Installation Design Standard
Chapter 3
(Energy Conservation Requirements for incorporation in the main text and supporting Appendices)

3.1 Introduction

3.1.1 The Building Design Standards encompass the function and character of the buildings as well as the arrangement of buildings to one another and to their environment. Use architectural style, materials, and colors indigenous to the region. Preserve the historically and culturally significant structures to add to an installations character and provide a sense of heritage. Incorporate energy conservation and sustainability in all structures[1].

3.4 Building Design Standards

3.4.3 Energy Conservation Standards follow:

3.4.3.1 Design buildings to be at least 30% better than current private sector standards (ASHRAE 90.1-2004 per the requirements of the Energy Policy Act (EPACT) 2005). See 10 CFR Parts 433, 435, and 436 for guidance. Energy conservation mandated by EPACT is directly related to the achievement of LEED®-NC EA Credit 1, Optimize Energy Performance points.

3.4.3.2 Use sustainable design principles for siting, orientation design, and construction. Follow the requirements of EO 13423.

3.4.3.3 Plan to meter all energy service to buildings. Plan to analyze building energy use.

3.5 Structural Character standards

3.5.5.1 Colors to match the standards will be implemented during normally scheduled paint cycles (See Appendix L, Exterior Color Charts.) (Fig. 1-3.4).

- Relate buildings with compatible material and similar colors.
- Select colors for material from the Army Standards Color Palette based on the desired function, appearance, attractiveness of the building, and its compatibility with adjacent building colors.
- Limit exterior building colors to the Army Standard Color Palette. This provides each area a coordinated palette of similar colors that are subdued and harmonious. Avoid the misuse of strong, loud colors.

Color, especially roof color, has an impact on energy usage. Reflective “cool roofs” which reduce the building cooling load, are available in many colors besides white. For more information on “cool roofs” see Chapter 3 Energy Appendix 3.4

[1] In sections 3.1 through 3.15 highlighted text indicates proposed changes. Section 3.18 is new.

3.5.7.5. Use Energy Star roofing materials (see Chapter 3 Energy Appendix 3.4). Use "Cool roof" materials for climate zones 1-5.

3.5.8 **Fenestration.** Building fenestration includes features such as doors, windows, shading devices, and building decoration details. These features should be similar in arrangement, design, size, and proportion for architectural compatibility and visual consistency and continuity. ASHRAE Standard 90.1-2007 sets absolute minimum requirements for fenestration, however, most Army buildings shall have even more stringent requirements if they are to meet the 30% energy reduction requirement (see Section 3-18.6).

3.5.10 Awnings and Canopies. Awnings and canopies are authorized to protect entrances, interior surfaces, and personnel from the effects of weather. Refer to AR 420-70. While awning and canopies provide shading for energy efficiency as well, awnings and canopies are not credited towards 30% energy savings in the Federal standards because they are not permanent. Permanent shading devices such as overhangs can count towards the necessary savings.

3.14.6.1 Artificial lighting and natural daylight will be incorporated into designs taking into consideration the work activities involved. When possible use lower level of general lighting, supplemented by task lighting and use architectural lighting in entrances, corridors, waiting rooms, and other spaces to light artwork and provide interest. All lighting should be occupancy sensored and daylighting controlled including task lighting. LEED credits related to lighting include those concerned with energy efficiency, controllability of systems, and the Light Pollution Reduction Credit. Lights should be located and controlled in a way that does not cause light pollution to emanate from the building.

3.14.6.2 Army installation buildings shall provide a high quality, energy efficient lighting environment. The lighting equipment/systems selected must satisfy both performance and aesthetics (Fig 1-3.8). Factors for consideration in this selection will be based on the following characteristics: glare, lumens per watt, color temperature, color rendering index, life and lumen maintenance, availability, switching, dimming capability, lighting power density, cost, and natural day lighting.

3.15 MECHANICAL SYSTEMS

3.15.1 This section shall consist of Plumbing and HVAC systems. For energy conservation criteria, see Chapter 3 Energy Appendices 4-15. Additional standards are being developed.

3.15.2. The absolute minimum requirements for service water heating and HVAC systems are found in Sections 7.4 and 6.4 of ASHRAE Standard 90.1-2007.

3.18 ENERGY CONSERVATION

3.18.1 All new Army facilities and all major renovations of existing Army facilities shall comply with the requirement of EPACT 2005 to reduce energy consumption by 30% compared to a facility designed in accordance with ASHRAE 90.1-2004. Building modifications should be classified as a major renovation if the cost of renovation project exceeds 25% of the building value with the project including all or some of the following elements: alteration of overall features of the building's envelope, substantial replacement of the building's lighting, plumbing, electrical, and heating, ventilating, and air conditioning (HVAC) systems in combination with other significant alterations of the building's spaces. Other modifications to a building may be categorized as a major renovation depending on the overall magnitude and scope of the work to be accomplished. Buildings classified as major renovation projects will comply with all energy and water conservation requirements (EO 13423), and all methods and standards applicable to new construction. All building components and systems being renovated or replaced must comply with their respective energy and water conservation criteria. Major upgrades to "new building" energy and water conservation levels should be planned for funding as early as possible on DD Form 1391. Funding requirements to implement energy and water conservation measures will be an integral part of the concept design.

3.18.2. The target energy consumption budget (excluding plug and process loads) developed in compliance with the requirements of EPACT 2005 for selected tier 1 Army facilities and different DOE Climate Zones in kBtu per ft^2 per year not to be exceeded are listed in the *Chapter 3 Energy Conservation Appendix 1.2*. The use of the Prescriptive Technology Solution Set, listed in the Energy Appendix, will result in an annual energy consumption less than or equal to the target energy budget figure, meets life cycle cost effectiveness requirements and does not require calculations according to the ASHRAE Standard 90.1 Appendix G. When Prescriptive Technology Solution Sets are used, mandatory requirements of the ASHRAE Standard 90.1-2007 shall also be met. For the building types addressed in the *Chapter 3 Energy Conservation Appendices 14-17*, requirements of the EPACT 2005 can be also met using designer developed specific .technology sets. In this case to prove that target energy consumption budgets are met, calculations prescribed in the ASHRAE Standard 90.1 Appendix G shall be performed and life cycle cost effectiveness analysis be provided.

