88
6'	72	68	58	48	44	48	58	68	72
5'	59	56	50	44	42	44	50	56	59
4'	45	43	40	37	36	37	40	43	45
3'	34	34	33	31	31	31	33	34	34
2'	28	27	27	26	26	26	27	27	28
1'	23	23	23	23	23	23	23	23	23
Floor									

Continuous Row*

Ceiling	0'	1'	2'	3'	4'	5'	6'	7'	8'
8'	95	95	95	95	95	95	95	95	95
7'	128	129	129	129	129	129	129	129	129
6'	113	113	114	114	114	114	114	114	115
5'	96	97	98	98	99	99	99	99	99
4'	76	78	78	79	79	79	80	79	79
3'	60	62	62	63	63	63	64	64	64
2'	49	50	51	51	52	52	52	52	52
1'	41	43	43	44	44	44	45	45	45
Floor									

ORDERING INFORMATION

Sample Number: RWW-232MI-120V-EB81-U

Series
RWW=Recessed Wall Wash

Number of Lamps
1=1 Lamp
2=2 Lamps
T1=2' x 4' fixture with one Biax Lamp at each end

Wattage
32= 32W T8 (48")
BX40= 40W Biax (24")[1, 2]
BX50= 50W Biax (24")[1, 2]
BX55= 55W Biax (24")[1, 2]

Louver Finish
I=Semi-Specular/Haze (Low Iridescent) Standard
MI=Specular/Mirrored (Low Iridescent)

Voltage [3]
120V= 120 Volt
277V= 277 Volt
347V= 347 Volt
UNV= Universal 120/277[4] Voltage

Options
GL= Single Element Fuse
GM= Double Element Fuse
EL= Emergency Installed

Ballast Type [3]
Blank=Standard Magnetic Biax Ballast
EB=Electronic Instant Start
ER=T8 Electronic Program Rapid Start. Total Harmonic Distortion < 10%
TEB= T5 Biax Elec Instant Start. Total Harmonic Distortion < 10%
DLS= Digital Lighting System Dimming

Lamp Size
5= T5 Biax
8= T8

Number of Ballasts
1= 1 Ballast
2= 2 Ballast

Options
PLUS=Higher Ballast Factor > 1.13. Total Harmonic Distortion < 20%
RLS= Rotor Lock Socket (T8 Lamp only)
RIF1= Radio Interference Suppressor
REP= Riveted End Plates

Packaging
U=Unit Pack
PALC=Palletized Fixtures in Carton

Notes:
1 Electronic Ballast only.
2 Biax only available in 1 lamp cross section.
3 Products also available in non-US voltage and frequencies for international markets
4 UNV available in T5 and T8 linear only. Not available when specifying emergencies. Voltage must be specific.

ACCESSORIES

TBW2 = Thin White Baffle Accessory (2' Fixture) [4]
TBW4 = Thin White Baffle Accessory (4' Fixture) [4]
CAL2 = Clear Acrylic Lens (2' Fixture)
CAL4 = Clear Acrylic Lens (4' Fixture)
DF-104-W = 4' Version Drywall Frame Kit

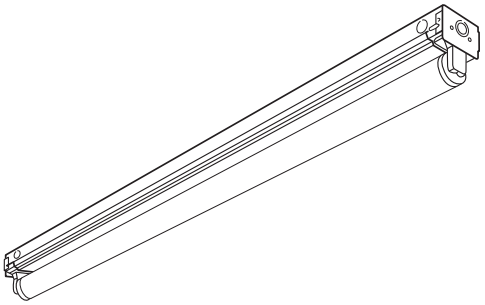
SHIPPING INFORMATION

Catalog No.	Wt.
RWW-132	17.5
RWW-232	17.5
RWW-T1BX40	18.0

Columbia
LIGHTING

CH

2', 3', 4', or 8' Heavy Duty Narrow Channel / 1or 2-Lamp T5, T8



PROJECT INFORMATION

Project Name

Type

Catalog No.

Date

FEATURES

- Available 2', 3', 4', or 8'
- Heavy die formed steel channel
- Snap-on cover. No tools required. No hardware to lose
- Rotary lock lampholders for positive lamp contact
- Channel ends double as joiners
- Individual or row mounting. Surface or suspended

CONSTRUCTION
Heavy gauge cold rolled steel housings fully assembled. Channel cover provides room-side access to ballast.

FINISH
White painted parts are treated with a five stage phosphate bonding process and finished with a high reflectance baked enamel.

ELECTRICAL
Standard class "P", thermally protected, auto-resetting HPF ballast, sound rated A. All ballast leads extend a minimum of 6" through access location. NEC/CEC-compliant ballast disconnect is standard.

CERTIFICATION
All luminaires are built to UL 1598 standards and bear appropriate UL and cUL or CSA labels. Damp location labeling is standard. Emergency-equipped fixtures labeled UL 924.

ORDERING INFORMATION

EXAMPLE CH4-132-E347-GLR

CH – – **E** –

MODEL
- **CH** Heavy Duty Narrow Channel

SIZE
- **2** 2'
- **3** 3'
- **4** 4'
- **8** 8'

NO. OF LAMPS IN CROSS SECTION
- **1** One
- **2** Two

LAMP TYPE
- **17** 2', T8: 17 Watt
- **25** 3', T8: 25 Watt
- **32** 4', T8: 32 Watt
- **21** 3', T5: 21 Watt
- **28** 4', T5: 28 Watt

BALLAST
- **E** Electronic T8, Instant Start

For a specific ballast vendor, show as option.

VOLTAGE
- **U** 120V-277V
- **347** 347V

OPTIONS
- **GLR** Fast Blow Fuse
- **GMF** Slow Blow Fuse
- **EL** Emergency Battery Pack
- **PAF** Paint After Fabrication

ACCESSORIES (ORDER SEPARATELY)
- **ITB4** Hanger for close mounting on a T-Bar ceiling
- **CHWG3** 3' Wire Guard
- **CHWG4** 4' Wire Guard, 2 required for 8' fixture
- **CHRA3** 3' Asymmetric Reflector
- **CHRA4** 4' Asymmetric Reflector, 2 required for 8' fixture
- **CHR3** 3' Symmetric Reflector
- **CHR4** 4' Symmetric Reflector, 2 required for 8' fixture

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Hubbell Lighting, Inc.

PHOTOMETRIC DATA

Test **8959** Test Date **1/8/03**

LUMINAIRE DATA

Luminaire	**CH4-140-LE** **CH Striplight** **48" × 3³⁄₁₆" Single Lamp Striplight**
Ballast	**412-L-TC-P**
Ballast Factor	**0.95**
Lamp	**F40CW**
Lumens per Lamp	**1350**
Watts	**52**
Shielding Angle	**N/A**
Spacing Criterion	**0° = 1.24 90° = 1.65**
Luminous Opening in Feet	**Length: 4.00** **Width: 0.27** **Height: 0.00**

ZONAL LUMEN SUMMARY

Zone	Lumens	%Lamp	%Fixt.
0-30	357	11.3	12.1
0-40	612	19.4	20.7
0-60	1242	39.4	42.0
0-90	2170	68.9	73.3
0-180	2959	93.9	100.0

ENERGY DATA

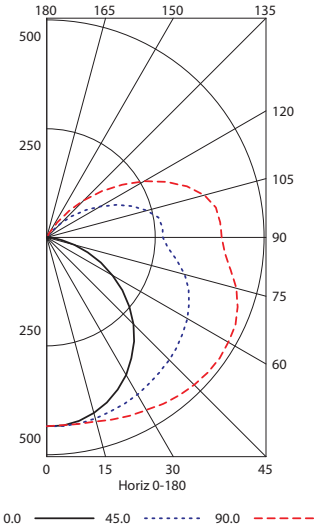
Total Luminaire Efficiency	**93.9%**
Luminaire Efficacy Rating (LER)	**N/A**
IESNA RP-1-1993 Compliance	**Noncompliant**
Comparative Yearly Lighting Energy Cost per 1000 Lumens	**$N/A based on 3000 hrs. and $0.08 per KWH**

COEFFICIENTS OF UTILIZATION (%)

RCR	RC	80				70				50			0
	RW	70	50	30	10	70	50	30	10	50	30	10	0
	1	92	86	81	76	87	82	77	72	73	69	66	49
	2	83	73	65	59	78	69	62	56	62	56	51	38
	3	74	63	54	47	70	59	52	45	53	46	41	30
	4	67	55	46	39	63	52	44	37	46	39	34	25
	5	62	49	39	33	58	46	38	31	41	34	29	21
	6	57	43	34	28	53	41	33	27	37	30	25	18
	7	52	39	30	24	49	37	29	23	33	26	21	15
	8	48	35	27	21	45	33	26	20	30	23	19	13
	9	45	32	24	19	42	31	23	18	28	21	17	12
	10	42	29	22	17	40	28	21	16	25	19	15	11

RCR = Room Cavity Ratio
RC = Effective Ceiling Cavity Reflectance **RW** = Wall Reflectance

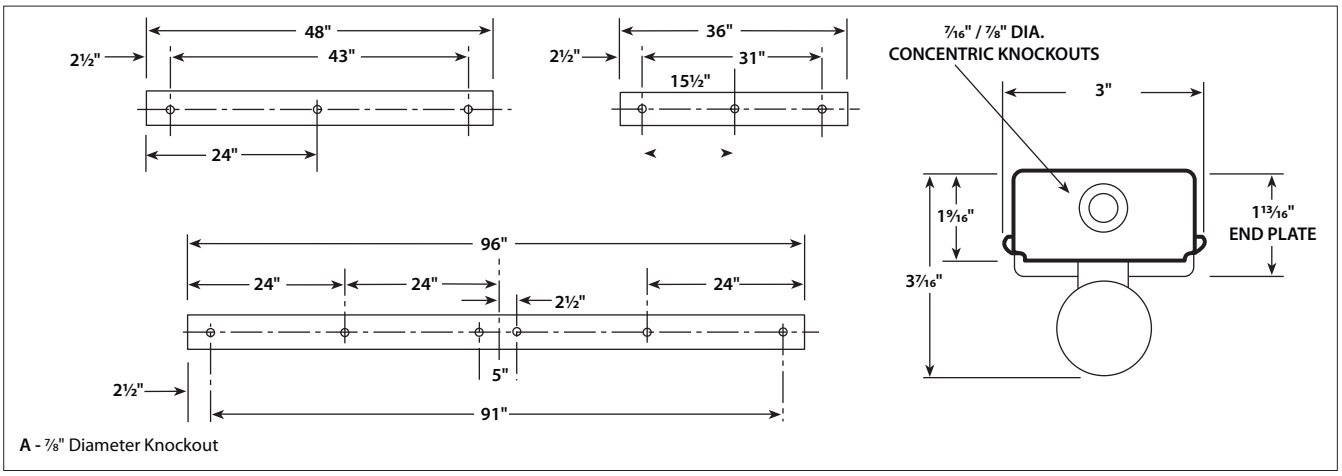
INDOOR CANDELA PLOT



AVG. LUMINANCE (Candela/Sq. M.)

Average Luminance Angle	0.0	22.5	45.0	67.5	90.0
0	4325	4325	4325	4325	4325
30	4201	4362	4799	5144	5271
40	4059	4437	5256	5933	6167
45	3975	4524	5610	6470	6751
50	3845	4621	6063	7132	7489
55	3684	4796	6638	8028	8427
60	3488	5063	7435	9090	9608
65	3231	5495	8513	10612	11273
70	2914	6149	10112	12793	13609
75	2542	7278	12631	16251	17367
80	2066	9413	17448	22901	24623
85	1830	15553	32020	43227	47001

DIMENSIONAL DATA

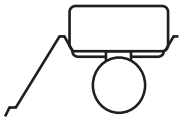


A - ⅞" Diameter Knockout

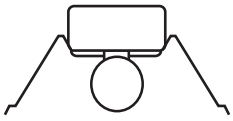
MOUNTING DATA

ITB4

ACCESSORY REFLECTORS



CHRA3
CHRA4



CHR3
CHR4

NOTE: All dimensions are in inches; dimensions and specifications are subject to change without notice. Please consult factory or check sample for verification.

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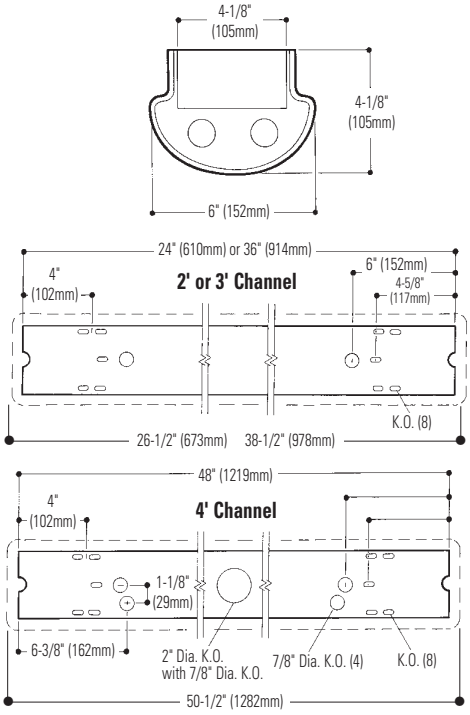
Belmont 6" Cloud

Surface Mount Fluorescent, 24", 36 or 48" Lengths
2 Lamp T8

- 6" white opal acrylic lens (vacuum formed).
- Can be horizontally or vertically wall mounted.
- Can be ceiling mounted.
- Efficiency 69.0%.
- Lens secured to body with screws at ends..
- Quarter turn latch secures channel cover for easy wireway access.
- Heavy duty channel of code gauge die formed steel.
- Fully enclosed wiring.
- UL Listed snap-on end caps (body).
- Green grounding screw installed in channel.

Features

Dimensions



Job Information	**Type:**
Job Name:	
Cat. No.:	
Lamp(s):	
Volts/Ballast:	

For Factory Technical Information: (978) 657-7600 • Fax (978) 658-0595
631 Airport Road, Fall River, MA 02720 • (508) 679-8131 • Fax (508) 674-4710
07/09
We reserve the right to change details of design, materials and finish.
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Section 4/Folio I55-10 Rev. A

Lightolier is a Philips group brand

PHILIPS

Chassis
Model No. SW4S232HPFUNVHI
with shielding BCW6X48

LER = FP - 69.0 IW - 29.6 BF - 0.88
Comparative yearly lighting energy cost per 1000 lumens = $3.87

Report Number: 19743
Lamp: F32T8
Luminaire: Belmont 6" Cloud, 24", 36" or 48" Lengths, 2 Lamp T8
Ballast: Electronic
Report is based on 2850 Lumens per lamp.

Efficiency: 69.0%

CIE Type-Direct-Indirect

Plane:	0-Deg	90-Deg
Spacing Criteria:	1.2	1.2

COEFFICIENTS OF UTILIZATION – ZONAL CAVITY METHOD. EFFECTIVE FLOOR CAVITY REFLECTANCE 0.20

PCC	80			70			50	
RCR	70	50	30	70	50	30	50	30
1	68	64	60	64	60	57	54	51
2	60	55	50	57	52	46	46	41
3	56	47	41	52	45	40	40	35
4	51	41	35	46	40	34	34	30
5	46	36	30	42	34	28	30	27
6	42	33	27	40	30	26	28	23
7	39	29	23	36	28	23	25	20
8	36	27	20	34	26	20	23	19
9	34	25	19	32	23	17	20	17
10	32	23	17	29	22	17	20	14

LUMINANCE DATA IN CANDELA/SQ. METER

AVERAGE IN DEG.	AVERAGE 0-DEG.	AVERAGE 45-DEG.	AVERAGE CROSS
45	3092.	2648.	2737.
55	2832.	2537.	2725.
65	2329.	2446.	2748.
75	1696.	2461.	2818.
85	655.	2619.	3085.

CANDLEPOWER

Angle	End	45.0	Cross
0	708	708	708
5	702	707	707
15	688	693	698
25	624	649	673
35	551	595	639
45	457	535	599
55	349	472	560
65	221	402	511
75	108	339	453
85	20	280	403
95	19	246	364
105	49	226	330
115	79	212	306
125	108	186	261
135	128	167	226
145	138	147	186
155	152	123	152
165	162	108	143
175	167	162	157

LIGHT DISTRIBUTION

ZONE	LUMENS	% LAMP	% FIXT
0- 30	562	9.9	14.3
0- 40	936	16.4	23.8
0- 60	1764	31.0	44.9
0- 90	2762	48.5	70.3
90-180	1169	20.5	29.7
0-180	3931	69.0	100.0

Ordering Information

NOTE: Chassis and shielding are packed in separate cartons. When ordering, enter as separate line items.

Length	Shielding	Chassis	Lamp	Ballast	20THD	10THD
2'	**BCW6X24**	**SW2S217HPFUNVHI**	2-T8	2 Lamp Elec. T8	–	**HI**
3'	**BCW6X36**	**SW3S225HPFUNVHI**	2-T8	2 Lamp Elec. T8	–	**HI**
4'	**BCW6X48**	**SW4S232HPFUNVHI**	2-T8	2 Lamp Elec. T8	–	**HI**

NOTE: Chassis and shielding shown are stock items. For other ballast options see Folio **H110-42**.

NOTE: UNV =120-277.

Specifications

Materials: Chassis parts are die-formed heavy gauge code cold rolled steel, 4-1/8" channel width.
Ballast Cover: Code gauge steel secured with quarter turn latch.
Lens: 6" white opal acrylic lens (vacuum formed).
Finish: Chassis exterior–phosphate undercoating, baked white polyester enamel.
Electrical: Thermally protected class "P" ballast, non PCB. If K.O. is within 3" of ballast, use wire suitable for at least 90°.
Labels: I.B.E.W./UL and ULc Listed.
This product may have a mercury containing lamp. Manage in accord with Disposal Laws. See: www.lamprecycle.org

Job Information **Type:**

For Factory Technical Information: (978) 657-7600 • Fax (978) 658-0595
631 Airport Road, Fall River, MA 02720 • (508) 679-8131 • Fax (508) 674-4710
We reserve the right to change details of design, materials and finish.
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PHILIPS

C 2
SERIES

CORDELIA

Job Name	
Catalog Number	
Notes	Type

features

- A unique bi-level luminaire controlled by an integral ultra-sonic motion sensor, designed to provide safe, dependable illumination while conserving energy. Suitable for ceiling or wall mounting
- Bi-level fixtures operate at a low standby light level, offering safety and security with full light output instantly upon occupancy with areas fully lit only as needed
- Ideal for stairwells, restrooms, laundry rooms and other areas where maximum light levels are not required on a constant basis
- The ultra-sonic sensor features enhanced sensitivity and a lamp conditioning circuit (patented) that keeps new lamps on for 100 hours to assure long lamp life and proper operation
- For safety and compliance purposes in areas designated as emergency egress, we recommend choosing a standby light level that will provide minimum code compliant light levels while in the standby mode. In most municipalities, this is 1 FC average (2 FC in NYC). See back for options

construction

- Housings are die-formed of code gauge steel, with riveted end plates and socket supports
- Quality construction throughout for long-term dependable service
- Vandal resistant options including heavy gauge end plates, tamper-proof screws and hi-impact diffusers
- Ample knockouts are provided for convenient mounting with recessed or surface power feeds
- New York City Department of Buildings calendar #4525
- All fixtures are U.L. listed and IBEW union made

diffuser

- One-piece extruded clear, light stabilized acrylic is standard
- Features a linear refractive pattern for even illumination
- Grooved formation on the edges allow for a tight, no light leak attachment to the body
- Optional polycarbonate lens

All units are U.L. listed as emergency power and lighting equipment (U.L.-924) when equipped with optional battery back-up and meet requirements of the life safety code/NFPA101, NEC/OSHA and most state and local codes.

electrical

- All electrical components are U.L. listed
- Ballasts are class P, thermally protected T8 Electronic
- Optional battery backup available for one or two light emergency operation at various output levels. Please consult factory for your specific emergency pack requirements

finish

- Painted with a lighting grade baked white enamel, having a reflectance factor exceeding 87% for premium quality and durability
- Prior to painting, all metal parts are treated with a multi-stage phosphate bonding process to ensure adhesion and inhibit rusting

sensor

- High frequency, extremely sensitive ultra-sonic, internally mounted
- LED status indicator light
- Exclusive lamp conditioning circuit (patented)
- New fail-safe feature switches light level to high (100%) if sensor is physically damaged
- New 5 minute walk-test feature, easy-set time and sensitivity controls, compact design

LaMar Lighting Company, Inc.

occu-smart® technology

Protected by one or more US Patents Nos. 7,271,543 & 7,081,715

Occu-smart is a registered trademark of LaMar Lighting Co., Inc.