3.18.3. Energy efficient and sustainable building design shall be a collaborative and coordinated effort of architects, electrical, mechanical and structural engineers. It can not be achieved through analysis and optimization of the individual components and subsystems. A holistic "whole building" design approach shall collaboratively integrate different building elements and systems to optimize the overall project sustainability, water and energy efficiency. Creative design of the building floor plan and configuration, envelope, orientation and fenestration can minimize energy needed to ventilate, condition and light the facility. Integration of the mechanical systems design must be coordinated with the designs of other involved building systems and features including the building envelope, lighting system, and occupant activities. Understanding how one system (or individual components within a given system) affects another is essential to making the most of the available opportunities for energy savings.

3.18.4. A building's cooling and heating needs are affected by the performance of interrelated building systems and characteristics, including building envelope characteristics; passive solar design elements, such as daylighting, lighting systems, plug-in and other internal loads. The appropriate HVAC design solution shall be determined only after the requirements and contributing thermal loads of these interrelated systems have been thoroughly reviewed and all possible efficiency gains through sustainable design strategies have been carefully considered.

3.18.5 In all new Army facilities and all major renovations only Energy Star or FEMP designated products shall be used. The term "Energy Star product" means a product that is rated for energy efficiency under an Energy Star program. The term "FEMP designated product" means a product that is designated under the Federal Energy Management Program of the Department of Energy as being among the highest 25 percent of equivalent products for energy efficiency. When selecting integral sized electric motors, choose NEMA PREMIUM type motors that conform to NEMA MG 1, minimum Class F insulation system. Motors with efficiencies lower than the NEMA PREMIUM standard may only be used in unique applications that require a high constant torque speed ratio (e.g., inverter duty or vector duty type motors that conform to NEMA MG 1, Part 30 or Part 31).

3.18.6. Building envelope insulation is critical in reducing heating and cooling loads throughout the year round performance. Levels of the building envelop insulation for new construction and major renovation shall meet requirements listed in The *Chapter 3 Energy Conservation Appendix 3.1*

3.18.7. Windows are a critical design component of an energy efficient and sustainable building envelope. They affect the building's thermal performance as well as provide natural daylight to enter the structure. Windows for new Army facilities and major renovations shall meet requirements specified in the *Chapter 3 Energy Conservation Appendix 3.2*

3.18.8. Building envelopes for new office buildings, office portions of mixed office and open space (e.g., company operations facilities), dining, barracks and instructional/training facilities and undergoing major renovations shall be designed and constructed with a continuous air barrier to control air leakage into, or out of, the conditioned space. Mandatory requirements for the continuous air barrier design and construction are provided in *Chapter 3 Energy Conservation Appendix 3.5*

Performance of the continuous air barrier for the opaque building envelope shall be demonstrated by the following tests:

(a) Test the completed building and demonstrate that the air leakage rate of the building envelope does not exceed 0.25cfm/ft2 at a pressure differential of 0.3" w.g. (75 Pa) in accordance with ASTM's E 779 (2003) or E-1827-96 (2002). Accomplish tests using either pressurization or depressurization or both. Divide the volume of air leakage in CFM @ 0.3" w.g. (L/s @ 75 Pa) by the area of the pressure boundary of the building, including roof or ceiling, walls and floor to produce the air leakage rate in cfm/ft2 @ 0.3" w.g. (L/s.m2 @ 75 Pa). Do not test the building until verifying that the continuous air barrier is in place and installed without failures in accordance with installation instructions so that repairs to the continuous air barrier, if needed to comply with the required air leakage rate, can be done in a timely manner.

(b) Test the completed building using Infrared Thermography testing. Use infrared cameras with a resolution of 0.1deg C or better. Perform testing on the building envelope in accordance with ISO 6781:1983 and ASTM C1060-90(1997). Determine air leakage pathways using ASTM E 1186-03 Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems, and perform corrective work as necessary to achieve the whole building air leakage rate specified in (a) above. (c) Notify the Government at least three working days prior to the tests to provide the Government the opportunity to witness the tests. Provide the Government written test results confirming the results of all tests.

3.18.9. Lighting systems in new, retrofitted or acquired buildings shall have the correct light level for the tasks being performed (*Chapter 3 Energy Conservation Appendix 2.3*) and be equipped with Energy Star or FEMP designated lighting technologies.

3.18.10 Energy conservation and sustainability criteria for new and renovated Army facilities are shown in the *Chapter 3 Energy Conservation Appendix 1.3*.

3.18. 11 New buildings and buildings undergoing major renovations 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 [EISA2007]:

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

Unless it is demonstrated to be not LCC effective, reduce energy consumption beyond the requirement of EPACT 2005 (Section 1.18.1) and use renewable energy to the extend specified in the above table.

3.18.12. Not less than 30 percent of the hot water demand for each new Federal building or Federal building undergoing a major renovation will be met through the installation and use of solar hot water heaters [IESA 2007] unless demonstrated to not be lifecycle cost-effective. The amount that is cost effective will be installed.

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- Appendix 12. HVAC Motor Considerations (TBD/FA)
- Appendix 13. Energy Metering (to be developed)

[2] To be developed given additional funds available

- Appendix 14. Prescriptive set and optional energy saving technologies for barracks
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- Appendix 17. Prescriptive set and optional energy saving technologies for dining facilities (to be completed)

Appendix 1: Energy Policies

1.1. Current Polices and Directives on Energy Conservation

New and existing Federal buildings will be more energy efficient. There are many policies, regulations, executive orders, and legislative mandates driving both energy conservation and green buildings to make it feasible to ignore energy conservation.

The three most significant drivers of energy efficiency in the DOD and other Federal buildings are (listed chronologically):

- The Energy Policy Act of 2005
- *Army Energy Strategy for Installations* of 2005
- Executive Order 13423
- The Energy Independence and Security Act of 2007

1.1.1. The Energy Policy Act of 2005 has 11 sections in Title 1 – Energy Efficiency, Subtitle A – Federal Programs that impact Federal agencies. See http://thomas.loc.gov/cgi-bin/bdquery/z?d109:h.r.00006: for complete text. From a building manager standpoint, the important requirements are:

- Percentage reduction in buildings energy use (Section 102)
- Energy use measurement (Section 103)
- Procurement of energy efficient products (Section 104)
- Use of energy saving performance contracts (Section 105)
- Voluntary reductions in industrial energy intensity (Section 106)
- Increased use of recovered mineral component in projects involving cement or concrete (Section 108)
- New Federal building energy efficiency and sustainability standards (Section 109)

1.1.2. Executive Order 13423 – Strengthening Federal Environmental, Energy, and Transportation Management – provides a number of goals for agencies in Section 2. See http://www.whitehouse.gov/news/releases/2007/01/20070124-2.html for complete text. Many of these goals are relevant to building managers, including:

- Improve energy efficiency and reduce greenhouse gas emissions
- Increase renewable energy use
- Reduce water consumption intensity
- Use of sustainable environmental practices
- Reduction of hazardous and toxic chemical disposal
- Use of the Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings set forth in the Federal Leadership in High Performance and Sustainable Building Memorandum of Understanding

1.1.3. The Energy Independence and Security Act of 2007 has 9 sections that impact Federal agencies in Title 1 - Energy Savings in Buildings and Industry, Subtitle C – High Performance Federal Buildings. See http://thomas.loc.gov/cgi-bin/bdquery/z?d110:h.r.00006: for complete text. From a building manager standpoint, the important requirements are:

- Increased percentage reduction in buildings energy use (Section 431)
- Energy and water evaluations every four years (Section 432)
- Identification of commissioning and retro-commissioning opportunities (Section 432)
- Use of an energy benchmarking system (Section 432)
- Fossil fuel reduction targets for selected buildings (Section 433)
- Requirement that capital energy investments that are not major renovations be life cycle cost-effective (Section 434)
- Requirement for Energy Star label on leased buildings (Section 435)
- Audits of Federal green building performance (Section 437)
- Specific requirement for storm water runoff on facilities more than 5000 square feet in footprint (Section 438)
- Increase in public building lifetime from 25 to 40 years (Section 441)

1.1.4. Army Energy Strategy for Installations. The Strategy sets the general direction for the Army in five major initiatives (http://army-energy.hqda.pentagon.mil/programs/plan.asp) :

1. Eliminate energy waste in existing facilities
   Eliminate and reduce energy inefficiencies that waste natural and financial resources, and do so in a manner that does not adversely impact comfort and quality of the facilities in which Soldiers, families, civilians and contractors work and live.
2. Increase energy efficiency in new construction and renovations
   Increase the use of energy technologies that provide the greatest cost-effectiveness, energy efficiency and support environmental considerations.
3. Reduce dependence on fossil fuels
   Increase the use of clean, renewable energy to reduce dependency on fossil fuels and to optimize environmental benefits and sustainability.
4. Conserve water resources
   Reduce water use to conserve water resources for drinking and domestic purposes.
5. Improve energy security
   Provide for the security and reliability of energy and water systems in order to provide dependable utility services.

The Strategy sets forth the Army's energy goals for 25 years and the Campaign Plan defines the intermediate actions, approaches, initiatives, and funding over the 25 years to ensure the Army successfully achieves long-range energy and water management goals. The Army Energy and Water Campaign Plan for Installations was implemented in late 2005 and used in the FY 2008-2013 POM development process. This version is the current update to support the FY 2010-2015 POM development. The Army Energy and

Water Campaign Plan will be reviewed for updates every two calendar years during odd years.

The bottom line from all these documents is that the Army and other Federal buildings will be built to be more efficient and more sustainable, that these buildings' energy usage will decrease, and that design engineers, contractors and building managers are expected to play an active role in reducing energy and water usage.

1.2. Baseline and target energy budgets to meet EPACT 2005 requirements to new construction

The 2005 Energy Policy Act requires that Federal facilities be built to achieve at least a 30 percent energy savings over the 2004 International Energy Code or ASHRAE Standard 90.1-2004 as appropriate, and that energy efficient designs must be life cycle cost effective. A team comprised of researchers and engineers of Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), Department of Energy National Renewable Energy Laboratory, USACE Centers of Standardization and the Military Technology Group of the American Society of Heating Refrigeration and Air-Conditioning Engineers has developed design guides to achieve 30 percent energy savings over a baseline built to the minimum requirements of ANSI/ASHRAE/IESNA Standard 90.1-2004 for new buildings to be constructed under Military Transformation Program.

Phase 1 of this project addresses four building types: basic training barracks, unaccompanied enlisted personal housing (UEPH) barracks, battalion headquarters (BHQ), and tactical equipment maintenance facilities (TEMF). Phase 2 of this project is studying dining facilities (DFAC), child development centers (CDC), company operations facilities (COF) and reserve centers. To develop a baseline for target energy budgets which reflect the requirements of the EPACT 2005, typical buildings representing each category of the tier 1 facilities were selected and requirements of the ASHRAE Standard 90.1 2004 to the building envelope and energy consuming systems were defined. Based on this information a computer analysis was performed using EnergyPlus version 2 (DOE 2007) which resulted in baseline and target energy budgets for all DOE 15 climate zones (Figure 1-1) for each facility type. These results are summarized in Table 1-1.