C 2 SERIES

CORDELIA

ordering guide

NOTE: SOME ORDERING OPTIONS APPEAR ON PRODUCT LINE. FOR OTHER OPTIONS, SEE LIST AT RIGHT.

SAMPLE ORDER NUMBER

C2 — 2 — 32 — [ ] — E8 — U — PA — AS — [ ]

SERIES | NO. LAMPS | WATTAGE | TANDEM | BALLAST TYPE | VOLTAGE | LENS OPTION | LIGHTING OPTION | OPTION | DIMENSIONS | LAMP TYPE

T-8 ORDERING GUIDE

C2	1	31U		E8	1, 7, U	PA, PF, PC	FO, AS		6″ x 24″	FB31T8
C2	1	17		E8	1, 7, U	PA, PF, PC	FO, AS		6″ x 24″	F17T8
C2	1	25		E8	1, 7, U	PA, PF, PC	FO, AS		6″ x 36″	F25T8
C2	1	25	T	E8	1, 7, U	PA, PF, PC	2C, FO, AS		6″ x 72″	F25T8
C2	1	32		E8	1, 7, U	PA, PF, PC	FO, AS		6″ x 48″	F32T8
C2	1	32	T	E8	1, 7, U	PA, PF, PC	2C, FO, AS		6″ x 96″	F32T8
C2	2	17		E8	1, 7, U	PA, PF, PC	2C, FO, AS		6″ x 24″	F17T8
C2	2	25		E8	1, 7, U	PA, PF, PC	2C, FO, AS		6″ x 36″	F25T8
C2	2	25	T	E8	1, 7, U	PA, PF, PC	2C, FO, AS		6″ x 36″	F25T8
C2	2	32		E8	1, 7, U	PA, PF, PC	2C, FO, AS		6″ x 48″	F32T8
C2	2	32	T	E8	1, 7, U	PA, PF, PC	2C, FO, AS		6″ x 96″	F32T8

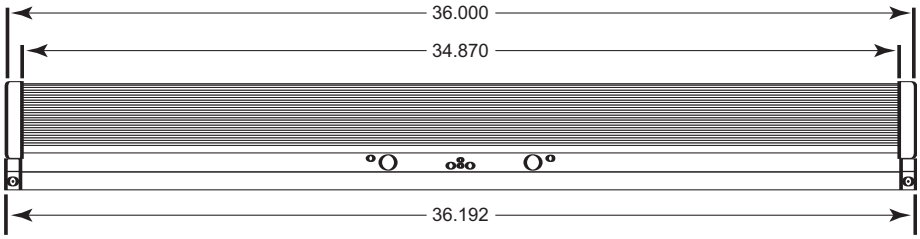
NOTE: TANDEM UNITS CONTAIN DOUBLE THE AMOUNT OF LAMPS SHOWN

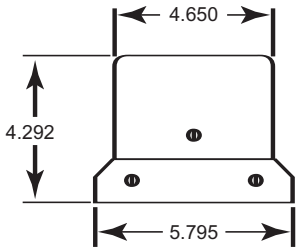
NOTE: STANDBY OPTION "AS" - UNIVERSAL VOLTAGE STANDARD

dimensional data

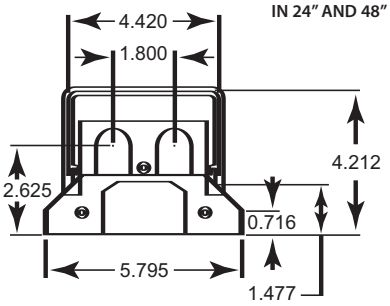
NOTE: SPECIFICATIONS AND DIMENSIONAL DATA ARE SUBJECT TO CHANGE WITHOUT NOTICE.

cross sections





ALSO AVAILABLE IN 24″ AND 48″



options

OPTIONS: INSERT APPROPRIATE CODE FOR CUSTOMIZED ORDERING

BALLAST
E8 Electronic T8
Program rapid start ballasts are used for lamps that are cycled on/off or dimmed

VOLTAGE
1 120V
7 277V
U Universal 120-277V

DIFFUSER OPTIONS
PA Prismatic acrylic
PC Polycarbonate

LIGHTING OPTIONS
2C 1 lamp on constantly/1 lamp sensored
FO All lamps on/off, All lamps sensored on
AS User selectable standby options 5, 10, 20 & 30% Nominal Light Output

GENERAL OPTIONS
EM Emergency pack, 1 lamp 90 min. up to 500 lu.
TP Heavy gauge ends, tamper-proof screws

Consult Factory for higher lumen battery pack availability and additional options not shown or listed

accessories

LAMP OPTIONS
12 T8 741K
15 T8 735K
10 T8 730K
13 T8 841K
16 T8 835K
11 T8 830K

BEFORE INSTALLATION, PLEASE CONSULT YOUR LOCAL ORDINANCES AND BUILDING CODES FOR COMPLIANCE

occu-smart® technology

Protected by one or more US Patents Nos. 7,271,543 & 7,081,715

Revised 5/09

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Fax (631) 777-7705 • Outside NY (800) 724-7743 • www.lamarlighting.com

LaMar Lighting Company, Inc.

LITECONTROL

Type:
Project:

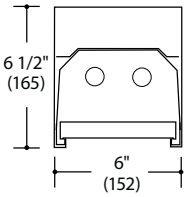
Mod-66™

P-D-66N, S-D-66N

Pendant-Mounted Direct
Surface-Mounted Direct

Specifications

P-D-66N or S-D-66N



HOUSING. Die-formed and welded steel, with 3/8" regression at housing bottom for rigidity and appearance, furnished with 6" long, 20-gauge steel splines for precise alignment at each joint. End headers have clearance holes for easy row installation and are notched under lamps for more even diffuser luminance and continuous baffle appearance.
END CAPS. Steel, 14-gauge, with no holes or knockouts, finished to match housing. Four fasteners on each end cap allow tight attachment to ends of individual fixtures and ends of rows.
REFLECTORS. Standard: Die-formed steel with high-reflectance white finish. Parabolic Reflector/Baffle (**PARSS**): Die-formed semi-specular anodized aluminum reflector and baffle assembly. Available only on P-D-66N and S-D-66N in 1-lamp cross-section.
LAMPING. Available in one- and two-lamp T8. Easy baffle removal to access/replace lamps without tools.
BALLAST. Electronic Ballast (**ELB**), high power factor, thermally protected Class P, Sound Rated A, less than 10% THD, manufactured by a UL Listed manufacturer, as available, determined by Litecontrol. Ballasts with a voltage range of 120 to 277 will be used when fixture configuration and ballast availability allow. The minimum number of ballasts will be used.
TANDEM WIRING. When selected from Ordering guide below, fixtures wired to switch in-line lamps separately, providing two levels of light (two-lamp cross-section fixtures only).
SYSTEM CONNECTORS. Corners, tees, crosses, and straight extensions available. Die-formed 20-gauge steel. Bottom and exposed sides to be smooth with no exposed fasteners or knockouts. Each system connector shall have a rigid cross-member with a .687" diameter stem hole at center to accept any of Litecontrol's pendant assemblies.
MOUNTING. This direct-only fixture may be either surface-mounted or pendant-mounted using Litecontrol's standard suspension system.
CERTIFICATION. Fixture and electrical components shall be UL and/or CUL Listed and shall bear the I.B.E.W., A.F. of L. label.
Note: Litecontrol reserves the right to change specifications without notice for product development and improvement.

Ordering guide

Product, lamping, & length

P -	D -	66N	2	4	T8 -
Mounting	Distribution	Series	Lamp Count	Nominal Length(ft)	Lamp Type
P Pendant-Mounted **S** Surface-Mounted	**D** Direct	**66N**	**1, 2 →** **1, 2 →** **1, 2 →** **2, 4 →** **2, 4 →** see **notes**	**2** **3** **4** **6** **8**	**T8**

Mounting Options
- add to end of order number

Aircraft Cables
- ☐ **FAI/ACC** (field adjustable) *standard*
- ☐ **ACC** (fixed)

Stems
- ☐ **P6S** (stem)
- ☐ **SC/P6** (sloped ceiling)
- ☐ **EQ/P6** (earthquake)

Cross-section lamping

1-T8 P-D	2-T8 P-D	1-T8 PARSS

Options

PBSS -	CWM -	TW -	ELB -	EF -	120
Baffle	Finish	Tandem Wiring	Ballast	Other options	Volts
PARSS (1-lamp) **PBSS** **BW** **PWA** **PAT.12** (XA) **PAT.19** **FP** see **Diffusers**	**CWM** (Matte White) is standard see *LiteColors*™ in Product Guide for other finishes	**- -** **TW** see **notes**	**ELB** is standard **DA/ELB** **HEL/ELB** **ECO/ELB** see **Ballast options**	**EF** **F** see **Other options**	**120** **277**

notes:
Lamp Count = total number of lamps in the fixture
Tandem Wiring not available for one-lamp cross-section fixtures

For Ordering guide information in shaded areas, choose selection by reading ACROSS the shaded areas for correct specifications.

P-D-66N24T8-PBSS-CWM-TW-ELB-EF-120-FAI/ACC is a typical catalog number for a 2-lamp (2 lamps in cross-section), 4-foot long T8 fixture with parabolic baffle, Matte White finish, tandem-wired electronic ballast, emergency fluorescent ballast, 120 volts, mounted with field adjustable aircraft cables.

Questions to Ask
1. 120 or 277 volt? **2.** Row information, including desired fixture length?
3. White, *LiteColor*, or special color? **3.** Diffuser type? **4.** Tandem-wired?
5. Surface-mounted, cables or stems, what length? **6.** Other options?

litecontrol.com

Diffusers

PARSS	Parabolic Reflector/Baffle. Semi-specular anodized aluminum, parabolic reflector with 1.4" high x 2" OC parabolic baffles. **For P-D-66N or S-D-66N one-lamp cross-section fixtures only.**
PBSS	Parabolic Baffle, Semi-specular Aluminum. 1.4" high x 2" OC. (Used with standard reflector.)
BW	Blade Baffle, White. 3/4" high x 3/4" OC, 20-gauge steel, regressed.
PWA	Louver. Parabolic specular aluminum, acrylic 1/2" cube, regressed.
PAT. 12 (XA)	Lens. Diagonal 3/16" conical prisms, .100" thick extruded acrylic, regressed.
PAT.19	Lens. 3/16" square prisms, .156" thick extruded acrylic, regressed.
FP	Lens. White acrylic, .100" thick, regressed.

Ballast options

Specify in place of **ELB**, contact factory for availability/compatibility with lamping:

DA/ELB	Advance Mark VII Dimming Ballast.
HEL/ELB	Osram Sylvania Dimming Ballast.
ECO/ELB	Lutron ECO-10 Dimming Ballast.

Other options

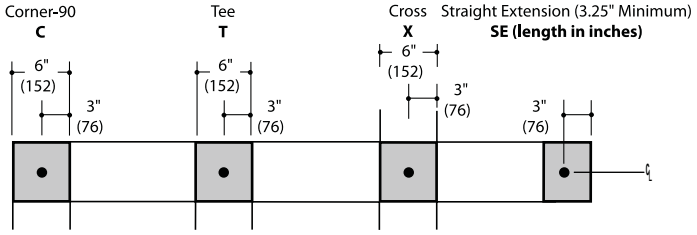
EF	Emergency Fluorescent Ballast. Battery-powered ballast from a UL Listed manufacturer will operate one T8 lamp for 1 1/2 hours.
F	Fuse. Slow or fast blow, determined by Litecontrol.

System connectors

Catalog Number

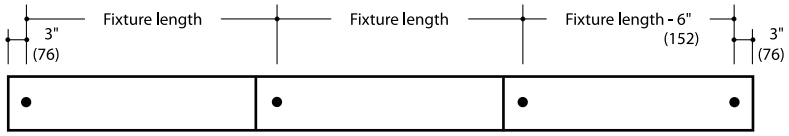
Series	-	Connector	-	Finish
P-D-66N00		C		
P-D-66N00		T		
P-D-66N00		X		
P-D-66N00		SE (length)		

P-D-66N00-C-CWM is a typical catalog number for a 90° corner connector finished Matte White.
P-D-66N00-SE 9.375"-CWM is a typical catalog number for a straight extension 9 3/8" long, finished Matte White.



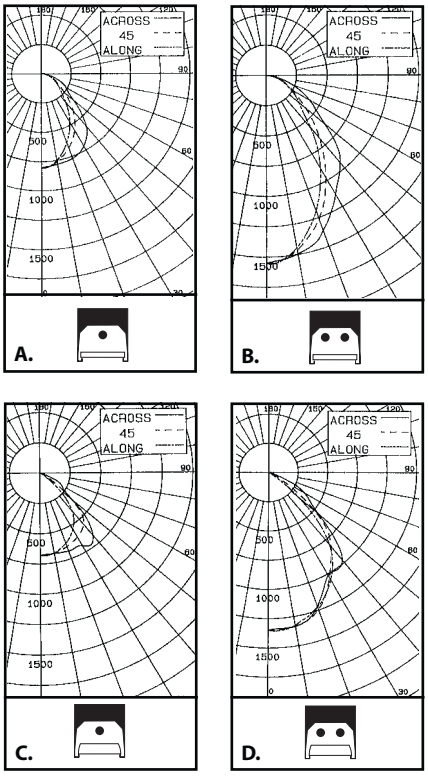
Planning for installation

Row diagram



Fixture Lengths: 2', 3', 4', 6', and 8'
● Indicates pendant locations

Photometric data



A. S-D-66N14T8-BW 54.0% Efficiency
Litecontrol Certified Test Report #12111300

B. S-D-66N24T8-BW 47.2% Efficiency
Litecontrol Certified Test Report #12121300

C. S-D-66N14T8-PBSS 50.9% Efficiency
Litecontrol Certified Test Report #12111340

D. S-D-66N24T8-PBSS 43.3% Efficiency
Litecontrol Certified Test Report #12121340

For photometric information on other combinations, see website.

Click on
Quick Find 66d
litecontrol.com

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MAXLITE™
ENERGY EFFICIENT LIGHTING PRODUCTS

PRODUCT FOCUS

TABLE & FLOOR LAMPS

Energy Saving Fixtures

FOR >> RESIDENTIAL
>> HOSPITALITY/OFFICE
>> COLLEGE CAMPUS
>> DORMITORY

Advanced Technology Fits all GU24 bulb fixtures

MAX9642

ML6G522WI★GU24
ML6G522CSAB★GU24
ML6G522CSNI★GU24

ML5G261CSNI/BP★GU24
ML5G261CSAB/BP★GU24

ML5G261CSNI★GU24
ML5G261CSAB★GU24
ML5G261WI★GU24

- GU24 Fixtures accept all wattages of bulbs with GU24 base
- Table lamps include 1 x 26W 2700K energy efficient GU24 base lamp
- Floor lamps include 2 x 26W 2700K energy efficient GU24 base lamps
- All fixtures ENERGY STAR qualified
- Long lamp life – lasts up to 10,000 hours
- All models; shade included in box.

ENERGY STAR

★ ENERGY STAR® Qualified
GU24= Latest socket technology

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MaxLite West™: 1-800-793-1212 Fax: 909-944-1442 info@maxlite.com www.maxlite.com

*All specifications are subject to change without notice

MAXLITE™
ENERGY EFFICIENT LIGHTING PRODUCTS

PRODUCT FOCUS TABLE & FLOOR LAMPS

Energy Saving Fixtures

ML5G261WI★
10,000 Hour
(7) 6762720438 (8)*

ML5G261CSNI★
10,000 Hour
(7) 6762720436 (4)*

ML5G261CSNI/BP★
10,000 Hour
(7) 6762711521 (9)*

ML6G522CSNI★
10,000 Hour
(7) 6762711519 (6)*

ML6G522CSAB★
10,000 Hour
(7) 6762711434 (2)*

ML6G522WI★
10,000 Hour
(7) 6762722007 (4)*

ML5G261CSAB★
10,000 Hour
(7) 6762720435 (7)*

ML5G261CSAB/BP★
10,000 Hour
(7) 6762711520 (2)*

TABLE LAMP&FLOOR LAMPSPECIFICATIONS

Watts	Order Code	Description	Incandescent Equivalent	Lumens	Lamp Life (Hrs)	Case Pack	Dimensions (W" x MOL")	K
★ 26	70170	ML5G261CSNI 'Classic' Nickel Table Lamp	100	1650	10,000	4	12 x 20	2700
★ 26	70169	ML5G261CSAB 'Classic' Antique Brass Table Lamp	100	1650	10,000	4	12 x 20	2700
★ 26	70173	ML5G261CSNI/BP 'Classic' Nickel Table Lamp Bulk Pk	100	1650	10,000	4	15 x 23	2700
★ 26	70164	ML5G261CSAB/BP 'Classic' Antique Brass Table Lamp Bulk Pk	100	1650	10,000	4	15 x 23	2700
★ 26	70171	ML5G261WI Wrought Iron Table Lamp	100	1650	10,000	4	12 x 20	2700
★ 52	70172	ML6G522CSNI Satin Nickel Floor Lamp	200	3300	10,000	1	17 x 61	2700
★ 52	70185	ML6G522CSAB Antique Brass Floor Lamp	200	3300	10,000	1	17 x 61	2700
★ 52	70187	ML6G522WI Wrought Iron Floor Lamp	200	3300	10,000	1	17 x 61	2700

SPECIAL NOTES

>GU24:
- Two-year warranty
- For GU24 replacement bulbs visit your local lighting and hardware store or go to www.maxlite.com/GU24.
- Now with 90°C Max. Ballast Case Temperature

APPLICATIONS

- Suitable for general lighting in living rooms, dining rooms and bedrooms
- Accent lighting in offices and waiting rooms

LOCATIONS

- Residential
- Hospitality
- Office

BENEFITS

- GU24 Fixtures accept all wattages of bulbs with GU24 base
- Table lamps include 1 x 26W 2700K energy efficient GU24 base lamp
- Floor lamps include 2 x 26W 2700K energy efficient GU24 base lamp
- All fixtures ENERGY STAR qualified
- Long lamp life – lasts 10,000 hours
- All models; shade included in box

SPECIFICATIONS

- Ballast Type >> Electronic
- Starting Method >> Instant Start
- Input Line Voltage >> 120VAC
- Input Line Frequency >> 50/60HZ
- Mini. Starting Temp. >> 0°F
- Max. Operating Temp. >> 100°F
- Max. Ballast Case Temp. >> 90°C
- Color Rendering Index >> 82

MAX9642

All specifications are subject to change without notice

Fits all GU24 bulb fixtures

c UL us LISTED

FCC Certified
* UPC Codes
★ ENERGY STAR® Qualified

MaxLite™: 1-800-555-5629 Fax: 973-244-7300 info@maxlite.com www.maxlite.com
MaxLite West™: 1-800-793-1212 Fax: 909-944-1442 info@maxlite.com www.maxlite.com

Type ..... Catalog number .....

FEATURES

OPTICAL SYSTEM

- Self-flanged, semi-specular or matte-diffuse reflector.
- Patented Vertisys® - Bounding Ray™ Optical Principle design (US Patent #5,800,050) provides lamp before lamp image. Lamp image that reflects smoothly from the top of the reflector to the aperture, providing optimal fixture performance and efficiency.

MECHANICAL SYSTEM

- 16-gauge galvanized steel mounting/plaster frame with friction support clips to retain optical system. Maximum 7/8" ceiling thickness.
- 16-gauge galvanized steel mounting bars with continuous 4" vertical adjustment are shipped pre-installed. Post installation adjustment possible without the use of tools from above or below ceiling.
- Galvanized steel junction box with hinged access covers and spring latch. Two combination 1/2"–3/4" and three 1/2" knockouts for straight-through conduit runs. Capacity: 8 (4 in, 4 out) No. 12 AWG conductors, rated for 90°C.

ELECTRICAL SYSTEM

- Rugged aluminum lampholder housing.
- Vertically-mounted, positive-latch, thermoplastic socket.
- Class P, thermally protected, high power factor electronic ballast mounted to the junction box.
- Simply5™ technology available. SIMPLY5™ LIGHTING INTELLIGENCE

LISTING

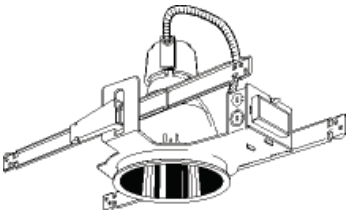
- Fixtures are UL Listed for thru-branch wiring, Non-IC recessed mounting and damp locations. Listed and labeled to comply with Canadian Standards.