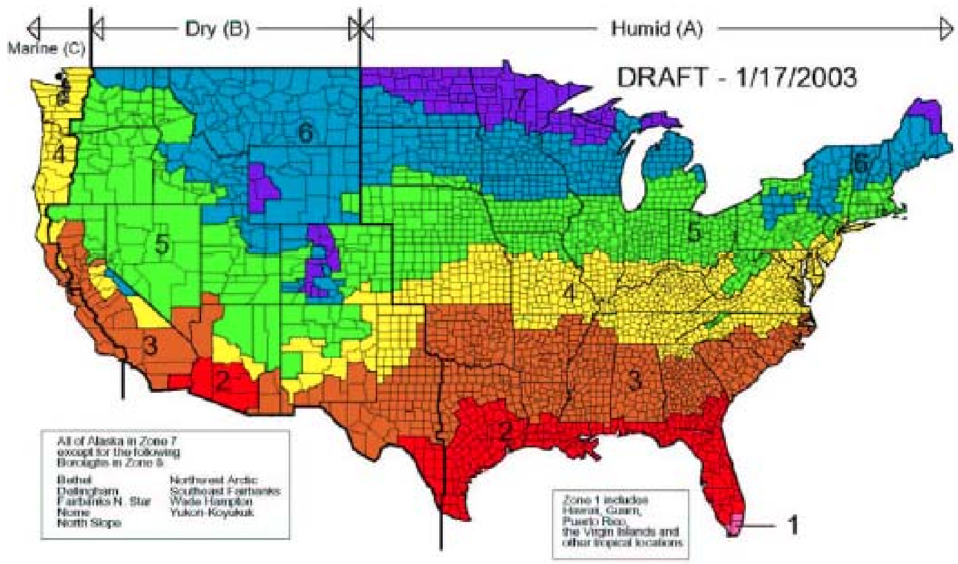


Figure 1-1. DOE Climate zones

Table 1-1. Baseline and target energy budgets (not including plug/process loads)

UEPH Climate zone	90.1 Baseline Annual Energy Budget (w/o process loads) (KBTU/sq ft-yr)	30% Better Target Energy Budget (w/o process loads) (KBTU/sq ft-yr)	Annual Process Loads (KBTU/sq ft-yr)
Miami, 1A	82	58	20
Houston, 2A	82	57	20
Phoenix, 2B	45	32	20
Memphis, 3A	71	50	20
El Paso, 3B	42	30	20
San Francisco, 3C	47	33	20
Baltimore, 4A	75	52	20
Albuquerque, 4B	48	34	20
Seattle, 4C	60	42	20
Chicago, 5A	77	54	20
Colo. Springs, 5B	54	38	20
Burlington, 6A	83	58	20
Helena, 6B	68	47	20
Duluth, 7A	91	64	20
Fairbanks, 8A	123	86	20

Training Barracks Climate zone	90.1 Baseline Annual Energy Budget (w/o process loads) (KBTU/sq ft-yr)	30% Better Target Energy Budget (w/o process loads) (KBTU/sq ft-yr)	Annual Process Loads (KBTU/sq ft-yr)
Miami, 1A	120	84	3
Houston, 2A	119	83	3
Phoenix, 2B	69	48	3
Memphis, 3A	122	85	3
El Paso, 3B	76	53	3
San Francisco, 3C	96	67	3
Baltimore, 4A	135	95	3
Albuquerque, 4B	93	65	3
Seattle, 4C	117	82	3
Chicago, 5A	146	102	3
Colo. Springs, 5B	111	78	3
Burlington, 6A	159	111	3
Helena, 6B	133	93	3
Duluth, 7A	176	123	3
Fairbanks, 8A	225	158	3

BHQ Climate zone	90.1 Baseline Annual Energy Budget (w/o process loads) (KBTU/sq ft-yr)	30% Better Target Energy Budget (w/o process loads) (KBTU/sq ft-yr)	Annual Process Loads (KBTU/sq ft-yr)
Miami, 1A	31	22	10
Houston, 2A	30	21	10
Phoenix, 2B	31	22	10
Memphis, 3A	33	23	10
El Paso, 3B	28	20	10
San Francisco, 3C	25	18	10
Baltimore, 4A	37	26	10
Albuquerque, 4B	31	22	10
Seattle, 4C	32	22	10
Chicago, 5A	44	31	10
Colo. Springs, 5B	37	26	10
Burlington, 6A	51	36	10
Helena, 6B	47	33	10
Duluth, 7A	60	42	10
Fairbanks, 8A	92	65	10

TEMF Climate zone	90.1 Baseline Annual Energy Budget (w/o process loads) (KBTU/sq ft-yr)	30% Better Target Energy Budget (w/o process loads) (KBTU/sq ft-yr)	Annual Process Loads (KBTU/sq ft-yr)
Miami, 1A	36	25	7
Houston, 2A	45	32	7
Phoenix, 2B	42	29	7
Memphis, 3A	56	39	7
El Paso, 3B	47	33	7
San Francisco, 3C	43	30	7
Baltimore, 4A	75	52	7
Albuquerque, 4B	61	43	7
Seattle, 4C	64	45	7
Chicago, 5A	93	65	7
Colo. Springs, 5B	80	56	7
Burlington, 6A	108	75	7
Helena, 6B	99	69	7
Duluth, 7A	134	94	7
Fairbanks, 8A	207	145	7

DFAC - draft Climate zone	90.1 Baseline Annual Energy Budget (w/o process loads) (KBTU/sq ft-yr)	30% Better Target Energy Budget (w/o process loads) (KBTU/sq ft-yr)	Annual Process Loads (KBTU/sq ft-yr)
Miami, 1A	242	170	113
Houston, 2A	250	175	112
Phoenix, 2B	236	165	112
Memphis, 3A	263	184	112
El Paso, 3B	243	170	112
San Francisco, 3C	220	154	111
Baltimore, 4A	291	204	111
Albuquerque, 4B	257	180	111
Seattle, 4C	261	182	111
Chicago, 5A	322	225	111
Colo. Springs, 5B	282	198	111
Burlington, 6A	353	247	111
Helena, 6B	324	227	111
Duluth, 7A	397	278	111
Fairbanks, 8A	519	364	111

Results for CDC, COF, and Reserve Centers will be included in Table 1-1 when complete.

The study also recommended a set of energy efficient solutions for each type of facilities and climate zone (see Appendices 14-17) that enable the 30 percent energy savings, and create more productive environments that provide better thermal conditions and indoor air quality to soldiers and workers.

1.3 LEED Energy Credits

1.3.1 U. S. Green Building Council Leadership in Energy and Environmental Design – New Construction (LEED®-NC). All vertical construction projects with climate control, beginning with the FY08 military construction program (except family housing), are required to be certifiable at a minimum of the Silver level of the LEED®**-NC**.

1.3.2 LEED certification and EPACT compliance. For new Army facilities that will be self-certified in LEED, all applicable results from the EPACT 2005 30% better study discussed above may be used to determine applicable LEED credits without the need for further energy analyses.

Achieving the EPACT 2005 mandated 30% improvement in energy consumption compared to a minimum ASHRAE 90.1-2004 facility will directly facilitate achievement of maximum credit for LEED credits EA1 “Optimize Energy Performance” which has 10 possible points. EPACT 2005 requires a 30% reduction in energy consumption not including plug or process loads. LEED EA1 requires percentage reductions in energy cost savings including plug and process loads. For self-certified Army projects, the LEED evaluation team may substitute site energy consumption, as determined in the EPACT 2005 30% Better energy analyses, for energy cost savings but must consider the plug and process loads in the calculations. Army buildings generally have small process loads. For all those buildings, a 30% savings in accordance with EPACT 2005 rules will equate to better than a 28% savings according to LEED NC rules which equates to a minimum of 6 LEED points for EA1.

The prescriptive solutions discussed in Appendices 14-17 generally result in savings significantly greater than 30%. Many of these cases result in the maximum of 10 LEED EA1 points. These prescriptive solutions also contribute to LEED points for credits EQ6.2 and EQ7.1.

Appendix 2: Requirements for Thermal Comfort, Ventilation rates, and Lighting levels

The simplest, most cost-effective, and easiest way to save energy in a building is to turn off all the lights, all the heating and cooling systems, and unplug all the appliance and equipment. This building would use no energy whatsoever, but it would be uncomfortably cold and hot, inadequately ventilated, dimly lit by whatever light comes in the windows, and a very unpleasant place to work. Freezing in the dark is not the object of energy conservation.

The object of energy conservation is to use the minimal amount of energy necessary to perform the required work in a building in a safe and efficient manner. The amount of energy a building uses depends upon its size (small Vs. large), the location (hot climate like Miami, FL; moderate climate like Washington, DC; or cold climate like Anchorage AK), and the type of building (barrack, office, warehouse, laboratory). For any given building, factors like ventilation rates, thermostat set points, and lighting levels have a significant impact on the energy consumption. All other things being equal, a building with higher ventilation rates will usually use more energy than a building with lower ventilation rates. A building with lower light levels will use less energy than a building with higher light levels. And a building with higher heating set points and lower cooling set points will use more energy than a building with lower heating set points and higher cooling set points.

It is important that engineers and O&M personnel design for and use appropriate rates and set points to maintain occupant comfort, health, and productivity AND minimize energy usage. Setting these rates and set points can be as much an art as a science, but there are a number of standard references that are used to help in the operation of the building. The following references provide guidance on the suggested values.

2.1. Thermal Requirements

Thermal requirements include criteria for thermal comfort and health, process needs, and criteria preventing mold mildew and other damage to he building materials or furnishings.

2.1.1. Thermal comfort and health criteria primarily involve the temperature and humidity conditions in the building. Too high a temperature means that occupants are uncomfortably hot. Too low a temperature means that occupants are uncomfortably cold. The wrong humidity means that occupants feel damp or sweaty or too dry. Thermal comfort is defined by ASHRAE Standard 55 Thermal Environmental Conditions for Human Occupancy. The latest version of Standard 55 was published in 2004 and is available from ASHRAE.

The following Dry Bulb room air temperatures are within the ASHRAE Standard 55 range and shall not be exceeded [IDG Benelux]:

Cooling Period: The DBT in occupied spaces shall not be set below 70oF (21oC) with the RH maintained below 50%. When the space is unoccupied during the short period of time, room thermostat shall be reset to 85oF (29oC) with the relative humidity maintained below 50%. In space unoccupied for an extended period of time, temperature shall not be controlled but the building air RH shall be maintained below 50%.

Heating period: Relative humidity of ALL building air shall be maintained below 50% and above 30% at all times (unless required differently for health reasons at the hospitals, day care facilities or by processes). The DBT in occupied spaces shall not exceed the following:

(1) Barracks and other living quarters: 70oF (21oC) Monday through Friday from 0500-2200 and 65ºF (18oC) from 2200-0500. Temperature settings for barracks Saturday and Sunday 70º (21oC) from 0600-2200 and 65ºF (18oC) from 2200-0600.

(2)Offices, warehouses, etc. where personnel work seated or in standing position involving little or no exercise: 70oF (21oC) during working hours and not more than 55oF (12.80C) during non-working hours.

(3) Child Care facilities: 72oF (22.2oC) during working hours.

(4) Issue and similar rooms: 60 oF/15.5oC.