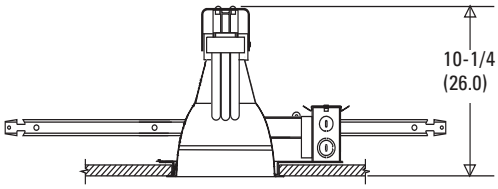
Compact Fluorescent Downlights

6" AFV

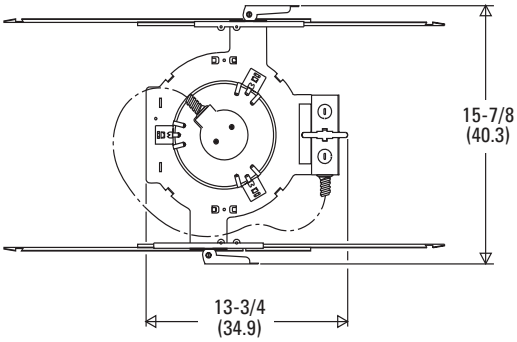
Lensed Reflector

Vertical Double Twin-Tube or Triple-Tube Lamp





Aperture:	6-1/4 (15.9)
Ceiling opening:	7-1/8 (18.1)
Overlap trim:	7-1/2 (19.1)
Lens recess:	1-1/2 (3.8)



All dimensions are inches (centimeters)

*Maximum height depends on lamp wattage/type, dimensions range from 10-1/4" for 18DTT, 26DTT and 42 TRT; 9-3/8" for 13DTT, 18TRT, 26TRT and 32TRT

ORDERING INFORMATION

Example: **AFV 32TRT 6MB CGL MVOLT WLP**

Choose the boldface catalog nomenclature that best suits your needs and write it on the appropriate line. Order accessories as separate catalog numbers (shipped separately).

AFV

Series

AFV

Wattage/Lamp

13DTT
18DTT
26DTT
18TRT
26TRT
32TRT
42TRT

Aperture/Trim color

6AR Clear
6PR Pewter
6UBR Umber
6WTR Wheat
6WR[1] White painted
6MB[1] Black baffle
6WB[1] White baffle

Finish

(blank) Semi-specular
LD Matte-diffuse

Lens type

CGL Clear glass lens
CAL Clear acrylic lens
PCL Clear poly-carbonate lens
T73 Tempered prismatic lens

Voltage

MVOLT[2]
120
277
347

Ballast[3]

(blank) Electronic ballast
DMHL[4] Lutron Compact SE™ electronic dimming ballast. Minimum dimming level 5%
ADEZ[4] Advance Mark 10® electronic dimming ballast. Minimum dimming level 5%
S5[5] SIMPLY5™ system ballast
S5 HW SIMPLY5™ system ballast less Reloc

Options

ELR[6] Emergency battery pack. Remote test switch
GMF[7] Single, slow-blow fuse
GLR[7] Single, fast-blow fuse
TRW White painted flange (standard on MB and WB)
TRBL Black painted flange
GSKT Foam gasketing
WLP With 3500°K lamp (shipped separately)
LRC[8] Provides compatibility with Lithonia Reloc System. Reloc System can be installed less this option with connectors provided by others. Access above ceiling required
CP[9] Chicago Plenum
CSA CSA Certified
BDP[10] Ballast disconnect plug
ELRHL[6] High lumen output emergency battery pack. Remote test switch provided

NOTES
1 Not available with finishes.
2 Multi-volt electronic ballast capable of operating on any line voltage from 120V through 277V, 50 or 60Hz.
3 For additional ballast types, refer to Technical Bulletins tab.
4 Available in 120V or 277V only. Not available with 13DTT.
5 Simply5™ includes 9' S5 MLC Reloc wiring system (shipped separately). Available in 120V or 277V only. Not available in 13W or 18W. See simply5.net for more information.
6 For dimensional changes, refer to Technical Bulletins tab.
7 Not available with MVOLT.
8 For compatible Reloc systems, refer to Technical Bulletins tab.
9 Not available with ELR option.
10 Meets codes that require in-fixture disconnect.

Accessories

Order as separate catalog numbers.

SCA6 Sloped ceiling adapter. Degree of slope must be specified (10D, 15D, 20D, 25D, 30D). Ex: SCA6 10D
CTA4-8 YK Ceiling thickness adapter. (Extends mounting frame to accommodate ceiling thickness up to 4-1/4" DTT and 3-1/4" TRT)

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An Acuity Brands Company

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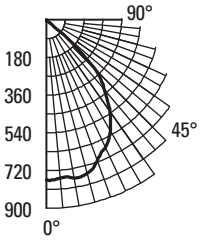
www.gothamlighting.com

AFV 6 LENSED **DCF-390**

6" **AFV** Lensed Reflector

Distribution curve	Distribution data	Output data	Coefficient of utilization	Illuminance Data at 30" Above Floor for a Single Luminaire

AFV 26TRT 6AR CGL, (1) PL-T 26W/30K/4P lamp, 1800 rated lumens, 1.2 s/mh, Test no. LTL7766



From 0°	cp.	Lumens
0°	764	0
5°	800	76
15°	806	228
25°	701	324
35°	579	364
45°	325	252
55°	5	4
65°	0	0
75°	0	0
85°	0	0
90°	0	0

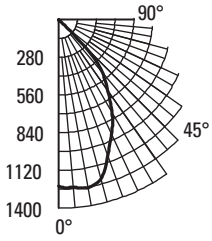
Zone	Lumens	%lamp
0°-30°	629	35.0
0°-40°	993	55.2
0°-60°	1249	69.4
0°-90°	1249	69.4
90°-180°	0	0.0
0°-180°	1249	69.4*

*Efficiency

ρf	80%		20%		70%		50%	
ρc								
ρw	50%	30%	50%	30%	50%	30%	50%	30%
1	76	74	73	70	69	68		
2	70	66	69	64	64	62		
3	64	60	65	58	59	57		
4	59	54	61	53	55	52		
5	54	49	57	48	51	48		
6	50	45	54	44	47	44		
7	46	41	51	41	44	40		
8	43	38	48	37	41	37		
9	40	35	45	34	38	34		
10	37	32	42	32	35	32		

Mount height	Initial fc at beam center	50% beam angle 63.9° Beam diameter	50% beam angle 63.9° fc at beam edge	10% beam angle 93.8° Beam diameter	10% beam angle 93.8° fc at beam edge
8'	25.3	6.9'	12.6	11.8'	2.5
10'	13.6	9.3'	6.8	16.0'	1.3
12'	8.5	11.8'	4.2	20.3'	0.8
14'	5.8	14.3'	2.9	24.6'	0.6
16'	4.2	16.8'	2.1	28.9'	0.4

AFV 32TRT 6AR CGL, (1) PL-T 32W/30K/4P lamp, 2400 rated lumens, 1.0 s/mh, Test no. LTL7728



From 0°	cp.	Lumens
0°	1236	0
5°	1325	126
15°	1252	355
25°	953	441
35°	678	426
45°	258	200
55°	4	4
65°	1	0
75°	0	0
85°	0	0
90°	0	0

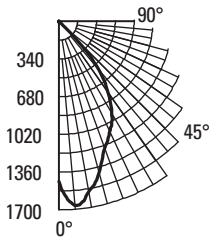
Zone	Lumens	%lamp
0°-30°	922	38.4
0°-40°	1348	56.2
0°-60°	1551	64.6
0°-90°	1552	64.7
90°-180°	0	0.0
0°-180°	1552	64.7*

*Efficiency

ρf	80%		20%		70%		50%	
ρc								
ρw	50%	30%	50%	30%	50%	30%	50%	30%
1	71	69	68	66	64	63		
2	65	63	65	60	60	59		
3	61	57	61	55	56	54		
4	56	52	58	51	53	50		
5	52	48	55	47	49	46		
6	48	44	52	43	46	43		
7	45	41	49	40	43	40		
8	42	38	46	37	40	37		
9	39	35	44	35	38	35		
10	37	33	42	33	36	32		

Mount height	Initial fc at beam center	50% beam angle 55.3° Beam diameter	50% beam angle 55.3° fc at beam edge	10% beam angle 87.6° Beam diameter	10% beam angle 87.6° fc at beam edge
8'	40.9	5.8'	20.4	10.6'	4.0
10'	22.0	7.9'	11.0	14.4'	2.2
12'	13.7	9.9'	6.8	18.2'	1.4
14'	9.3	12.0'	4.7	22.1'	0.9
16'	6.8	14.1'	3.4	25.9'	0.7

AFV 42TRT 6AR CGL, (1) PL-T 42W/30/4P lamp, 3200 rated lumens, 1.0 s/mh, Test no. LTL7729



From 0°	cp.	Lumens
0°	1443	0
5°	1569	150
15°	1349	383
25°	1053	488
35°	756	475
45°	224	174
55°	10	9
65°	4	4
75°	2	2
85°	2	2
90°	0	0

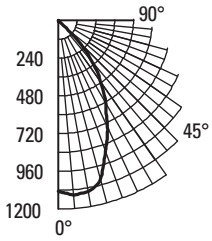
Zone	Lumens	%lamp
0°-30°	1020	31.9
0°-40°	1494	46.7
0°-60°	1677	52.4
0°-90°	1684	52.6
90°-180°	0	0.0
0°-180°	1684	52.6*

*Efficiency

ρf	80%		20%		70%		50%	
ρc								
ρw	50%	30%	50%	30%	50%	30%	50%	30%
1	58	56	55	53	52	52		
2	53	51	53	49	49	48		
3	49	47	50	45	46	44		
4	46	43	47	41	43	41		
5	42	39	45	38	40	38		
6	40	36	42	36	38	35		
7	37	34	40	33	35	33		
8	34	31	38	31	33	30		
9	32	29	36	29	31	28		
10	30	27	34	27	29	27		

Mount height	Initial fc at beam center	50% beam angle 53.7° Beam diameter	50% beam angle 53.7° fc at beam edge	10% beam angle 85.9° Beam diameter	10% beam angle 85.9° fc at beam edge
8'	47.7	5.6'	23.8	10.2'	4.7
10'	25.7	7.6'	12.8	14.0'	2.5
12'	16.0	9.6'	8.0	17.7'	1.6
14'	10.9	11.7'	5.5	21.4'	1.1
16'	7.9	13.7'	4.0	25.1'	0.8

AFV 32TRT 6MB CGL, (1) PL-T 32W/30/4P lamp, 2400 rated lumens, 1.0 s/mh, Test no. LTL7730



From 0°	cp.	Lumens
0°	1087	0
5°	1177	112
15°	1064	302
25°	747	346
35°	483	303
45°	162	126
55°	2	2
65°	0	0
75°	0	0
85°	0	0
90°	0	0

Zone	Lumens	%lamp
0°-30°	760	31.7
0°-40°	1063	44.3
0°-60°	1191	49.6
0°-90°	1191	49.6
90°-180°	0	0.0
0°-180°	1191	49.6*

*Efficiency

ρf	80%		20%		70%		50%	
ρc								
ρw	50%	30%	50%	30%	50%	30%	50%	30%
1	54	53	52	50	49	49		
2	50	48	50	46	46	45		
3	47	44	47	43	44	42		
4	43	41	45	40	41	39		
5	41	38	42	37	38	36		
6	38	35	40	34	36	34		
7	35	32	38	32	34	31		
8	33	30	36	30	32	29		
9	31	28	34	28	30	27		
10	29	26	33	26	28	26		

Mount height	Initial fc at beam center	50% beam angle 50.9° Beam diameter	50% beam angle 50.9° fc at beam edge	10% beam angle 84.3° Beam diameter	10% beam angle 84.3° fc at beam edge
8'	35.9	5.2'	18.0	10.0'	3.6
10'	19.3	7.1'	9.7	13.6'	1.9
12'	12.0	9.0'	6.0	17.2'	1.2
14'	8.2	10.9'	4.1	20.8'	0.8
16'	6.0	12.8'	3.0	24.5'	0.6

NOTES:
1. For electrical characteristics consult Technical Bulletins tab.
2. Tested to current IES and NEMA standards under stabilized laboratoryconditions. Various operating factors can cause differences between laboratory data and actual field measurements. Dimensions and specifications are based on the most current available data and are subject to change without notice.

DCF-390

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DCF-390

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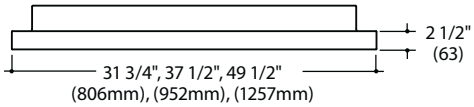
LITECONTROL

Fixture Type:
Project name:



Aura™

P-D-3800, S-D-3800

Pendant-Mounted Direct
Surface-Mounted Direct

Product Description

Part of the Inde-Pendant family of round fixtures, Aura offers a clean metal rim with a flat lens bottom, available in three sizes . This fixture is Cradle to Cradle Silver Certified[CM] by MBDC.

Ordering Guide

Product, Lamping, & Length							Options				
P -	**D -**	**38**	M	3	**0**	**T8U6 -**	**FP -**	TCWM	ELB10	F	120
Mounting	Distribution	Series	Diameter	Lamp Count	Nominal Length(ft)	Lamp Type	Diffuser	Finish	Ballast	Other options	Volts
P Pendant-Mounted **S** Surface-Mounted	**D** Direct	**38**	**S →** **M →** **L →**	**1** **3** **5** see **notes**	**0**	**T8U6**	**FP**	**TCWM** (Textured Matte White) is standard see *LiteColors*™ in Product Guide for other finishes	**ELB10** is standard **DA/MK7** see **notes**	**F** **LP/EF** see **Other options**	**120** **277**

Suspension P6S/ACC X"
See Planning for installation for description.
Specify Dimension "X" from ceiling to top of fixture with order.

notes:
Lamp Count = total number of lamps in the fixture
For Ordering guide information in shaded areas, choose selection by reading ACROSS the shaded areas for correct specifications.

P-D-38M30T8U6-FP-TCWM-ELB10-F-120-P6S/ACC35" is a typical catalog number for a medium diameter 3-lamp direct T8U6 fixture with white acrylic lens, textured matte white finish, electronic ballast, fuse, 120 volts and combination stem/cable mounting with 35 1/4" suspension.

Cross-section lamping

38S 1-U6 | **38M** 3-U6 | **38L** 5-U6

Diameter

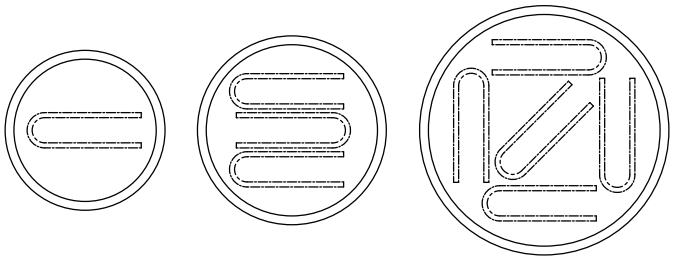
S Small diameter is 31 3/4"
M Medium diameter is 37 1/2"
L Large diameter is 49 1/2"

Ballast Options

Specify in place of **ELB10**
DA/MK7 Dimming electronic ballast, Advance Mark VII.

Other Options

F Fuse. Slow or fast blow, determined by Litecontrol.
LP/EF Low profile emergency dimming ballast.



38S **38M** **38L**

Questions to Ask

1. Diameter of fixture? **2.** White, LiteColor, or special color?
3. Other options? **4.** Dimension "X": advise length and type of suspension required.

revised 11/4/09

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litecontrol.com

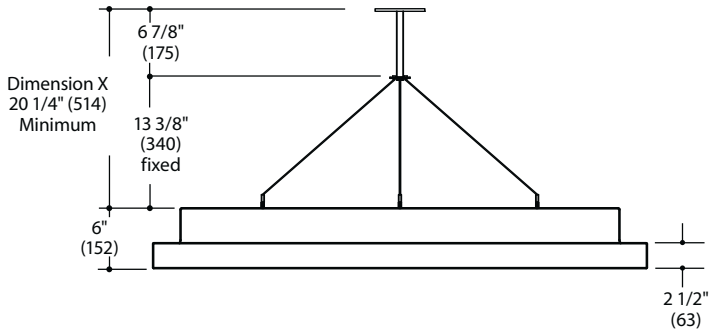
Specifications

HOUSING. Housings are cold rolled spun steel. Small diameter is 31 3/4", medium diameter is 37 1/2" and large diameter is 49 1/2". Housing has 1/4-20 nuts welded to inside of housing.
DIFFUSER. Flat Plastic (**FP**) lens as downlight shield.
LAMPING. T8 U-lamp with 6" leg spacing.
BALLAST. Electronic Ballast (**ELB10**), high power factor, thermally protected Class P, Sound Rated A, manufactured by a UL Listed manufacturer, as available, determined by Litecontrol. The minimum number of ballasts will be used.
BALLAST DISCONNECT. Fixture comes equipped with a ballast disconnect device that consists of a polarized male-female plug set wired between the ballast and the branch circuit conductors supplying the fixture.
SUSPENSION. Each fixture is suspended with one P6S stem plus three aircraft cables and an intermediate retaining plate. The minimum recommended total suspension length is 20 1/4".
CERTIFICATION. Fixture and electrical components shall be UL and/or CUL Listed and shall bear the I.B.E.W., A.F. of L. label. This fixture is Cradle to Cradle Certified[CM] Silver by MBDC.

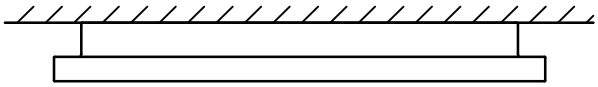
Note: Litecontrol reserves the right to change specifications without notice for product development and improvement.

Planning for installation

Pendant-mount



Surface-mount



Suspension Assembly & Mounting:

P6S/ACC

Provided with a combination P6S (5/8" diameter) stem and three-cable (3/32" diameter aircraft cable) assembly. The stem mounts to a 3 1/2" octagonal x 2 1/8" deep outlet box independently supported above the ceiling plane. The outlet box is then covered by a 5" diameter x 1/4" deep canopy (provided).

Suspension Length:

P6S/ACC

Per the diagram above, specify the dimension "X" for ceiling-to-top-of-fixture suspension length. Standard lengths for dimension "X" available for Aura are: 20 1/4", 23 1/4", and 35 1/4". The standard length of the aircraft portion of the suspension is 13 3/8", and the stem length will be determined by Litecontrol to complete the specified total suspension dimension "X". The aircraft cable attachments provide vertical adjustment to the overall suspension of about 1/2". For special suspension requirements, including dimensions "X" other than those listed above, contact factory.

Cradle to Cradle Certified[CM] is a certification mark of MBDC.

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JUNO®

TRAC-MASTER®

MHv™ Metal Halide Trac

CYLINDRA™ T4, GU6.5 LAMPHOLDERS

TM254

Project: _____

Fixture Type: _____

Location: _____

Contact/Phone: _____

PRODUCT DESCRIPTION

The contemporary styling of the Cylindra fixture enables it to subtly enhance practically any decor without diverting attention from the surrounding environment. Soft curved surfaces combine with clean, crisp edges to provide a uniquely attractive aesthetic. Cylindra's integral, twist-on accessory holder accommodates one accessory. Combined with the new vertical ballast design, the MHv Series offers practical functionality with one of the smallest footprints in CMH Trac fixtures.

T4 ceramic metal halide lamps produce light output equivalent to halogen lamps of 3-4 times the wattage. They produce a crisp, white light in 3000K color temperature with a color rendering index of up to 80+. Combined with new electronic ballast technology, these lamps last up to 12,000 hours with no perceived shift in color temperature. Ceramic metal halide trac fixtures are ideal for accent and perimeter lighting from higher ceilings and/or to create dramatic accents in settings, such as display windows, where contrast with high ambient light levels are required.

PRODUCT SPECIFICATIONS

Construction Die cast aluminum housing • Extruded aluminum vertically mounted ballast housing.

Socket GU6.5 twist & lock bi-pin base, ceramic/PPS • 5kV rated with nickel plated contacts.

Aiming Full 360˚ horizontal coverage eliminates aiming dead spots • 90˚ vertical aiming capability.

Reflector Precision designed integral reflector provides either spot, flood or narrow flood distributions with commonly available T4 GU6.5 lamps • Faceted reflector ensures a properly color-mixed beam • Accessory reflector assemblies available to convert from one beam distribution to another without the use of tools.