(5) Special process rooms, such as paint shops and drying rooms: 80oF (26.6oC) allowed, or the one required by the process.

(6) Shops, hangars and other buildings where employees work in a standing position or exercise moderately, such as sorting, or light packing or crating: 60 oF/15.5oC during the day; 40oF (4.4oC) during night time.

(7)Shops, warehouses and the like, where employees do work involving considerable exercise, such as foundries, heavy packing, crating, and stacking, or where heat is required to protect material or installed equipment from freezing: 40oF (4.4oC). EXCEPTION: Localized heat, not to exceed 55oF (13oC) may be furnished in areas where the work requires medium or light personnel activity.

(8) Heat will not be permitted in warehouse areas that do not contain material or equipment requiring protection from freezing or condensation, and warehousing of stored goods is the only operation. Heat for the prevention of condensation on stored machinery and material will be supplied after a thorough survey of all conditions and the approval of the major Army or operating agency (DeCA, AAFES, etc.) manager.

(9) Buildings other than those specified above will not be heated to temperatures higher than 65ºF (18oC) without approval (in writing) from the subordinate garrison or garrison DPW.

When the space is unoccupied during the short period of time, room thermostat shall be set back to 55oF (13oC) with the relative humidity maintained below 50%. In space unoccupied for an extended period of time, temperature shall be controlled at 40oF (5oC) to prevent freezing with the building air RH maintained under 50%.

<u>2.1.2. Process related criteria</u> include temperature and humidity needed to perform the process housed in the building (e.g., painting, printing) or to operate process equipment such as electronics. While new design guidance for computer systems indicates a much higher tolerance for high temperatures than previously thought, there are specialized electronic and laboratory equipment that have fairly tight temperature and humidity requirements. An archival storage of important documents also involves relatively tight tolerances for temperature and humidity.

<u>2.1.3. Building materials and furnishings requirements</u>

The environmental conditions (temperature and humidity) maintained in indoor spaces determines not only the comfort of the occupants of those spaces but also the long-term “health” of the building itself. Historically, only the dry-bulb temperature of indoor spaces was controlled to achieve comfortable indoor conditions for the occupants. Little attention was given to control of moisture/humidity in the spaces. As a result, many existing Army buildings have significant mold/mildew problems.

Eliminating mold/mildew from Army buildings requires year-round control of both the dry-bulb temperature and the dew point temperature (or air relative humidity) in the indoor spaces. Control of indoor humidity will also significantly improve the comfort of Army building occupants.

Building materials and furnishing damage occurs when humid air meets a cold surface. Mold/mildew grows on a surface in a building when that surface’s relative humidity is above 85% for extended periods. This condition easily occurs in buildings even with low average air relative humidity when cold spots exist on poorly insulated supply air ducts and chilled water pipes, supply air diffusers and poorly insulated and not air tight building envelope elements and the areas with thermal bridges, etc. Careful design and operation of the building envelope and the HVAC, ventilation, and exhaust systems is required to eliminate the potential for mold growth in Army buildings. By controlling ALL the air inside the building above the dew point will reduce potential moisture related problems. According to the ASHRAE Humidity Control Design Guide, the suggested dew point limits which meet both health and mold problems requirements are < 57oF in summer and > 35oF in winter.

It is important, that designers and O&M personnel design and maintain the building and HVAC systems, to satisfy all three categories of requirements. In most of cases, thermal comfort requirements satisfy the process. Preventing moisture related problems require special attention to the design and building operation. Energy conservation shall not be achieved at expense of health, occupant’s wellbeing and building sustainability. Certain strategies and technologies can minimize or eliminate premium energy use.

2.1.4. Thermal requirements to unoccupied spaces.

Requirements for temperatures and relative humidity discussed above are developed for occupied spaces (Table 2-1). Many DOD and other government buildings are not occupied at night or on weekends. Some DOD facilities including barracks, administrative and dining facilities may be unoccupied for an extended period of time due to training and deployment. So, one of energy conservation strategies may be to set back temperatures for heating or set up for cooling. One source of guidance on set back or set up temperatures is ANSI/ASHRAE/IESNA Standard 90.1-2004 *Energy Standard for Buildings Except Low-Rise Residential Buildings*. Standard 90.1-2007 does not regulate thermostat set backs or set ups, but it does regulate the capabilities of thermostats installed in buildings. Section 6.4.3.3.2 of Standard 90.1-2004 Setback Controls – requires that heating systems in all parts of the US outside of Miami FL and the tropical islands (zones 2-8) must have a capability to be set back to 55°F. Heating systems in zone 1 are assumed to have minimal usage and therefore no need of setbacks. Cooling systems in hot dry areas (zones 1b, 2b, and 3b) must have the capability to be set up to 90°F. However, cooling systems in hot and humid climates (zones 1a, 2a, and 3a) are not required to have cooling setbacks due to potential for moisture problems. It is wasteful to cool DOD facilities left unoccupied for an extended period of time, which are located in hot and humid climates. Significant energy savings can be achieved without damage to building materials and furnishing if a combination of measures (discussed in Appendix 14) related to the building envelope and HVAC maintain the requirements for ALL the air inside the building.

Table 2-1. Requirements to dry bulb temperature and relative humidity for occupied and unoccupied facilities to reduce the risk of moisture related problems.

Occupancy/Use	Humidity not to exceed	Maximum Dry Bulb Temp	Minimum Dry Bulb Temp
Occupied	50%	75 °F	70 °F
Unoccupied (Short term)	50%	85 °F	55 °F
Unoccupied (long term)	50%	No Max	40 °F
Critical Equipment	50% or equip requirement if less	Equip max allowed	Equip min allowed

2.2. Ventilation rates

The key design considerations for maintaining adequate indoor air quality (IAQ) include providing adequate outdoor air rates which satisfy three major requirements: contaminant control, make-up air needs and building pressurization.

2.2.1. ASHRAE Standard 62-2007 specifies minimum outside air ventilation rates for residential, commercial, institutional, and industrial spaces. These rates for representative buildings at Army Installations are presented in Table 2-2.

2.2.2. Industrial buildings (i.e., motor pools, paint booths, plating tanks, etc.) require make-up air to replace the large volumes of air exhausted by process enclosures and open hoods. Make-up air rates depend upon the type and number of equipment requiring exhaust ventilation and efficiency of local exhausts. Minimum exhaust rates (and respective make-up air rates) are listed in Table 2-3, which is based on the ASHRAE Standard 62.1-2007 Table 6-4. and ASHRAE HVAC Applications Handbook (ASHRAE 2007), Kitchen Ventilation chapter.

Table 2-2. Minimum exhaust rates

Equipment /facility Category	Exhaust Rate, cfm/unit (L/s m^2)	Remarks
Educational Science Laboratory	1.00 cfm/ft2	ASHRAE Std 62.1-2007, Table 6-4
Janitor Closets, trash rooms	1.00 cfm/ft2	ASHRAE Std 62.1-2007, Table 6-4
Kitchenettes	0.3 cfm/ft2	ASHRAE Std 62.1-2007, Table 6-4
Kitchens – commercial	See Table 6	ASHRAE Standard 154
Motor Pools	1.5cfm/ft2	General exhaust ASHRAE Std 62.1-2007, Table 6-4
Motor Pools (vehicle exhaust	See Table	
Showers	60 cfm/unit	EN 15251, Table B5
	25/50 cfm/unit	ASHRAE Std 62.1-2007, Table 6-4
Toilets – private	25/50 cfm/unit	ASHRAE Std 62.1-2007, Table 6-4
Toilets –public	50/70 cfm/unit	ASHRAE Std 62.1-2007, Table 6-4
Laboratory hoods	ASHRAE Std 110 Method of Testing Performance of Laboratory Fume Hoods	ASHRAE HVAC Applications Handbook (ASHRAE 2007), Kitchen Laboratories Chapter, Table 2

Table 2-3. Exhaust flow rates by unlisted and listed cooking hood type.

Type of Hood		Minimum Exhaust Flow Rate (cfm per linear foot of hood)			
		Light Duty Equipment	Medium Duty Equipment	Heavy Duty Equipment	Extra Heavy Duty Equipment
Wall-mounted canopy,	unlisted	200	300	400	550
	listed	150 - 200	200 - 300	200 - 400	350+
Single island canopy,	unlisted	400	500	600	700
	listed	250 - 300	300 - 400	300 - 600	550+
Double island canopy,	unlisted	250	300	400	
	listed	150 - 200	200 - 300	250 - 400	500+
Eyebrow, unlisted		250	250	Not allowed	Not allowed
	listed	150 - 250	150 - 250	—	—
Backshelf/proximity,	unlisted	300	300	400	Not allowed
	listed	100 - 200	200 - 300	300 - 400	Not recommended
Source: ASHRAE Standard 154					

Mechanical codes recognize exceptions for hoods that have been tested against a recognized standard, such as Underwriters Laboratories (UL) Standard 710. Part of the UL standard is a “cooking smoke and flair up” test. This test is essentially a cooking effluent capture and containment (C&C) test where “no evidence of smoke or flame escaping outside the exhaust hood” must be observed. Hoods bearing a recognized laboratory mark are called *listed* hoods, while those constructed to the prescriptive requirements of the building code are called *unlisted* hoods.

As reflected by the range in exhaust rates in the table, a *listed* hood can be operated at a lower exhaust rate than an *unlisted* hood of comparable style and size over the same cook line. Lower exhaust rates may be proven by laboratory testing with specific hood(s) and appliance lineup using the test protocol described in ASTM Standard F-1704, *Test Method for Performance of Commercial Kitchen Ventilation Systems*. This process is sometimes referred to as “custom-engineering” a hood and is the foundation of this ECM. Within the specification to maximize hood performance and minimize exhaust rate are construction or installation details that include the addition of partial side panels, minimizing the gap between the appliances and the back wall and, in the case of canopy hoods, increasing the amount of overhang (e.g., from 6 to 18 in). These detailed specifications can permit a listed hood to operate satisfactorily at the lower end of the cfm range show (e.g., 200 cfm vs. 300 cfm) for a <u>30% or more saving</u> over the Code values and or standard design practice).

ASHRAE Standard 154 categorizes cooking appliances as light-, medium-, heavy-, and extra heavy-duty, depending on the strength of the thermal plume and the quantity of grease, smoke, heat, water vapor, and combustion products produced. The strength of the thermal plume is a major factor in determining the exhaust rate. By their nature, these thermal plumes rise by natural convection, but they are turbulent and different cooking processes have different “surge” characteristics.

Appliance Duty Classifications from ASHRAE Standard 154

Light Duty

- Gas and electric ovens (including standard, bake, roasting, revolving, retherm, convection, combination convection/steamer, conveyor, deck or deck-style pizza, and pas-try)
- Electric and gas steam-jacketed kettles
- Electric and gas compartment steamers (both pressure and atmospheric)
- Electric and gas cheesemelters
- Electric and gas rethermalizers

Medium Duty

- Electric discrete element ranges (with or without oven)
- Electric and gas hot-top ranges
- Electric and gas griddles
- Electric and gas double-sided griddles
- Electric and gas fryers (including open deep-fat fryers, donut fryers, kettle fryers, and pressure fryers)
- Electric and gas pasta cookers

• Electric and gas conveyor (pizza) ovens
• Electric and gas tilting skillets /braising pans
• Electric and gas rotisseries

Heavy Duty
• Electric and gas underfired broilers
• Electric and gas chain (conveyor) broilers
• Gas open-burner ranges (with or without oven)
• Electric and gas wok ranges
• Electric and gas overfired (upright) broilers
• Salamanders

Extra Heavy Duty
Appliances using solid fuel such as wood, charcoal, briquettes, and mesquite provide all or part of the heat source for cooking.