Accessory Holder Integral to fixture design • Die cast aluminum construction • Simple threaded mounting design • Accommodates one accessory • Fixture includes clear glass lens.

Adapter Oversized trac adapter for greater mounting stability • Copper alloy contacts provide precise spring action - no arcing and will not take a set • True, positive electrical ground • On/off switch included • Patented embossed polarity arrows on bottom of adapter • Spring-loaded positive latch with embossed polarity arrows secures trac light to trac • "Pull-up" contact to up position for two-circuit application.

Ballast Premium, high efficiency electronic enclosed in an extruded aluminum monolith • Provides optimum color stability and CRI uniformity from fixture to fixture • Controlled lamp output ensures stable normal operation maximizing lamp life • Faster hot restrike and lamp warm-up time compared to magnetic ballast • Automatic resetting thermal protection • MOV transient protection • End-of-life shutdown prevents nuisance cycling and flashing.

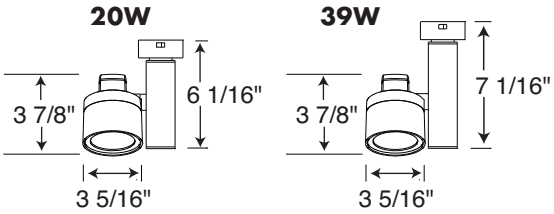
Labels UL and C-UL Listed.

Product specifications subject to change without notice.

T4 Metal Halide

Lamp 20W or 39W T4 **GU6.5 twist & lock bi-pin** base ceramic metal halide lamp.

Catalog Number	Distribution	Ballast	Finish	Lamp
TM254-20-WH-SP	13˚ Spot	20W	White	20W T4 GU6.5 Metal Halide
TM254-20-BL-SP	13˚ Spot	20W	Black	20W T4 GU6.5 Metal Halide
TM254-20-SL-SP	13˚ Spot	20W	Silver	20W T4 GU6.5 Metal Halide
TM254-20-WH-NFL	25˚ Narrow Flood	20W	White	20W T4 GU6.5 Metal Halide
TM254-20-BL-NFL	25˚ Narrow Flood	20W	Black	20W T4 GU6.5 Metal Halide
TM254-20-SL-NFL	25˚ Narrow Flood	20W	Silver	20W T4 GU6.5 Metal Halide
TM254-20-WH-FL	38˚ Flood	20W	White	20W T4 GU6.5 Metal Halide
TM254-20-BL-FL	38˚ Flood	20W	Black	20W T4 GU6.5 Metal Halide
TM254-20-SL-FL	38˚ Flood	20W	Silver	20W T4 GU6.5 Metal Halide
TM254-39-WH-SP	13˚ Spot	39W	White	39W T4 GU6.5 Metal Halide
TM254-39-BL-SP	13˚ Spot	39W	Black	39W T4 GU6.5 Metal Halide
TM254-39-SL-SP	13˚ Spot	39W	Silver	39W T4 GU6.5 Metal Halide
TM254-39-WH-NFL	25˚ Narrow Flood	39W	White	39W T4 GU6.5 Metal Halide
TM254-39-BL-NFL	25˚ Narrow Flood	39W	Black	39W T4 GU6.5 Metal Halide
TM254-39-SL-NFL	25˚ Narrow Flood	39W	Silver	39W T4 GU6.5 Metal Halide
TM254-39-WH-FL	38˚ Flood	39W	White	39W T4 GU6.5 Metal Halide
TM254-39-BL-FL	38˚ Flood	39W	Black	39W T4 GU6.5 Metal Halide
TM254-39-SL-FL	38˚ Flood	39W	Silver	39W T4 GU6.5 Metal Halide



ACCESSORIES	
Cat. No.	**Description**
TMR1-MINI-SP	Replacement Reflector, Spot
TMR1-MINI-NFL	Replacement Reflector, Narrow Flood
TMR1-MINI-FL	Replacement Reflector, Flood
T43	Monopoint
T591-6	Color Filters
T5928BL	Hexcell Louver
T5919	Dichroic Color Correction Lens (2700K)/UV Filter
T5921	Uniformity Lens
T5922	UV Filter
T597	Prismatic Spread Lens
T598	Linear Spread Lens

See specification sheet D1.2.0 and D1.2.2 for details.

REV-6/09

JUNO LIGHTING GROUP by Schneider Electric

TRAC-MASTER®

MHV™ Metal Halide Trac

CYLINDRA™ T4, GU6.5 LAMPHOLDERS

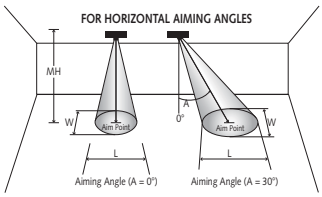
TM254

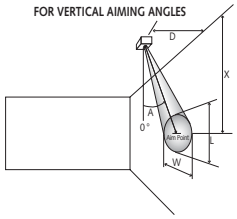
ENGINEERING DATA

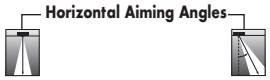
	20W	39W
ANSI #	M-156	M-130
Input Voltage	120V	120V
Input Current	0.20A	0.38A
Input Power	24.5W	45W
Power Factor	>.90	>.90
Lamp Current Crest Factor	<1.4 Typ.	<1.5 Typ.
Ballast Factor	1.0 Typ.	1.0 Typ.
T.H.D.	<20%	<20%
Max. Recommended Ambient Operating Temperature	40° C	40° C
EMI	FCC Part 18 Class B	FCC Part 18 Class B
Sound Rating	A	A

CBCP • Centerbeam candlepower
FC • Footcandles at beam center (aim point)

In vertical aiming applications, aim point (X) is determined by dividing distance from the wall (D) by the tangent of the desired aim angle (A) (0.5774 for 30˚, 1.0 for 45˚, 1.732 for 60˚).







Lamp	Beam Type	Beam Spread°	Rated Life	CBCP	0° MH	0° FC	0° L	0° W	30° FC	30° L	30° W	30° D	30° FC	30° X	30° L	30° W	45° FC	45° X	45° L	45° W	60° D	60° FC	60° X	60° L	60° W
20W T4 Ceramic Metal Halide	SP	**13°**	12000	8301	6	231	1.4	1.4	150	1.8	1.6	3	115	5.2	2.8	1.4	326	3.0	1.4	1.0	6	150	3.5	1.8	1.6
					8	130	1.8	1.8	84	2.4	2.1	4	65	6.9	3.8	1.8	183	4.0	1.8	1.3	9	67	5.2	2.7	2.4
					10	83	2.3	2.3	54	3.1	2.6	5	42	8.7	4.7	2.3	117	5.0	2.3	1.6	12	37	6.9	3.7	3.2
					12	58	2.7	2.7	37	3.7	3.2	6	29	10.4	5.7	2.7	82	6.0	2.8	1.9	15	24	8.7	4.6	3.9
					14	42	3.2	3.2	28	4.3	3.7	7	21	12.1	6.6	3.2	60	7.0	3.2	2.3	18	17	10.4	5.5	4.7
	FL	**25°**	12000	3447	4	215	1.8	1.8	140	2.4	2.0	2	108	3.5	4.2	1.8	305	2.0	1.9	1.3	4	140	2.3	2.4	2.0
					6	96	2.7	2.7	62	3.6	3.1	3	48	5.2	6.2	2.7	135	3.0	2.8	1.9	6	62	3.5	3.6	3.1
					8	54	3.5	3.5	35	4.8	4.1	4	27	6.9	8.3	3.5	76	4.0	3.7	2.5	8	35	4.6	4.8	4.1
					10	34	4.4	4.4	22	6.0	5.1	5	17	8.7	10.4	4.4	49	5.0	4.7	3.1	10	22	5.8	6.0	5.1
					12	24	5.3	5.3	16	7.2	6.1	6	12	10.4	12.5	5.3	34	6.0	5.6	3.8	12	16	6.9	7.2	6.1
	WFL	**38°**	12000	1910	4	119	2.8	2.8	78	3.8	3.2	2	60	3.5	8.6	2.8	169	2.0	3.1	1.9	2	310	1.2	1.9	1.6
					5	76	3.4	3.4	50	4.8	4.0	3	27	5.2	12.8	4.1	75	3.0	4.7	2.9	3	138	1.7	2.9	2.4
					6	53	4.1	4.1	34	5.7	4.8	4	15	6.9	17.1	5.5	42	4.0	6.3	3.9	4	78	2.3	3.8	3.2
					7	39	4.8	4.8	25	6.7	5.6	5	10	8.7	21.4	6.9	27	5.0	7.8	4.9	5	50	2.9	4.8	4.0
					8	30	5.5	5.5	19	7.6	6.4	6	7	10.4	**	8.3	19	6.0	9.4	5.8	6	34	3.5	5.7	4.8
39W T4 Ceramic Metal Halide	SP	**13°**	10000	17432	10	174	2.3	2.3	113	3.1	2.6	4	136	6.9	3.8	1.8	385	4.0	1.8	1.3	6	315	3.5	1.8	1.6
					12	121	2.7	2.7	79	3.7	3.2	5	87	8.7	4.7	2.3	247	5.0	2.3	1.6	9	140	5.2	2.7	2.4
					14	89	3.2	3.2	58	4.3	3.7	6	61	10.4	5.7	2.7	171	6.0	2.8	1.9	12	79	6.9	3.7	3.2
					16	68	3.6	3.6	44	4.9	4.2	7	44	12.1	6.6	3.2	126	7.0	3.2	2.3	15	50	8.7	4.6	3.9
					18	54	4.1	4.1	35	5.5	4.7	8	34	13.9	7.6	3.6	96	8.0	3.7	2.6	18	35	10.4	5.5	4.7
	FL	**25°**	10000	7239	8	113	3.5	3.5	73	4.8	4.1	3	101	5.2	6.2	2.7	284	3.0	2.8	1.9	4	294	2.3	2.4	2.0
					10	72	4.4	4.4	47	6.0	5.1	4	57	6.9	8.3	3.5	160	4.0	3.7	2.5	6	131	3.5	3.6	3.1
					12	50	5.3	5.3	33	7.2	6.1	5	36	8.7	10.4	4.4	102	5.0	4.7	3.1	8	73	4.6	4.8	4.1
					14	37	6.2	6.2	24	8.4	7.2	6	25	10.4	12.5	5.3	71	6.0	5.6	3.8	10	47	5.8	6.0	5.1
					16	28	7.1	7.1	18	9.6	8.2	7	18	12.1	14.6	6.2	52	7.0	6.5	4.4	12	33	6.9	7.2	6.1
	WFL	**38°**	10000	4011	6	111	4.1	4.1	72	5.7	4.8	2	125	3.5	8.6	2.8	355	2.0	3.1	1.9	3	289	1.7	2.9	2.4
					7	82	4.8	4.8	53	6.7	5.6	3	56	5.2	12.8	4.1	158	3.0	4.7	2.9	4	163	2.3	3.8	3.2
					8	63	5.5	5.5	41	7.6	6.4	4	31	6.9	17.1	5.5	89	4.0	6.3	3.9	5	104	2.9	4.8	4.0
					9	50	6.2	6.2	32	8.6	7.2	5	20	8.7	21.4	6.9	57	5.0	7.8	4.9	6	72	3.5	5.7	4.8
					10	40	6.9	6.9	26	9.6	8.0	6	14	10.4	**	8.3	39	6.0	9.4	5.8	7	53	4.0	6.7	5.6

The beam spread in degrees and the beam "L" and "W" in the following tables are computed at 50% of centerbeam candlepower and represent areas of "effective illumination."
**Due to steep aiming angle, length of beam extends beyond 25'.

Juno Lighting Group by Schneider Electric
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JUNO

TRAC-MASTER®

Avant Garde

CYLINDRA™ 22W LED

T253LED

Project: _____

Fixture Type: _____

Location: _____

Contact/Phone: _____

PRODUCT DESCRIPTION

The Cylindra™ 22W LED approximates the light output and distribution of 75W PAR30 halogen lamps, utilizing less than 1/3 of the energy and having a rated life of 50,000 hours. Available in 3000K and 4100K color temperatures, the white-light Cylindra LED is compatible with all Juno line voltage trac and monopoints. The contemporary styling of the Cylindra LED enables it to subtly enhance practically any decor without diverting attention from the surrounding environment. Soft curved surfaces combine with clean, crisp edges to provide a uniquely attractive aesthetic. Cylindra's integral, bayonet-mounted accessory holder accommodates up to two accessories if desired.

Cylindra 22W LED

Construction Die cast aluminum housing and custom designed concealed heat sink provides outstanding thermal management, yielding 70% average lumen maintenance at 50,000 hours of operation • Fashionable, elegant design complements any decor • Available in white, black and silver painted finishes.

LED Lumileds LUXEON Rebel LEDs provide outstanding reliability, performance and color quality/consistency • 3000K or 4100K white phosphor high performance LEDs • High CRI of 85 typical.

Driver Concealed in rear housing to minimize overall fixture footprint • Solid state electronic, Class 2 compliant • Integral overcurrent and short circuit protection • Class B FCC Part 15 rated • Not rated for dimming.

Optics Available in three factory-configured beam spreads • Beam patterns can be altered as desired using a variety of available light control accessories.

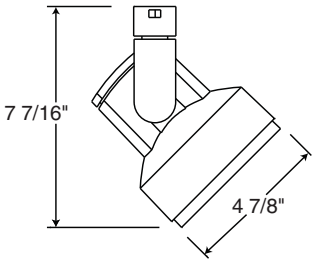
Adapter Copper alloy contacts provide precise spring action - no arcing and will not take a set • True, positive electrical ground • On/off switch included • Patented embossed polarity arrows on bottom of adapter • Spring-loaded positive latch with embossed polarity arrows secures trac fixture to trac • "Pull-up" contact to up position for two-circuit application.

Accessory Holder Integral to fixture design • Die cast aluminum construction • Precision bayonet mounting • Accommodates up to two accessories if desired.

Aiming 345° horizontal rotation • 90° vertical aiming capability.

Labels UL and C-UL Listed.

Product specifications subject to change without notice.



Catalog Number	Finish	Color Temperature	Nominal Wattage	Beam Spread
T253LED-3K-SP-WH	White	3000K	22W	10° Spot
T253LED-3K-SP-BL	Black	3000K	22W	10° Spot
T253LED-3K-SP-SL	Silver	3000K	22W	10° Spot
T253LED-3K-NFL-WH	White	3000K	22W	23° Narrow Flood
T253LED-3K-NFL-BL	Black	3000K	22W	23° Narrow Flood
T253LED-3K-NFL-SL	Silver	3000K	22W	23° Narrow Flood
T253LED-3K-FL-WH	White	3000K	22W	53° Wide Flood
T253LED-3K-FL-BL	Black	3000K	22W	53° Wide Flood
T253LED-3K-FL-SL	Silver	3000K	22W	53° Wide Flood
T253LED-4K-SP-WH	White	4100K	22W	10° Spot
T253LED-4K-SP-BL	Black	4100K	22W	10° Spot
T253LED-4K-SP-SL	Silver	4100K	22W	10° Spot
T253LED-4K-NFL-WH	White	4100K	22W	23° Narrow Flood
T253LED-4K-NFL-BL	Black	4100K	22W	23° Narrow Flood
T253LED-4K-NFL-SL	Silver	4100K	22W	23° Narrow Flood
T253LED-4K-FL-WH	White	4100K	22W	53° Wide Flood
T253LED-4K-FL-BL	Black	4100K	22W	53° Wide Flood
T253LED-4K-FL-SL	Silver	4100K	22W	53° Wide Flood

REV-4/5/10

ACCESSORIES

Cat. No.	Description
T569BL	Cube Cell Louver
T561-6	Color Filters
T5618	Color Correction Filter[1]
T5621	Uniformity Lens
T5622	UV Filter
T5677	Prismatic Spread Lens
T5678	Linear Spread Lens

See specification sheet D1.2.2 for details.

[1] T5618 corrects 3000K color to approximately 2700K and 4100K color to approximately 3500K.

JUNO LIGHTING GROUP by Schneider Electric

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Avant Garde

CYLINDRA™ 22W LED

T253LED

PERFORMANCE DATA[1]

Catalog Number	Input Voltage	Watts (Maximum)	Watts (Typical)	Lumens	Efficacy (LPW)	Rated Life (Hours)
T253LED-3K-SP	120V	25W	22.7W	967	43	50,000
T253LED-3K-NFL	120V	25W	22.7W	950	42	50,000
T253LED-3K-FL	120V	25W	22.7W	889	39	50,000
T253LED-4K-SP	120V	25W	22.7W	1063	47	50,000
T253LED-4K-NFL	120V	25W	22.7W	1045	46	50,000
T253LED-4K-FL	120V	25W	22.7W	978	43	50,000

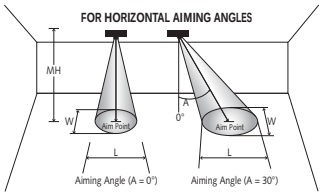
[1]Performance data, including Rated Life, is based on measurements of an individual fixture operating in a 25˚C ambient.

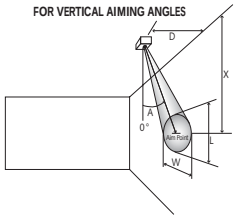
ELECTRICAL DATA

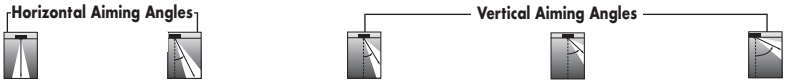
Input Voltage	120V
Input Current (max.)	0.2A
Power Factor	>0.92
T.H.D.	<20%

CBCP • Centerbeam candlepower
FC • Footcandles at beam center (aim point)

In vertical aiming applications, aim point (X) is determined by dividing distance from the wall (D) by the tangent of the desired aim angle (A) (0.5774 for 30˚, 1.0 for 45˚, 1.732 for 60˚).







Lamp	Beam Type	Beam Spread°	Rated Life	CBCP	0° MH	0° FC	0° L	0° W	30° FC	30° L	30° W	30° D	30° FC	30° X	30° L	30° W	45° FC	45° X	45° L	45° W	60° D	60° FC	60° X	60° L	60° W
Cylindra 22W LED, 3000K Spot	SP	**10°**	50000	20688	8	323	1.4	1.4	210	1.9	1.6	4	162	6.9	2.9	1.4	457	4.0	1.4	1.0	6	373	3.5	1.4	1.2
					10	207	1.7	1.7	134	2.3	2.0	6	72	10.4	4.3	2.1	203	6.0	2.1	1.5	9	166	5.2	2.1	1.8
					12	144	2.1	2.1	93	2.8	2.4	8	40	13.9	5.7	2.8	114	8.0	2.8	2.0	12	93	6.9	2.8	2.4
					14	106	2.4	2.4	69	3.3	2.8	10	26	17.3	7.2	3.5	73	10.0	3.5	2.5	15	60	8.7	3.5	3.0
					16	81	2.8	2.8	52	3.7	3.2	12	18	20.8	8.6	4.2	51	12.0	4.2	3.0	18	41	10.4	4.2	3.6
Cylindra 22W LED, 3000K Narrow Flood	NFL	**23°**	50000	5119	4	320	1.6	1.6	208	2.2	1.9	2	160	3.5	3.7	1.6	452	2.0	1.7	1.2	4	208	2.3	2.2	1.9
					6	142	2.4	2.4	92	3.3	2.8	3	71	5.2	5.6	2.4	201	3.0	2.5	1.7	6	92	3.5	3.3	2.8
					8	80	3.3	3.3	52	4.4	3.8	4	40	6.9	7.4	3.3	113	4.0	3.4	2.3	8	52	4.6	4.4	3.8
					10	51	4.1	4.1	33	5.5	4.7	5	26	8.7	9.3	4.1	72	5.0	4.2	2.9	10	33	5.8	5.5	4.7
					12	36	4.9	4.9	23	6.6	5.6	6	18	10.4	11.2	4.9	50	6.0	5.1	3.5	12	23	6.9	6.6	5.6
Cylindra 22W LED, 3000K Wide Flood	WFL	**53°**	50000	1139	3	127	3.0	3.0	82	4.3	3.5	2	36	3.5	**	4.0	101	2.0	5.3	2.8	2	185	1.2	2.9	2.3
					4	71	4.0	4.0	46	5.8	4.6	3	16	5.2	**	6.0	45	3.0	8.0	4.2	3	82	1.7	4.3	3.5
					5	46	5.0	5.0	30	7.2	5.8	4	9	6.9	**	8.0	25	4.0	10.6	5.6	4	46	2.3	5.8	4.6
					6	32	6.0	6.0	21	8.7	6.9	5	6	8.7	**	10.0	16	5.0	13.3	7.1	5	30	2.9	7.2	5.8
					7	23	7.0	7.0	15	10.1	8.1	6	4	10.4	**	12.0	11	6.0	15.9	8.5	6	21	3.5	8.7	6.9

For 4100K fixtures, use 1.11 multiplier.

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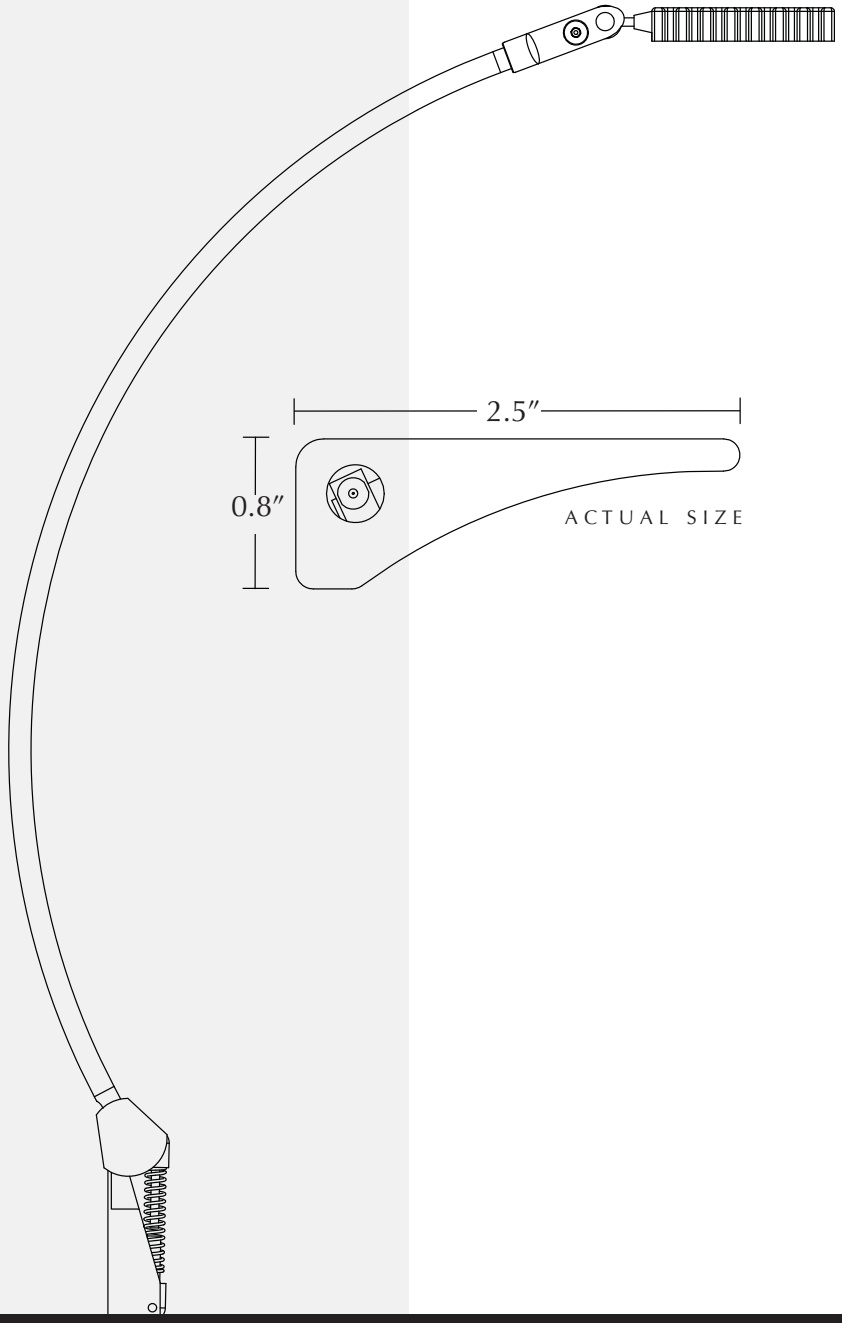
JUNO LIGHTING GROUP by Schneider Electric

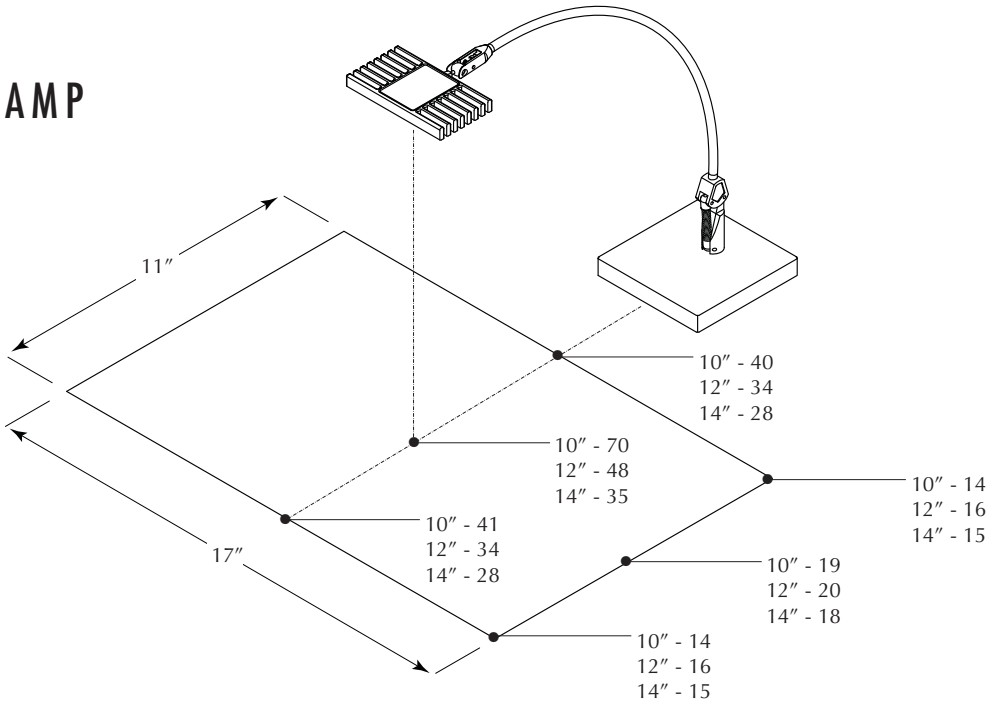
FINELITE'S **PERSONAL LIGHTING SYSTEM**

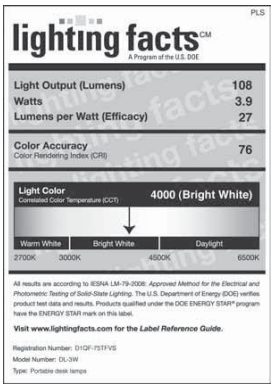
SPECIFICATIONS



3W DESK LAMP

Initial illuminance values in footcandles calculated using LM79 photometric reports to the desk surface at 10″, 12″ and 14″, lamp head mounting heights.





PLS

lighting factsCM
A Program of the U.S. DOE

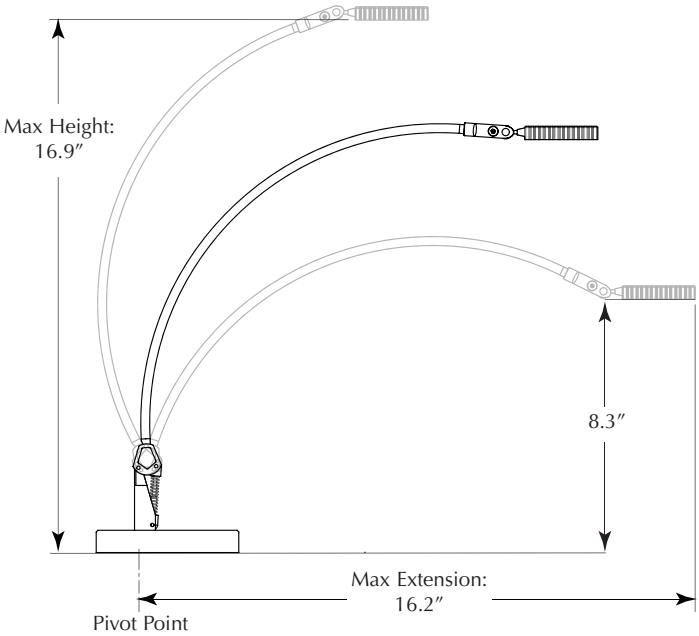
Light Output (Lumens)	108
Watts	3.9
Lumens per Watt (Efficacy)	27
Color Accuracy Color Rendering Index (CRI)	76
Light Color Correlated Color Temperature (CCT)	4000 (Bright White)

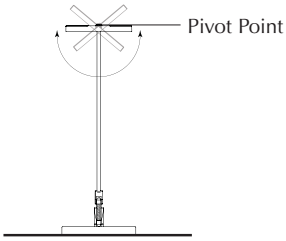
Warm White | Bright White | Daylight
2700K 3000K 4500K 6500K

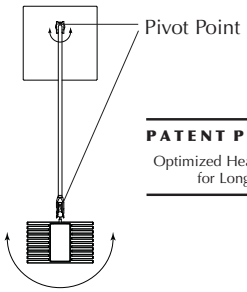
All results are according to IESNA LM-79-2008: *Approved Method for the Electrical and Photometric Testing of Solid-State Lighting*. The U.S. Department of Energy (DOE) verifies product test data and results. Products qualified under the DOE ENERGY STAR® program have the ENERGY STAR mark on this label.

Visit www.lightingfacts.com for the *Label Reference Guide*.

Registration Number: D1QF-7STFVS
Model Number: DL-3W
Type: Portable desk lamps



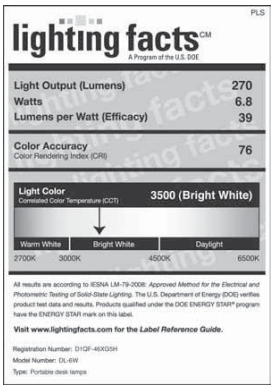


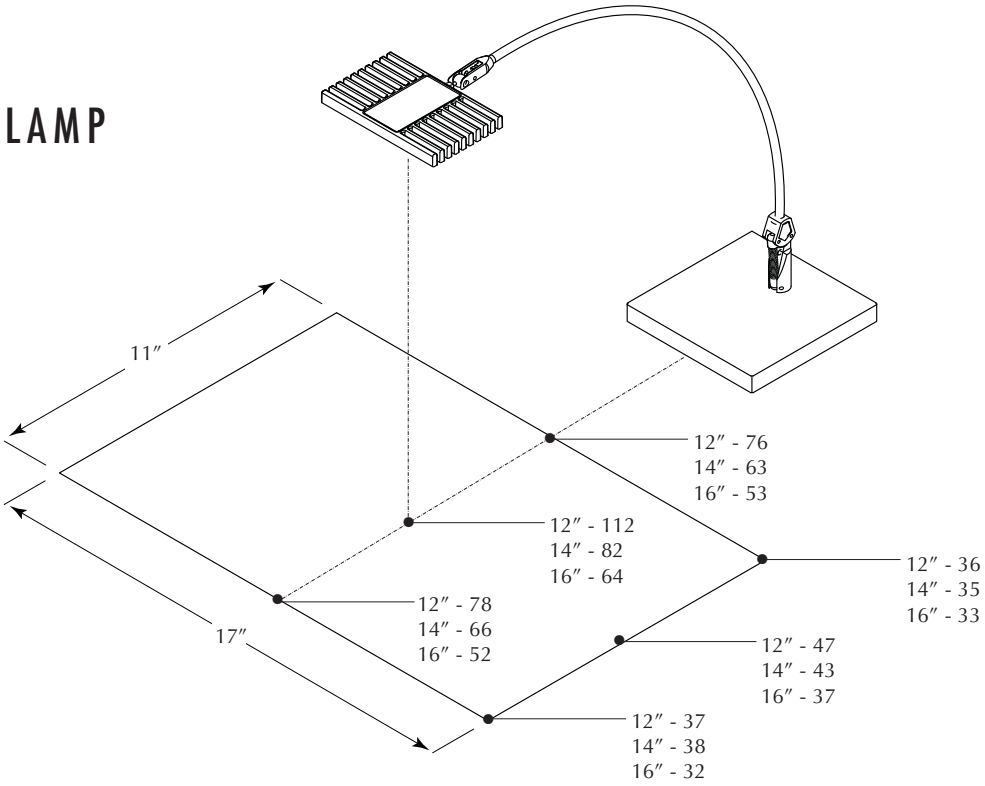


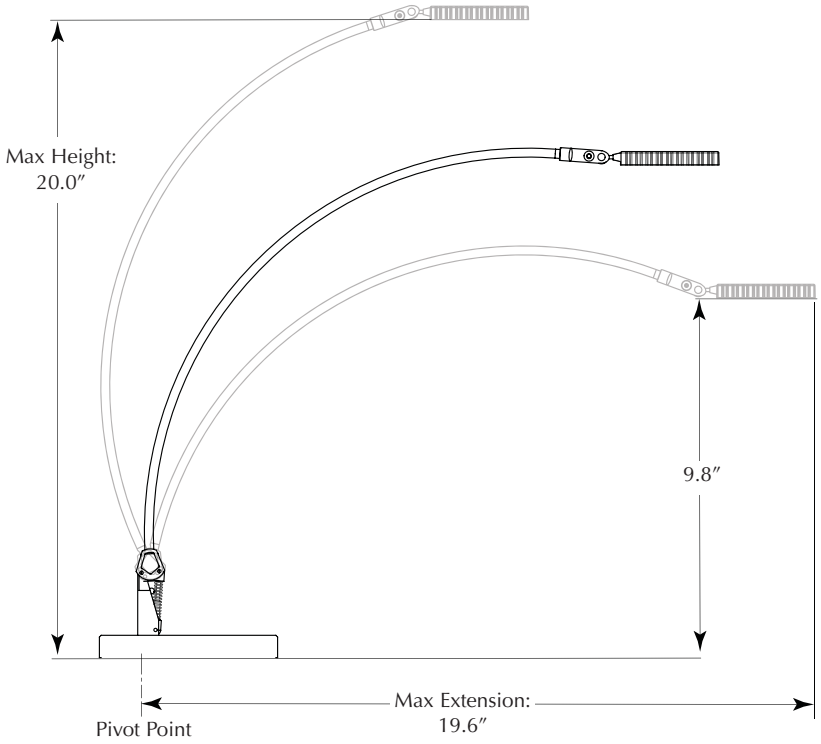
PATENT PENDING
Optimized Heat Radiation for Long Life

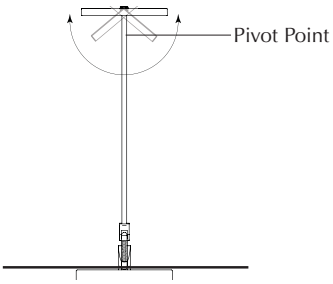
6W DESK LAMP

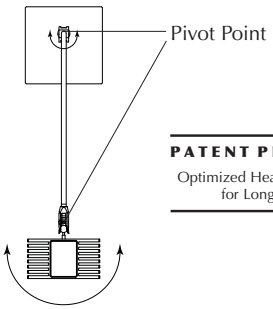
Initial illuminance values in footcandles calculated using LM79 photometric reports to the desk surface at 10″, 12″ and 14″, lamp head mounting heights.









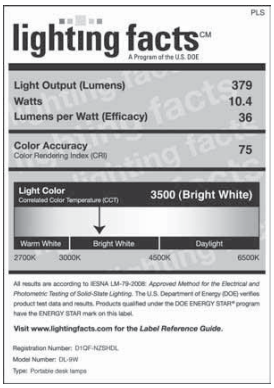


PATENT PENDING

Optimized Heat Radiation for Long Life

9W DESK LAMP

Initial illuminance values in footcandles calculated using LM79 photometric reports to the desk surface at 10″, 12″ and 14″, lamp head mounting heights.


PLS

lighting facts℠
A Program of the U.S. DOE

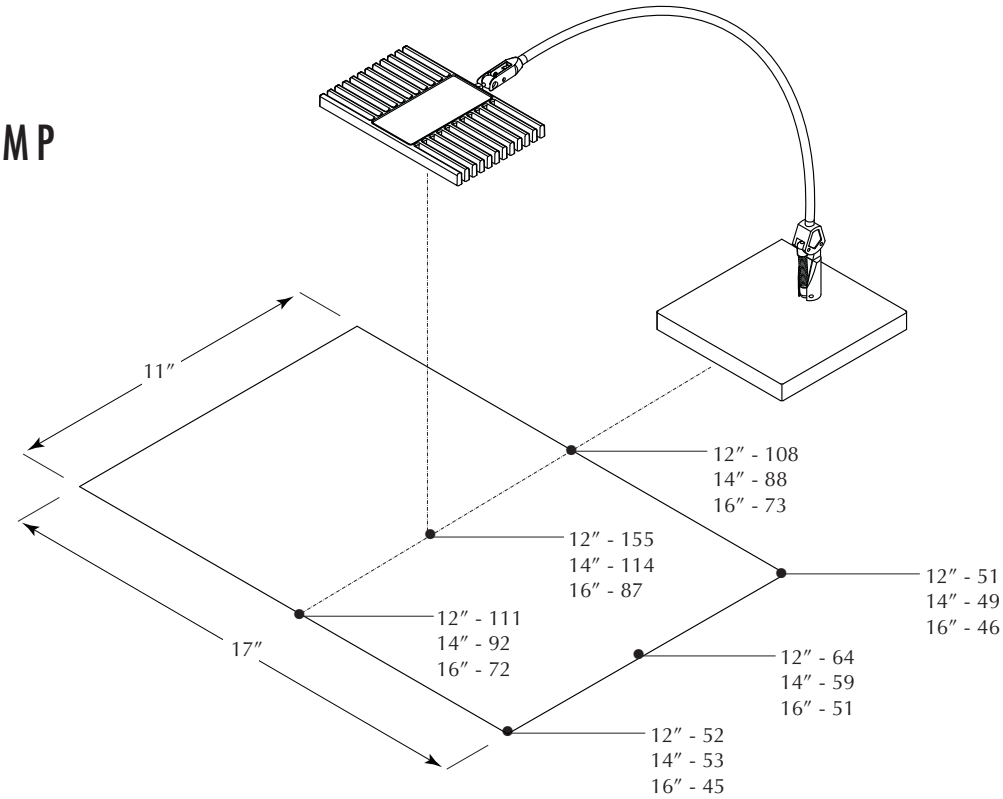
Light Output (Lumens)	379
Watts	10.4
Lumens per Watt (Efficacy)	36
Color Accuracy Color Rendering Index (CRI)	75
Light Color Correlated Color Temperature (CCT)	3500 (Bright White)

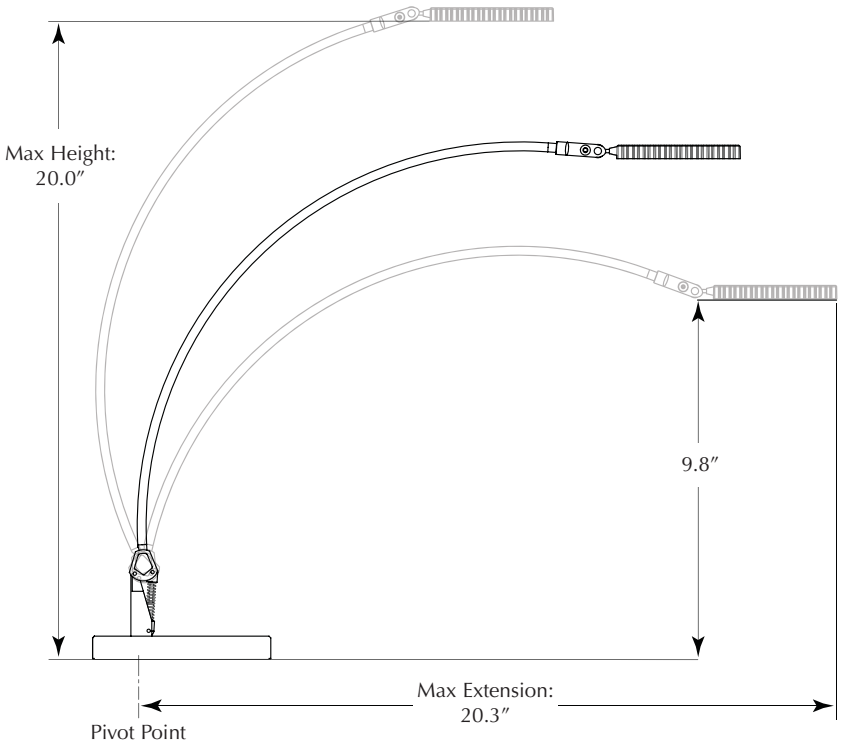
Warm White | Bright White | Daylight
2700K 3000K 4500K 6500K

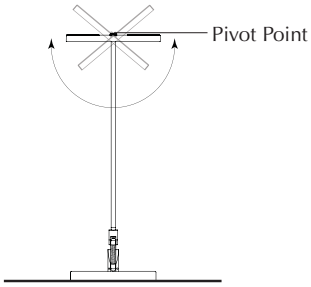
All results are according to IESNA LM-79-2008: *Approved Method for the Electrical and Photometric Testing of Solid-State Lighting*. The U.S. Department of Energy (DOE) verifies product test data and results. Products qualified under the DOE ENERGY STAR® program have the ENERGY STAR mark on this label.

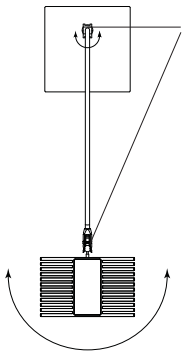
Visit www.lightingfacts.com for the *Label Reference Guide*.

Registration Number: D1QF-NZSHDL
Model Number: DL-9W
Type: Portable desk lamps









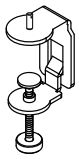
PATENT PENDING
Optimized Heat Radiation for Long Life

DESK LAMP TECHNICAL SPECIFICATIONS

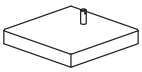
• **Light Source**	Solid State Lighting: 1-Watt Warm White LEDs
• **Junction Temperature**	T_j < 80 °C (175°F)
• **Light Source Life**	> 50,000 hours
• **Color Temperature**	3500 K (3W DL - 4000K)
• **Fixture Efficacy**	27-39 Lm/W
• **Cabling**	12-ft low voltage power cable with in-line switch
• **Certification**	UL / C-UL Listed
• **Power Supplies**	See last page for more information.

	3W Desk Lamp	**6W Desk Lamp**	**9W Desk Lamp**
• **Number of 1-Watt LEDs**	Three	Six	Nine
• **Input to Fixture**	24 VDC (3.9 watts nominal)	24 VDC (6.8 watts nominal)	24 VDC (10.4 watts nominal)
• **Fixture Head Size**	3.75″l x 2.05″w x 0.38″t	4.46″l x 2.76″w x 0.38″t	5.5″l x 3.46″w x 0.38″t
• **Cat. No.**	DL-3W-B (Black) DL-3W-S (Silver)	DL-6W-B (Black) DL-6W-S (Silver)	DL-9W-B (Black) DL-9W-S (Silver)

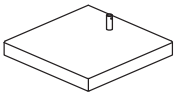
• **Mounting Options** Clamp / Weighted Base / Mounting Plate (Available in Black or Silver)



Clamp
Zero-clearance clamp affixes to back of desk without removing desk from cube for 1″ - 2.5″ thick desk.
Cat No. CL-B / CL-S



Weighted Base (For 3W Desk Lamp)
4″ x 4″ x 3/4″ with integral pin and protective feet.
Cat No. WB-4-B / WB-4-S



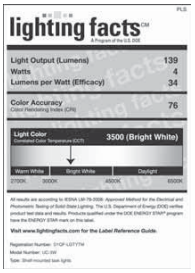
Weighted Base (For 6W / 9W Desk Lamp)
5″ x 5″ x 3/4″ with integral pin and protective feet.
Cat No. WB-5-B / WB-5-S

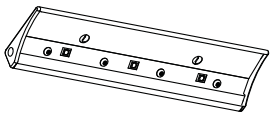
Mounting Plate
Flush mounting on table or work surface (1″ - 1.5″ thick).
Cat No. MP-B / MP-S

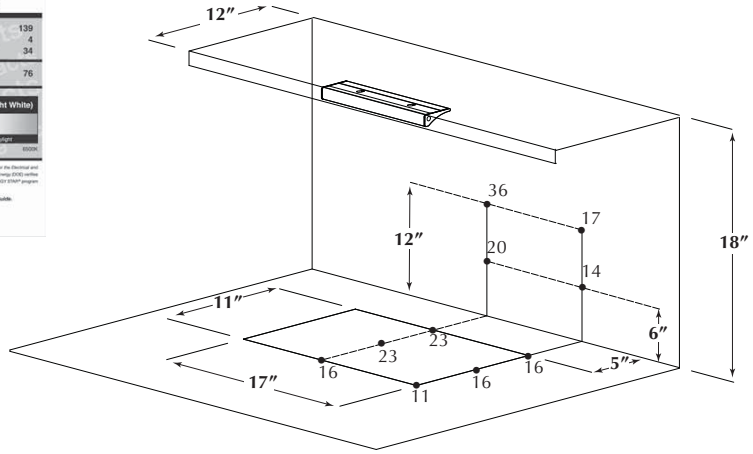
Note: *This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment.*

Initial illuminance values in footcandles calculated using LM79 photometric reports to the desk surface.

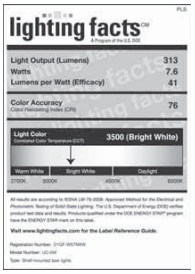
3W UNDERCABINET

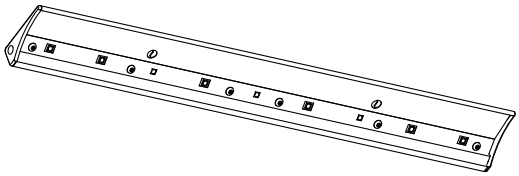


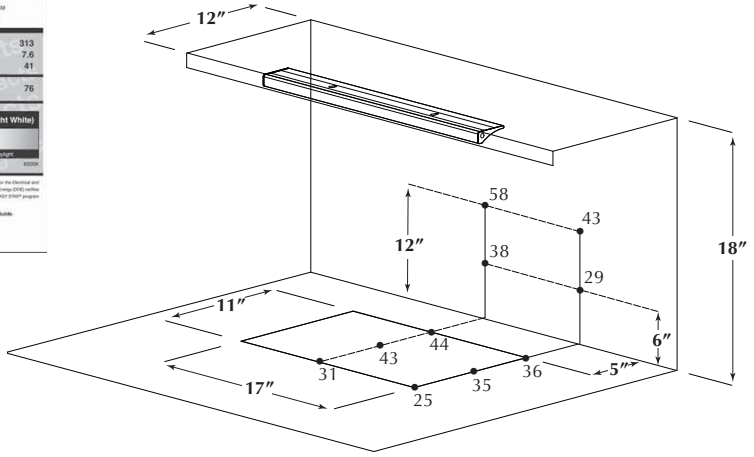




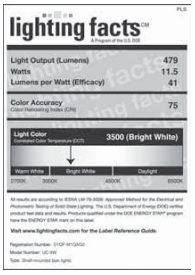
6W UNDERCABINET

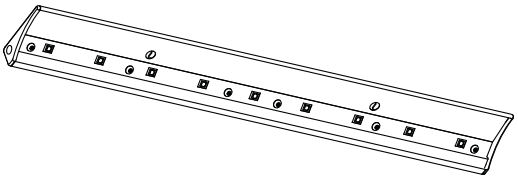


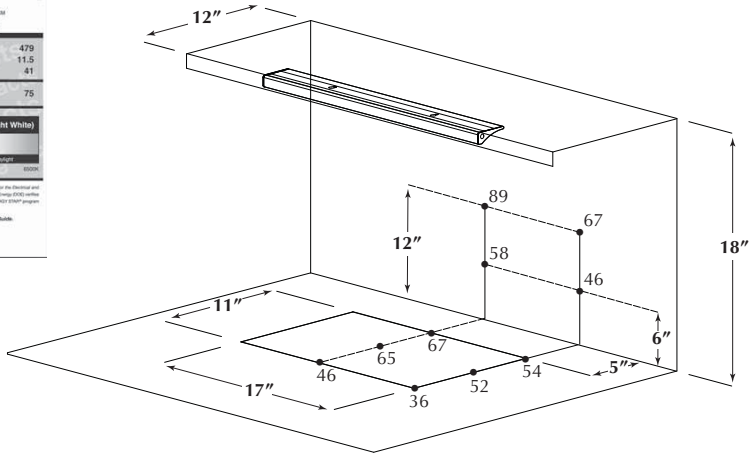




9W UNDERCABINET







UNDERCABINET TECHNICAL SPECIFICATIONS

• **Light Source**	Solid State Lighting: 1-Watt Warm White LEDs
• **Junction Temperature**	T_j < 80 °C (175°F)
• **Light Source Life**	> 50,000 hours
• **Color Temperature**	3500 K
• **Fixture Efficacy**	34-41 Lm/W
• **Cabling**	12-ft low voltage power cable with in-line switch / 6″ patch cord / Cable management clips
• **Certification**	UL / C-UL Listed
• **Power Supplies**	See last page for more information.

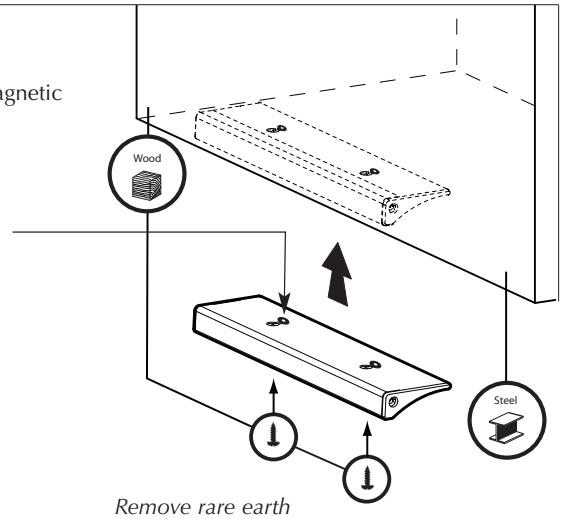
	3W Undercabinet	**6W Undercabinet**	**9W Undercabinet**
• **Number of 1-Watt LEDs**	Three	Six	Nine
• **Input to Fixture**	24 VDC (4.0 watts nominal)	24 VDC (7.6 watts nominal)	24 VDC (11.5 watts nominal)
• **Dimensions**	10.3″l x 2.5″w x 0.8t	21.3″l x 2.5″w x 0.8″t	21.3″l x 2.5″w x 0.8″t
• **Cat. No.**	UC-3W-S (Silver)	UC-6W-S (Silver)	UC-9W-S (Silver)

• **Mounting Options**

Each UC fixture is supplied with magnetic or mechanical mounting means.

Rare earth super-magnets provided pre-installed for mounting directly on steel.

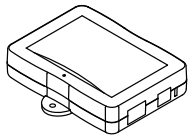
Note: *This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment.*



Remove rare earth magnets when installing with wood screws. Contact factory.

POWER SUPPLIES

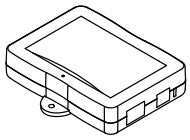
• Power Supply 21 Watts



Cat No. PS-21W
For use with any combination of PLS fixtures up to 21 watts

Input voltage: 100-240 VAC: 50-60Hz [Supplied with 5-ft AC power cord]
Output voltage: 24VDC [Output wattage is limited to 27W max]
(4) 2.5mm output jacks
(1) RJ11 jack for optional Watt Stopper DIF-110 occupancy sensor
Integrated switch to override occupancy sensor
Dimensions: 5.5″ x 5.2″ x 1.4″ • Finish: Matte Black • UL / C-UL Listed

• Power Supply 60 Watts



Cat No. PS-60W
For use with any combination of PLS fixtures up to 60 watts

Input Voltage: 100-240 VAC: 50-60Hz [Supplied with 5-ft AC power cord]
Output Voltage: 24VDC [Output wattage is limited to 68W max]
(4) 2.5mm output jacks
(1) RJ11 jack for optional Watt Stopper DIF-110 occupancy sensor
Integrated switch to override occupancy sensor
Dimensions: 5.5″ x 5.2″ x 1.4″ • Finish: Matte Black • UL / C-UL Listed

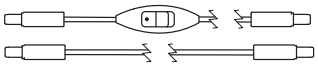
CABLES

• Patch Cables

(UC only) *Daisy chains two male 1.3mm jacks.*
Cat No. CP-3 [3″ Cable, Patch UC]
Cat No. CP-6 [6″ Cable, Patch UC]
Cat No. CP-14 [14″ Cable, Patch UC]
Cat No. CP-28 [28″ Cable, Patch UC]

• Power Cables

(UC only)
Cat No. CPS-12 [12′ Cable, Power SW, UC]
Cat No. CPN-12 [12′ Cable, Power N/SW, UC]

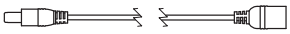


• Splitter Cable

(DL or UC)
Cat No. CY-6 [6″ Cable, Splitter]

• Extension Cable

(DL or UC)
Cat No. CX-8 [8′ Cable, Ext]



ACCESSORIES

• Occupancy Sensor

Cat No. DIF-110
Uses passive infrared (PIR) technology to detect occupancy
User adjustable time delay of 30 seconds to 30 minutes
Fresnel lens with up to 120° and 300 square feet of coverage
ASIC technology reduces components and enhances reliability
UL / C-UL Listed

Please refer to the PLS instruction sheet for system warranty information.

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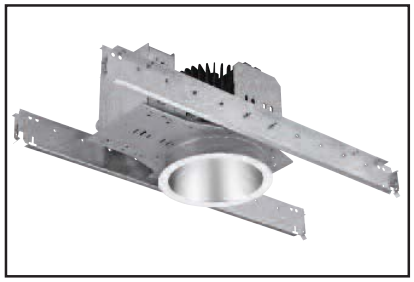
FINELITE
Better Lighting

OM6LED - 1500/2000

6" LED 1500/2000 Lumen Wall Wash

with MesoOptics® & Remote Phosphor



CAT. NO:

TYPE: PROJECT:

PRODUCT INFORMATION

1.Omega mixing chamber/optical assembly: Remote phosphor technology provides increased efficiency and color stability by redirecting back reflected light. Patented Meso Optic and phosphor lens assembly converts high brightness blue light into white light for an even diffused pattern, eliminating bright spots often created by individual LEDs. This technology provides consistent, stable color with CCT color control of +/- 100K over the life of the light engine and provides 20% higher efficiency.

2. LED Array: The LED Array consist of a metal core circuit board with 16 high brightness royal blue LEDs.

3. Thermal Management: A proprietary die-cast aluminum heat sink allows for easy and tooless installation to the housing yoke. The heat sink is designed to properly maintain junction temperatures in recessed non-ic applications to provide reliable performance over the life of the light engine. The heat sink incorporates alignment tabs to properly position the heat sink with the housing and rust resistant springs to secure the heat sink and reflector.

4. Housing: Precision die stamped 18ga galvanized steel mounting pan and yoke assembly. Allows for ceiling thickness up to 1-3/8". Yoke supports weight of heat sink and light engine assembly to prevent stress on finished reflector.

5. Reflector: Precision spun .050 aluminum reflectors are self flanged and snap to heat sink for consistent alignment to the optical assembly. Provides 50 degree visual cutoff to source and source image.

6. Lifetime/Lumen Maintenance: 1500 Lumen - 60,000 hour lifetime at 70% lumen maintenance light engine. (L70) 2000 Lumen - 57,000 hour lifetime at 70% lumen maintenance light engine. (L70)

7. C channels: Revelation c-channels are included and provide vertical and horizontal adjustments. These allow for fast and adjustment free installation in T-bar ceilings with 1/2" tile. C-channels simply snap on grid for proper alignment in 24" O.C. grid systems.

🍁 Canadian Specifications may vary from these shown, consult Canadian Division.

8. Junction Box: 16 ga galvanized steel. UL listed for 8 No. 12 AWG, 90C through branch circuit conductors. Allows inspection below ceiling.

9. Color: Available in three CCT options, 3000K, 3500K or 4000K with 80CRI +/-2%.

10. Electrical: The power supply/driver features Advance Intelli-volt 120-277VAC 50/60hz, with 0-10V analog dimming capability. The power supply is overload and short circuit protected as well as thermally regulated to prevent overheating. Sound rating A. Refer to dimming compatability spec sheet for complete details. Driver has rated lifetime of 50,000 hours. 70C maximum operating temperature, -20C minimum starting temperature.

6

1500 Lumen Package

Input Voltage	Input Current	Drive Current	Input Power	LED Power	THD %	Power Factor
120	0.25	350mA	27	23.1	10%	>0.9
277	0.11	350mA	27	23.1	10%	>0.9

2000 Lumen Package

Input Voltage	Input Current	Drive Current	Input Power	LED Power	THD %	Power Factor
120	0.36	520mA	39	35.4	10%	>0.9
277	0.17	520mA	39	35.4	10%	>0.9

11. Service: Modular construction allows for easy maintenance of complete system below ceiling. Removing reflector provides easy access to heat sink and light engine assembly. This assembly may be removed by de-pressing the springs which attach to the yoke and then simply opening protective cover and unplugging push in connector from LED board.

12. ETL, cUL, IBEW (Suitable for wet locations)

13. Photometric testing performed using IESNA - LM79 procedures. LED lifetime testing performed using IESNA - LM80 procedures.

14. 5 year Warranty

ENERGY STAR PARTNER

mesoOptics® by Ledalite

CATALOG SYSTEM AND OPTIONS

EXAMPLE OF COMPLETE CATALOG NUMBER: **OM6LED39120-R6LED30KWWCS**

HOUSING - ROUGH IN

Omega 6"	Wattage	Supply Voltage	Option
OM6LED	_____	_____	_____
	27 27 input watts	**120** 120 VAC 50/60Hz	**EM** - Bodine BSL17C Emergency Back-up
	39 39 input watts	**277** 277 VAC 50/60Hz	

LIGHT ENGINE - REFLECTOR

Omega 6"	CCT	Distribution	Reflector Finish
R6LED	_____	WW wall wash	_____
	30K 3000K		**CS** Clear Specular
	35K 3500K		**CSS** Clear Semi-Specular
	40K 4000K		**HZ** Haze
			GS Gold Specular
			WT Wheat
			PW Pewter
			BZ Bronze
			WH White
			FF Finish Flange (as suffix to color)

FIVE YEAR Warranty

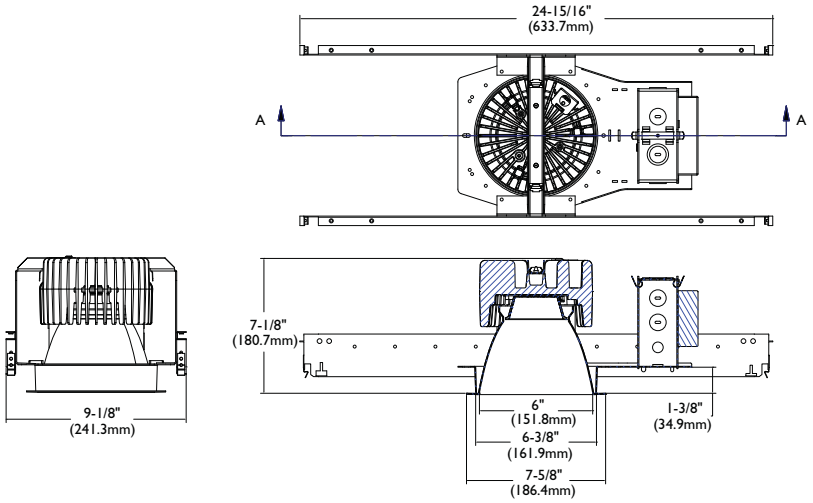
*Lumen output varies depending on CCT and distribution, refer to specific IES files for details.

PHILIPS omega

PHILIPS OMEGA
776 South Green St., Tupelo, MS 38804
Phone 662.842.7212 FAX 662.841.5501
www.omegalighting.com

PHILIPS DAY-BRITE CANADA
189 Bullock Drive, Markham, Ontario, Canada L3P 1W4
Phone 905.294.9570 FAX 800.268.0003
www.day-britecanada.com

DIMENSIONS



6

PHOTOMETRICS

OM6LED27120-R6LED40KWWCS

Wall Washer with Clear Reflector
Source: (1) 22 Blue LEDS
Reflectances: 80% ceiling, 50% walls, 20% floor
IES File: 28961.IES

Distance from ceiling (ft)	3' from wall, 3' on center		3' from wall, 4' on center		2'-6" from wall, 3' on center		2'-6" from wall, 2'-6" on center	
	Below Fixtures	Between Fixtures	Below Fixtures	Between Fixtures	Below Fixtures	Between Fixtures	Below Fixtures	Between Fixtures
1	4.0	4.0	4.0	4.0	5.0	5.0	5.0	5.0
2	10.0	8.0	11.0	10.0	14.0	13.0	16.0	15.0
3	12.0	10.0	14.0	13.0	17.0	14.0	19.0	17.0
4	14.0	10.0	15.0	14.0	20.0	18.0	22.0	22.0
5	15.0	13.0	17.0	17.0	21.0	21.0	24.0	23.0
6	15.0	15.0	18.0	17.0	20.0	21.0	23.0	23.0
7	14.0	15.0	18.0	18.0	19.0	18.0	22.0	20.0
8	14.0	14.0	17.0	17.0	17.0	17.0	19.0	19.0
9	13.0	13.0	16.0	16.0	8.0	15.0	16.0	17.0

Additional photometric test files are available @ omegalighting.com

PHILIPS omega

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atelier ten
195 Church Street, Suite 10C
New Haven, CT 06510
(203) 777 - 1400

Buidling Type: Unaccompanied Enlisted Personnel Housing (UEPH)

General Notes and Instructions:
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2. Programmatic, task, or architectural changes will affect the validity of this document and so it is accurate only insofar as the current space programming and design.
3. Illuminating Engineering Society of North America (IESNA) recommended illuminances, in units of footcandles [fc], are used where applicable.
4. Illuminance targets are used as a reference in design. These values may represent an average, minimum, or values for specific critical points.
5. Lighting control strategies shall be optimized for individual spaces, allowing appropriate hierarchy to control mechanisms.

	Design Criteria			Control Strategies				Technologies				Applicable Lighting Approaches					Notes	
				Levels	Automatic Interface													
Space	Target Illuminance at Task [fc] (Design Goal)	Target Lighting Power Density [W/ft^2] (Project Design Goal)	Allowable Lighting Power Density [W/ft^2] (ASHRAE/IESNA Std 90.1-2004/2007)	Switching - S Multi-Level - M Full Dimming - D	V - Vacancy [Manual ON / Auto OFF] O - Occupancy [Auto ON / Auto OFF]	Daylight (e.g. Photosensors)	Schedule (e.g. Astronomical time-clock)	Linear Fluorescent	Compact Fluorescent	Ceramic Metal Halide	Light Emitting Diodes	Overhead General Lighting	Overhead Ambient Lighting	Task Lighting	Wallwash / Perimeter Lighting	Adjustable Accent Lighting	Lighting	Controls
Corridor	10	0.50	0.5	S/M	O			✓				•			•			Occupancy sensors to reduce load to 25%-50% when vacancy is detected. Multi-Level ballasts may be appropriate in many cases
Living Quarters	5 - 30	0.60	1.1	S	V			✓	✓		✓	•	•	•				Vacancy sensors in bathroom, kitchen, and each bedroom. Low-load night lights in bath vanity areas; Sensors also switch off selected plug loads.
Mechanical / Electrical	30	0.70	1.5	S	O			✓				•					Locate luminaires relative to working areas and equipment	Dual-technology vacancy sensors with long time out
Restroom	20	0.80	0.9	S	O			✓	✓		✓	•			•		Lighting over sink and toilet wall will often be enough for entire restroom	Dual-technology vacancy sensor
Stair	10	0.50	0.6	M	O			✓				•					Locate luminaires to provide 10fc at landings	Use bi-level luminaire with integrated occupancy sensor
Storage (General)	10	0.50	0.8	S	O		⌚	✓				•					Locate and specify luminaires to light vertical surfaces	

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Buidling Type: Battalion/Brigade Headquarters (BN/BDE HQ)

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	Design Criteria			Control Strategies				Technologies				Applicable Lighting Approaches					Notes	
				Levels	Automatic Interface													
Space	Target Illuminance at Task [fc] (Design Goal)	Target Lighting Power Density [W/ft^2] (Project Design Goal)	Allowable Lighting Power Density [W/ft^2] (ASHRAE/IESNA Std 90.1-2004/2007)	Switching - S Multi-Level - M Full Dimming - D	V - Vacancy [Manual ON / Auto OFF] O - Occupancy [Auto ON / Auto OFF]	Daylight (e.g. Photosensors)	Schedule (e.g. Astronomical time-clock)	Linear Fluorescent	Compact Fluorescent	Ceramic Metal Halide	Light Emitting Diodes	Overhead General Lighting	Overhead Ambient Lighting	Task Lighting	Wallwash / Perimeter Lighting	Adjustable Accent Lighting	Lighting	Controls
Classroom / Training	40	0.75	1.4	S/M	V	☼	⏲	✓				•			•		Light teaching wall; minimize glare	Provide zoning and circuiting for lecture mode and AV mode, control teaching wall luminaires independent of general lighting
Conference Room	40	0.80	1.3	S/M/D	V	☼	⏲	✓				•			•		Provide light on people's faces if video conferencing, glare control	Multi-scene preset scene controller may be appropriate in some cases; Use multi-level or dimming ballasts where appropriate
Corridor	10	0.50	0.5	S/M	O			✓				•			•			Occupancy sensors to reduce load to 25%-50% when vacancy is detected. Multi-Level ballasts may be appropriate in many cases
Mechanical / Electrical	30	0.70	1.5	S	O			✓				•					Locate luminaires relative to working areas and equipment	Dual-technology vacancy sensors with long time out
Office (Open)	30 - 50	0.70	1.1	S/M/D	V	☼	⏲	✓		✓	✓	•	•	•	•	•	Use task/ambient scheme with furniture or ceiling mounted ambient lighting and furniture mounted task lighting	
Office (Enclosed)	30 - 50	0.90	1.1	S/M	V			✓			✓	•	•	•			Use task/ambient scheme with furniture or ceiling mounted ambient lighting and furniture mounted task lighting	Bi-level luminaires and vacancy sensors in private perimeter offices is sufficient for energy savings (photosensors not req)
Restroom / Shower	20	0.80	0.9	S	O			✓	✓		✓	•			•		Lighting over sink and toilet wall will often be enough for entire restroom	Dual-technology vacancy sensor
Server Room	30	0.85	1.5	S	O			✓				•					Locate and specify luminaires to light vertical surfaces between server racks	Locate one occupancy sensor per row of server racks
Stair	10	0.50	0.6	M	O			✓				•					Locate luminaires to provide 10fc at landings	Use bi-level luminaire with integrated occupancy sensor
Storage (General)	10	0.50	0.8	S	O		⏲	✓				•					Locate and specify luminaires to light vertical surfaces	
Telecom / SIPRNET	50	1.20	1.5	S	V			✓				•						

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New Haven, CT 06510
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Buidling Type: Tactical Equipment Maintenance Facility (TEMF)

General Notes and Instructions:
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4. Illuminance targets are used as a reference in design. These values may represent an average, minimum, or values for specific critical points.
5. Lighting control strategies shall be optimized for individual spaces, allowing appropriate hierarchy to control mechanisms.

	Design Criteria			Control Strategies				Technologies				Applicable Lighting Approaches					Notes	
				Levels	Automatic Interface													
Space	Target Illuminance at Task [fc] (Design Goal)	Target Lighting Power Density [W/ft^2] (Project Design Goal)	Allowable Lighting Power Density [W/ft^2] (ASHRAE/IESNA Std 90.1-2004/2007)	Switching - S Multi-Level - M Full Dimming - D	V - Vacancy [Manual ON / Auto OFF] O - Occupancy [Auto ON / Auto OFF]	Daylight (e.g. Photosensors)	Schedule (e.g. Astronomical time-clock)	Linear Fluorescent	Compact Fluorescent	Ceramic Metal Halide	Light Emitting Diodes	Overhead General Lighting	Overhead Ambient Lighting	Task Lighting	Wallwash / Perimeter Lighting	Adjustable Accent Lighting	Lighting	Controls
Classroom / Training	40	0.75	1.4	S/M	V	☼	⏲	✓				•			•		Light teaching wall; minimize glare	Provide zoning and circuiting for lecture mode and AV mode, control teaching wall luminaires independent of general lighting
Conference Room	40	0.80	1.3	S/M/D	V	☼	⏲	✓				•			•		Provide light on people's faces if video conferencing, glare control	Multi-scene preset scene controller may be appropriate in some cases; Use multi-level or dimming ballasts where appropriate
Consolidated Bench Repair	50	0.60	1.9	S	O		⏲	✓			✓	•		•			Locate luminaires relative to working areas and critical equipment	
Corridor	10	0.50	0.5	S/M	O			✓				•			•			Occupancy sensors to reduce load to 25%-50% when vacancy is detected. Multi-Level ballasts may be appropriate in many cases
Mechanical / Electrical	30	0.70	1.5	S	O			✓				•					Locate luminaires relative to working areas and equipment	Dual-technology vacancy sensors with long time out
Office (Open)	30 - 50	0.70	1.1	S/M/D	V	☼	⏲	✓		✓	✓	•	•	•	•	•	Use task/ambient scheme with furniture or ceiling mounted ambient lighting and furniture mounted task lighting	
Repair Bay / Vehicle Corridor	50	0.85	1.9	S	V	☼	⏲	✓				•					Luminaire mounting locations limited by overhead obstructions; optimize daylight; wire-guard and shielding recommended; Use narrow distribution	Luminaires wired for one-third/two-third/full output; luminaires and vacancy sensors zoned an controlled by repair bay
Restroom / Shower	20	0.80	0.9	S	O			✓	✓		✓	•			•		Lighting over sink and toilet wall will often be enough for entire restroom	Dual-technology vacancy sensor
Stair	10	0.50	0.6	M	O			✓				•					Locate luminaires to provide 10fc at landings	Use bi-level luminaire with integrated occupancy sensor
Storage (General)	10	0.50	0.8	S	O		⏲	✓				•					Locate and specify luminaires to light vertical surfaces	
Telecom / SIPRNET	50	1.20	1.5	S	V			✓				•						
Vault	40	0.70	1.9	S	O		⏲	✓			✓	•					Provide lighing on desks and work areas as well as vertical surfaces	

atelier ten
195 Church Street, Suite 10C
New Haven, CT 06510
(203) 777 - 1400

Buidling Type: Enlisted Personnel Dining Facility (EPDF)

General Notes and Instructions:
1. This document reflects Atelier Ten's current understanding of the spaces lighting design guidance.
2. Programmatic, task, or architectural changes will affect the validity of this document and so it is accurate only insofar as the current space programming and design.
3. Illuminating Engineering Society of North America (IESNA) recommended illuminances, in units of footcandles [fc], are used where applicable.
4. Illuminance targets are used as a reference in design. These values may represent an average, minimum, or values for specific critical points.
5. Lighting control strategies shall be optimized for individual spaces, allowing appropriate hierarchy to control mechanisms.

	Design Criteria			Control Strategies				Technologies				Applicable Lighting Approaches					Notes	
				Levels	Automatic Interface													
Space	Target Illuminance at Task [fc] (Design Goal)	Target Lighting Power Density [W/ft^2] (Project Design Goal)	Allowable Lighting Power Density [W/ft^2] (ASHRAE/IESNA Std 90.1-2004/2007)	Switching - S Multi-Level - M Full Dimming - D	V - Vacancy [Manual ON / Auto OFF] O - Occupancy [Auto ON / Auto OFF]	Daylight (e.g. Photosensors)	Schedule (e.g. Astronomical time-clock)	Linear Fluorescent	Compact Fluorescent	Ceramic Metal Halide	Light Emitting Diodes	Overhead General Lighting	Overhead Ambient Lighting	Task Lighting	Wallwash / Perimeter Lighting	Adjustable Accent Lighting	Lighting	Controls
Corridor	10	0.50	0.5	S/M	O			✓				•			•			Occupancy sensors to reduce load to 25%-50% when vacancy is detected. Multi-Level ballasts may be appropriate in many cases
Dining Area	20	0.60	0.9	S/M	O	☼	⏲	✓	✓	✓	✓	•			•			Daylight controls for perimeter luminaires closest to window walls
Dishwashing	50	0.65	1.2	S	O		⏲	✓				•					Locate luminaires relative to working areas and equipment	
Kitchen / Food Prep	50	0.65	1.2	S	O		⏲	✓				•					Locate luminaires relative to work areas; Shielded luminaires or coated lamps required	
Mechanical / Electrical	30	0.70	1.5	S	O			✓				•					Locate luminaires relative to working areas and equipment	Dual-technology vacancy sensors with long time out
Office (Enclosed)	30 - 50	0.90	1.1	S/M	V			✓			✓	•	•	•			Use task/ambient scheme with furniture or ceiling mounted ambient lighting and furniture mounted task lighting	Bi-level luminaires and vacancy sensors in private perimeter offices is sufficient for energy savings (photosensors not req)
Restroom / Shower	20	0.80	0.9	S	O			✓	✓		✓	•			•		Lighting over sink and toilet wall will often be enough for entire restroom	Dual-technology vacancy sensor
Serving Area	50	0.70	1.2	S	O		⏲	✓	✓	✓	✓	•		•		•	Locate luminaires relative to serving areas; Shielded luminaires or coated lamps required; Use accent lighting for food display areas	
Stair	10	0.50	0.6	M	O			✓				•					Locate luminaires to provide 10fc at landings	Use bi-level luminaire with integrated occupancy sensor
Storage (Dry Food)	10	0.70	0.8	S	O		⏲	✓				•					Locate and specify luminaires to light vertical surfaces	
Storage (General)	10	0.50	0.8	S	O		⏲	✓				•					Locate and specify luminaires to light vertical surfaces	

Lighting Design Guide Criteria Matrix

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Buidling Type: Company Operations Facility (COF)

General Notes and Instructions:
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2. Programmatic, task, or architectural changes will affect the validity of this document and so it is accurate only insofar as the current space programming and design.
3. Illuminating Engineering Society of North America (IESNA) recommended illuminances, in units of footcandles [fc], are used where applicable.
4. Illuminance targets are used as a reference in design. These values may represent an average, minimum, or values for specific critical points.
5. Lighting control strategies shall be optimized for individual spaces, allowing appropriate hierarchy to control mechanisms.

	Design Criteria			Control Strategies				Technologies				Applicable Lighting Approaches					Notes	
				Levels	Automatic Interface													
Space	Target Illuminance at Task [fc] (Design Goal)	Target Lighting Power Density [W/ft^2] (Project Design Goal)	Allowable Lighting Power Density [W/ft^2] (ASHRAE/IESNA Std 90.1-2004/2007)	Switching - S Multi-Level - M Full Dimming - D	V - Vacancy [Manual ON / Auto OFF] O - Occupancy [Auto ON / Auto OFF]	Daylight (e.g. Photosensors)	Schedule (e.g. Astronomical time-clock)	Linear Fluorescent	Compact Fluorescent	Ceramic Metal Halide	Light Emitting Diodes	Overhead General Lighting	Overhead Ambient Lighting	Task Lighting	Wallwash / Perimeter Lighting	Adjustable Accent Lighting	Lighting	Controls
Conference Room	40	0.80	1.3	S/M/D	V	☼	⏲	✓				•			•		Provide light on people's faces if video conferencing, glare control	Multi-scene preset scene controller may be appropriate in some cases; Use multi-level or dimming ballasts where appropriate
Corridor	10	0.50	0.5	S/M	O			✓				•			•			Occupancy sensors to reduce load to 25%-50% when vacancy is detected. Multi-Level ballasts may be appropriate in many cases
Mechanical / Electrical	30	0.70	1.5	S	O			✓				•					Locate luminaires relative to working areas and equipment	Dual-technology vacancy sensors with long time out
Office (Enclosed)	30 - 50	0.90	1.1	S/M	V			✓			✓	•	•	•			Use task/ambient scheme with furniture or ceiling mounted ambient lighting and furniture mounted task lighting	Bi-level luminaires and vacancy sensors in private perimeter offices is sufficient for energy savings (photosensors not req)
Readiness Bay	40	0.80	0.9	S	V	☼	⏲	✓				•						Use vacancy sensors to capture daylight savings
Restroom / Shower	20	0.80	0.9	S	O			✓	✓		✓	•			•		Lighting over sink and toilet wall will often be enough for entire restroom	Dual-technology vacancy sensor
Stair	10	0.50	0.6	M	O			✓				•					Locate luminaires to provide 10fc at landings	Use bi-level luminaire with integrated occupancy sensor
Storage (General)	10	0.50	0.8	S	O		⏲	✓				•					Locate and specify luminaires to light vertical surfaces	
Telecom / SIPRNET	50	1.20	1.5	S	V			✓				•						
Vault	40	0.70	1.9	S	O		⏲	✓			✓	•					Provide lighing on desks and work areas as well as vertical surfaces	

Appendix G:

Additional Information – All Buildings

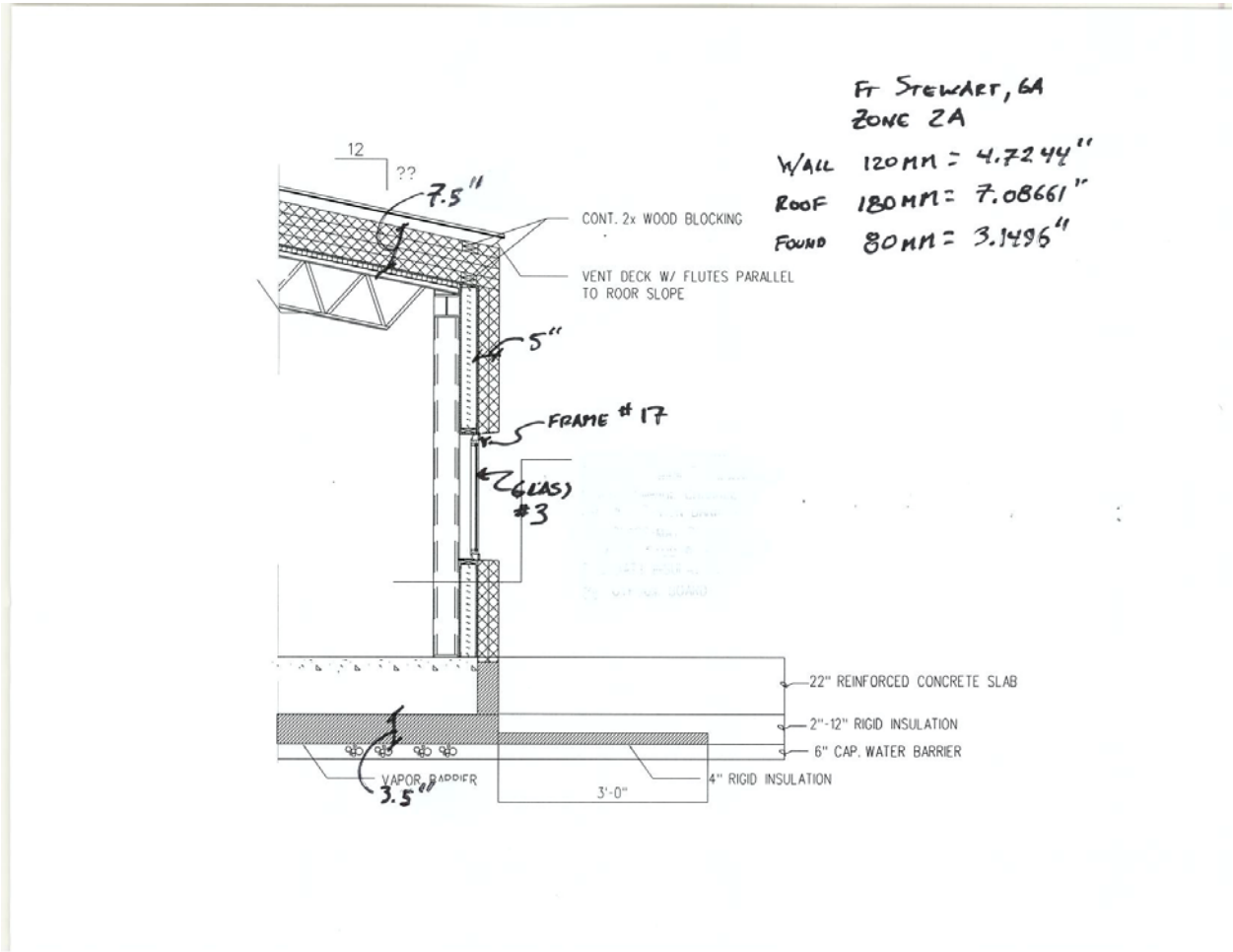

Figure G.1 Passive house wall section – CZ 2A Fort Stewart, GA

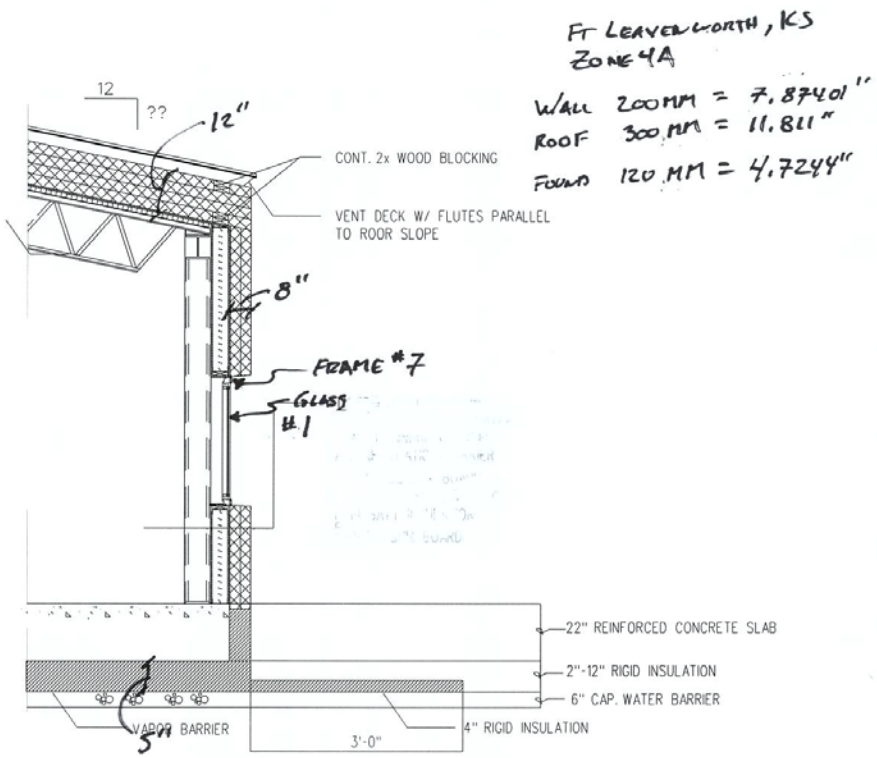

Figure G.2 Passive house wall section – CZ 4A Fort Leavenworth, KS

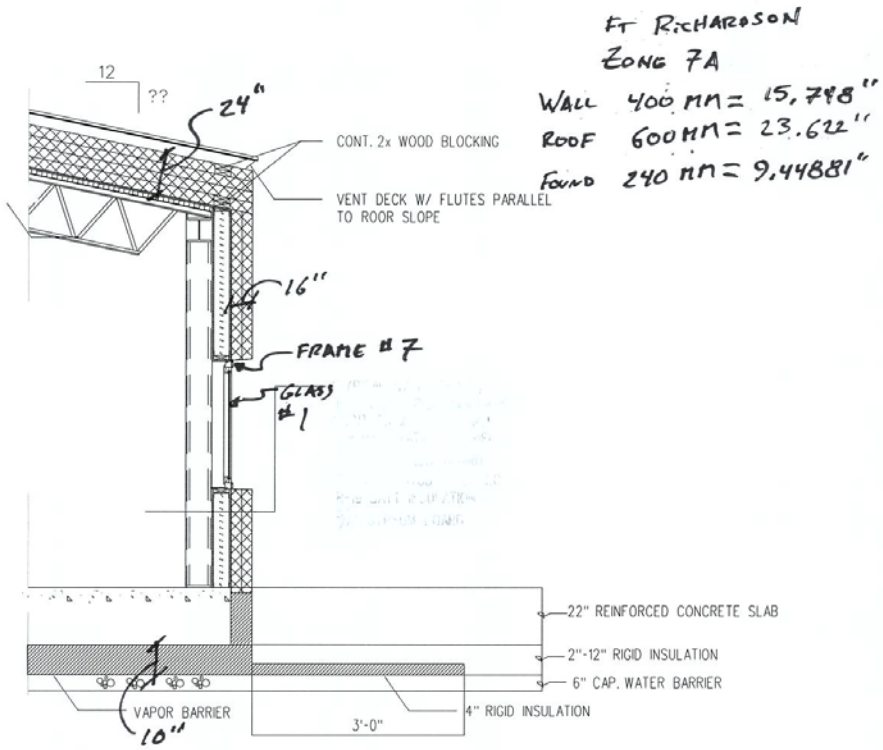

Figure G.3 Passive house wall section – CZ 7A Fort Richardson, AK

DOAS Schematics

Figure G.4: DOAS with unbalanced flow, Terminal Equipment performing latent cooling.

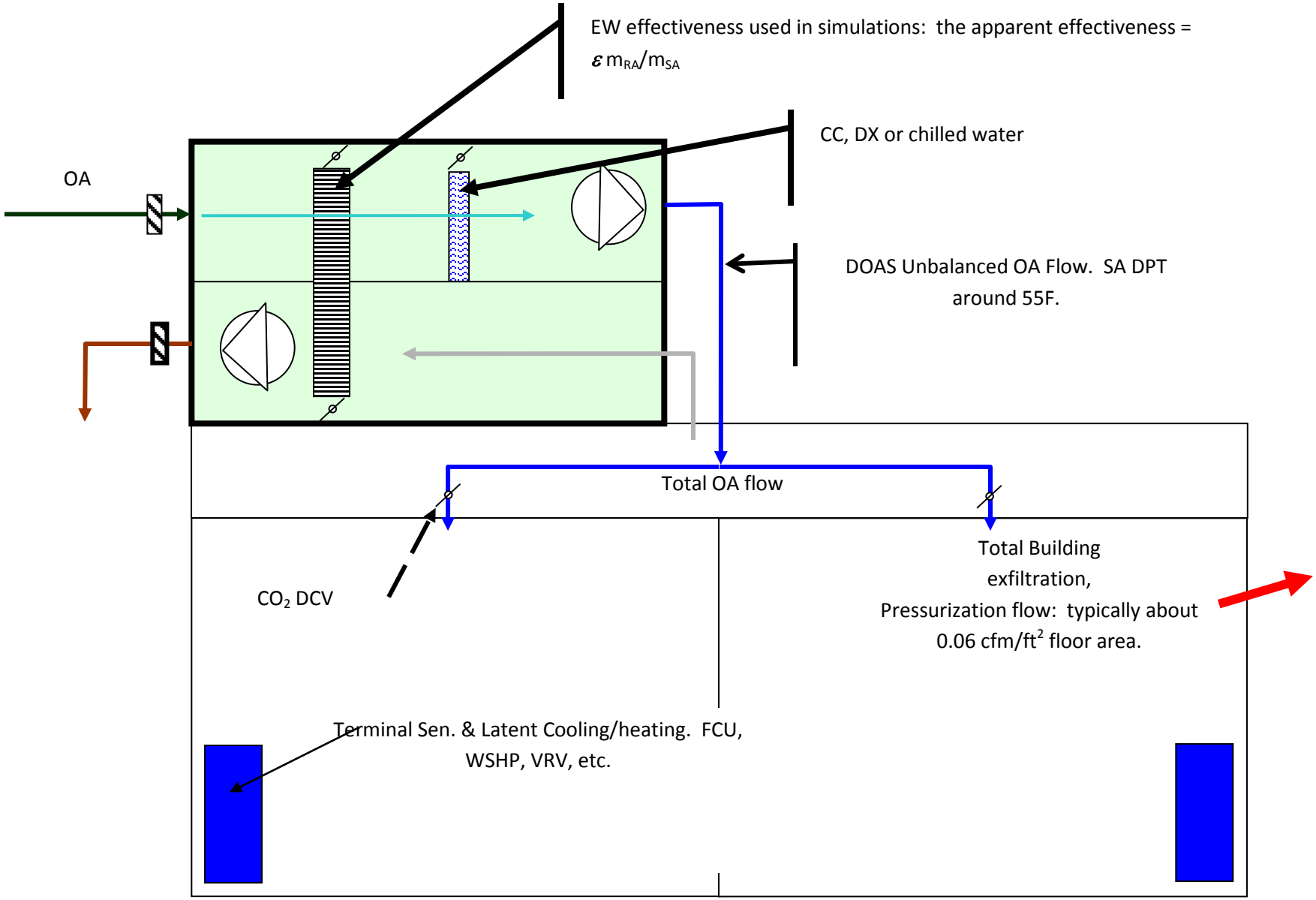

Figure G.5: DOAS with balanced flow + Pressurization unit, Terminal Equipment performing latent cooling.

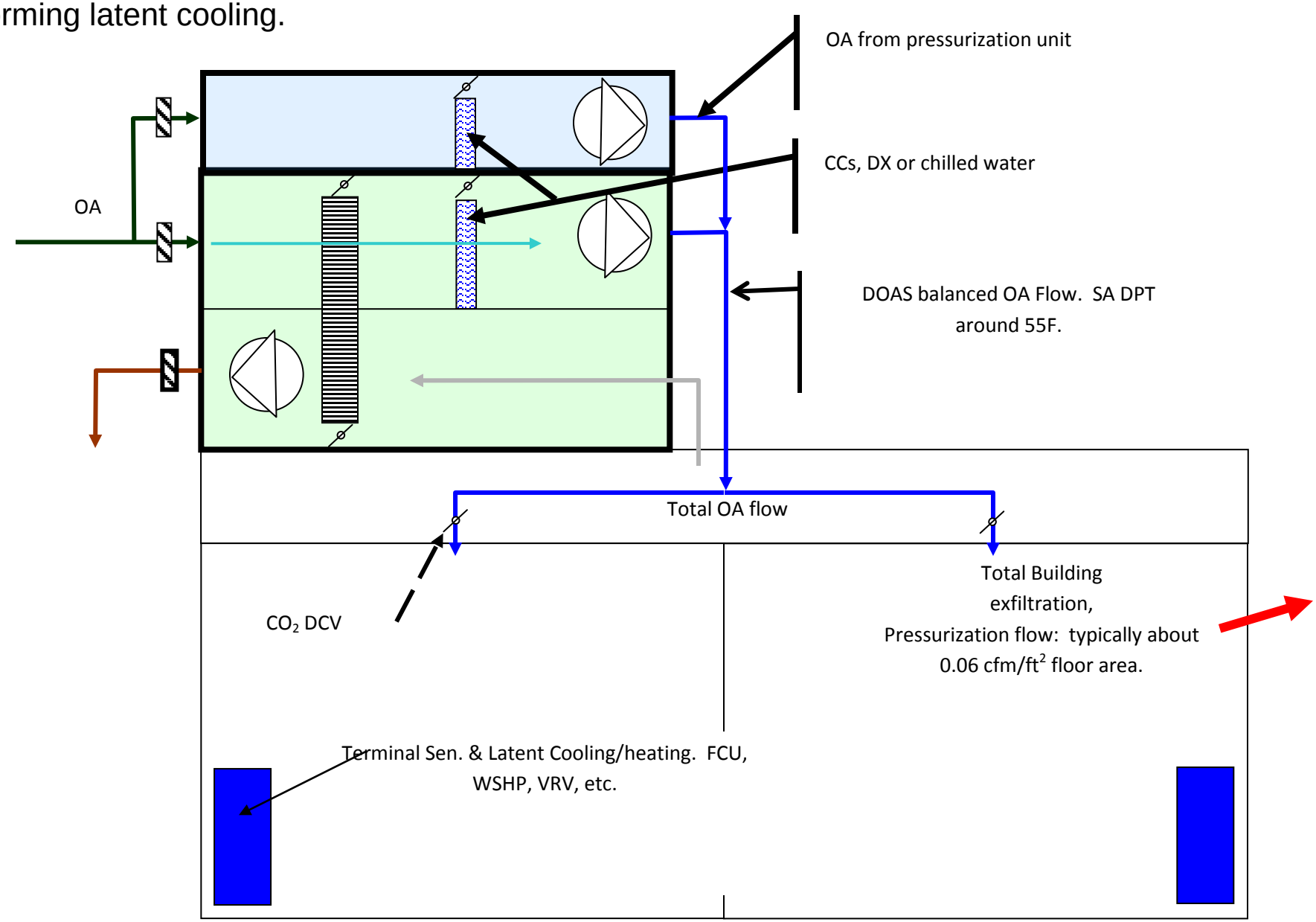

Figure G.6: DOAS with unbalanced flow—2nd wheel added, Terminal Equipment performing NO!! latent cooling.

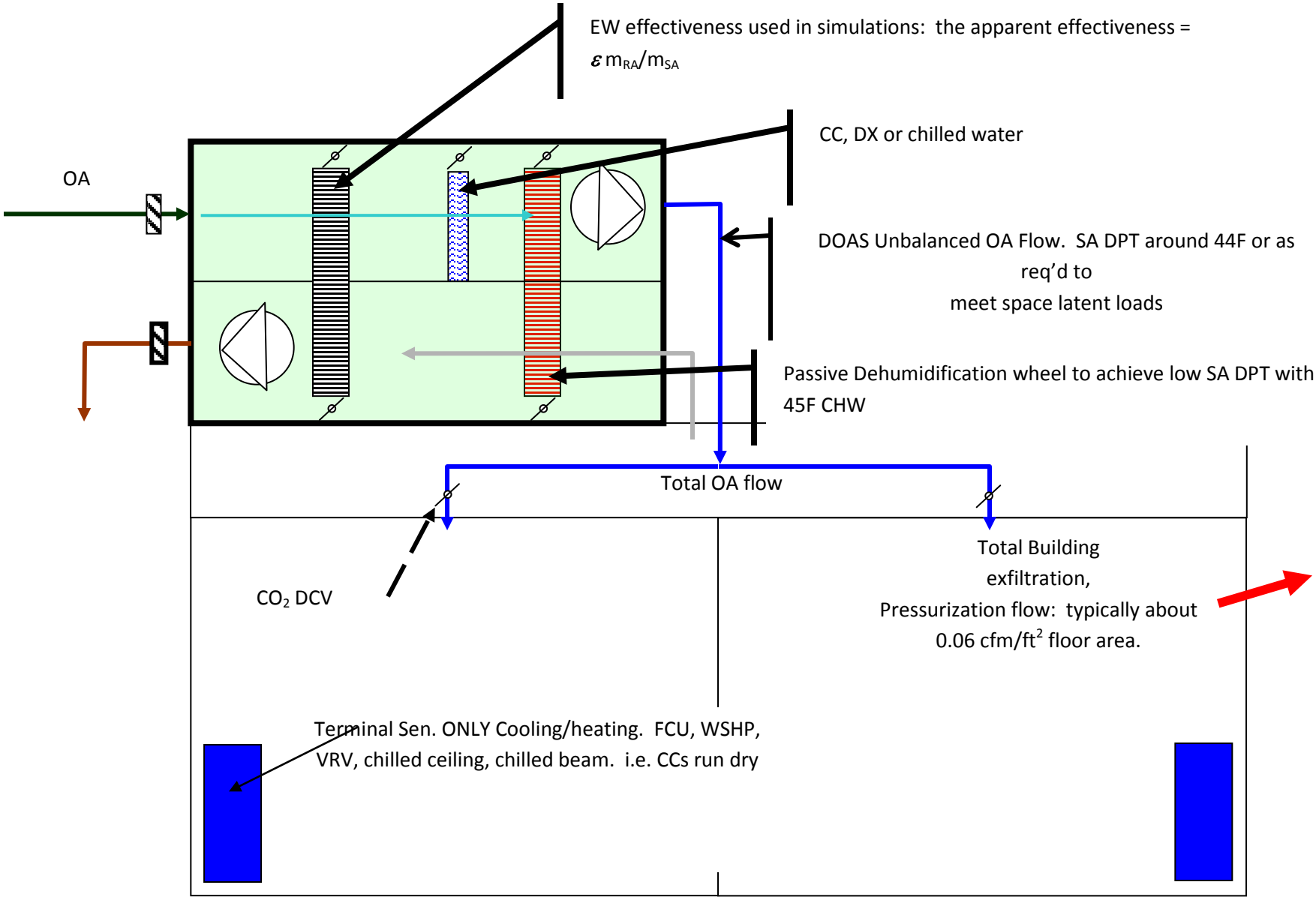
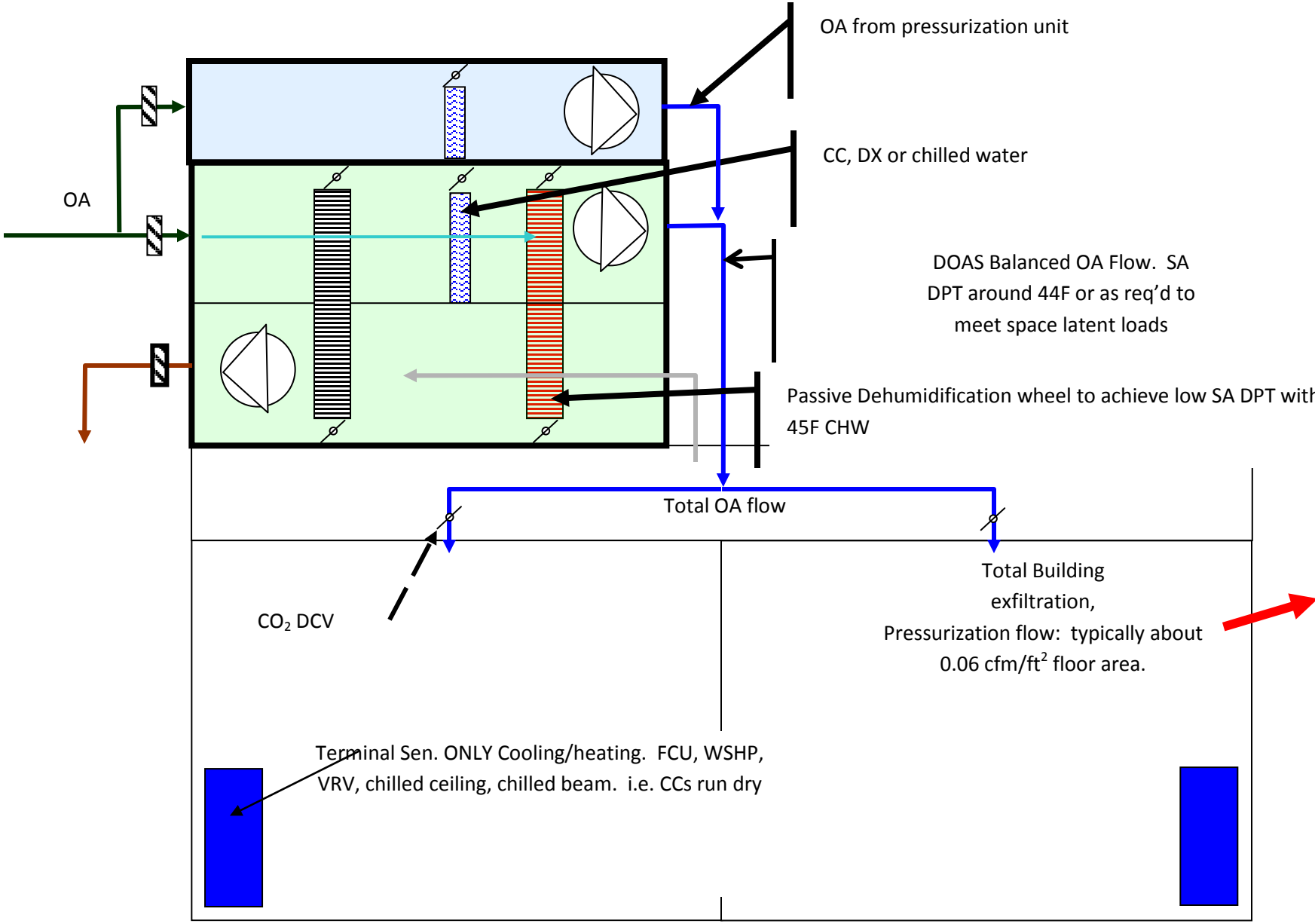
Figure G.7: DOAS with balanced flow—2nd wheel added, Terminal Equipment performing NO!! latent cooling.