Local exhausts and make-up air systems are significant energy consumers, required for heating and cooling the outside air and for transportation of supply and exhaust air. To extend it is feasible, change processes or use equipment with reduced contaminant and heat release into the space. To minimize hood exhaust airflow

- Use enclosed vs. open hoods when possible (e.g., over plating tanks, vehicle exhaust hoods, etc.). Otherwise, use high efficiency proximity hoods.
- Select location or co-location of process equipment (e.g., kitchen equipment) to increase local exhaust capture efficiency (Figure 2-2):
  - Position equipment (i.e., cooking appliances) close to the walls, avoid island installations when possible
  - Enclose appliances with the walls
- Use demand based exhaust ventilation systems (e.g., welding exhaust systems, kitchen hoods, see Figure 2-3)
- Use efficient hood configurations to to reduce exhaust flow (Figure 2-4)
- Avoid cross-drafts (i.e., in kitchen space, welding shops, laboratories, etc.)

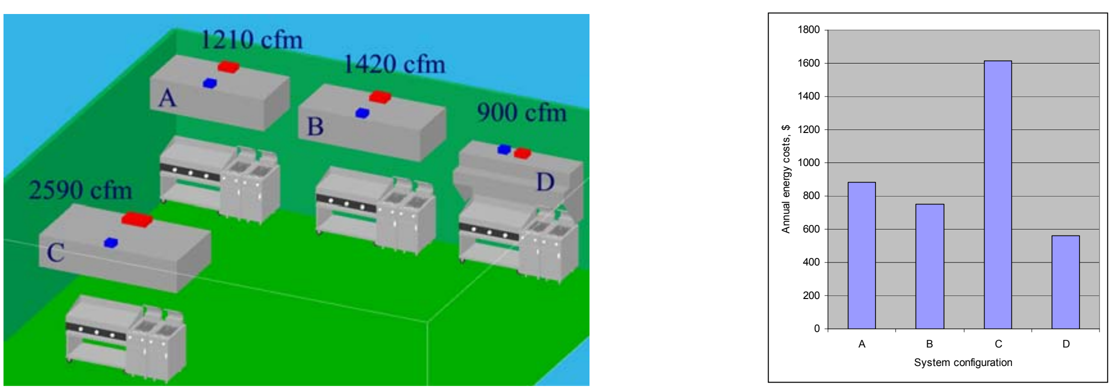


Figure 2-2. Effect of appliance position on the energy cost: A – appliances in the corner with canopy wall hood; B – appliances at the wall with canopy wall hood; C – appliances in the middle of the space with canopy island hood; D – appliances at the wall with close proximity back-shelf hood (Livchak Workshop 2007).

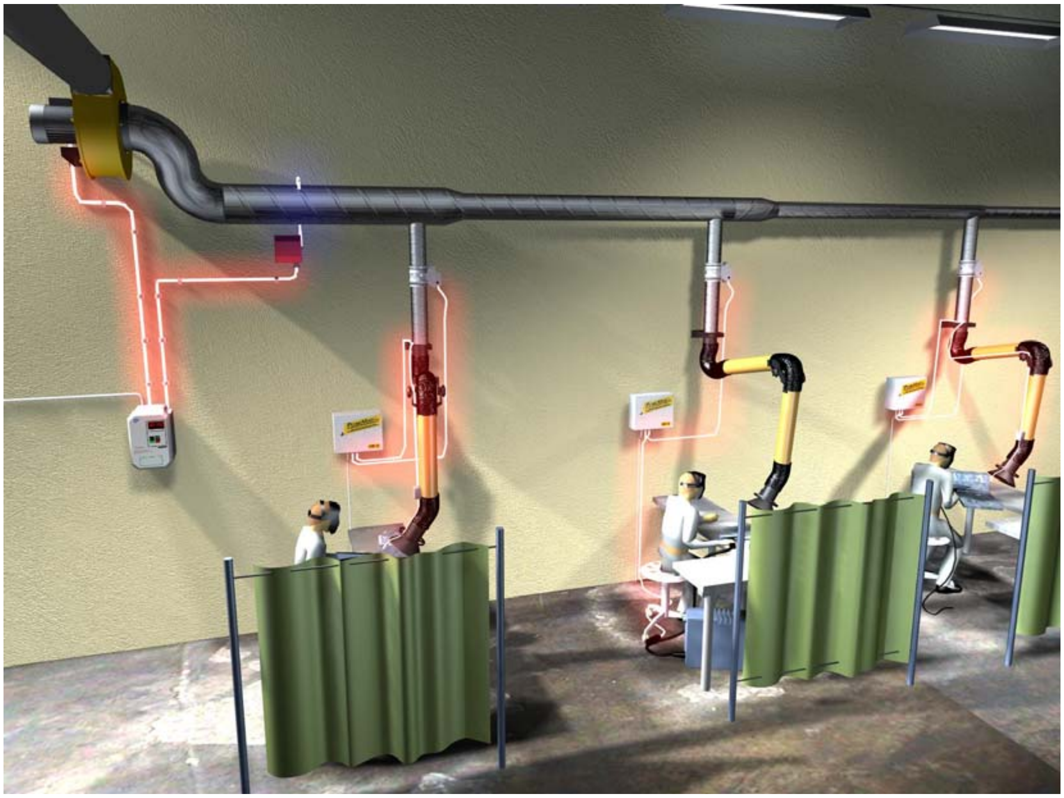


Figure 2-3. Schematic of the demand based exhaust ventilation system in welding shop (Annex 46 Fact Sheet).

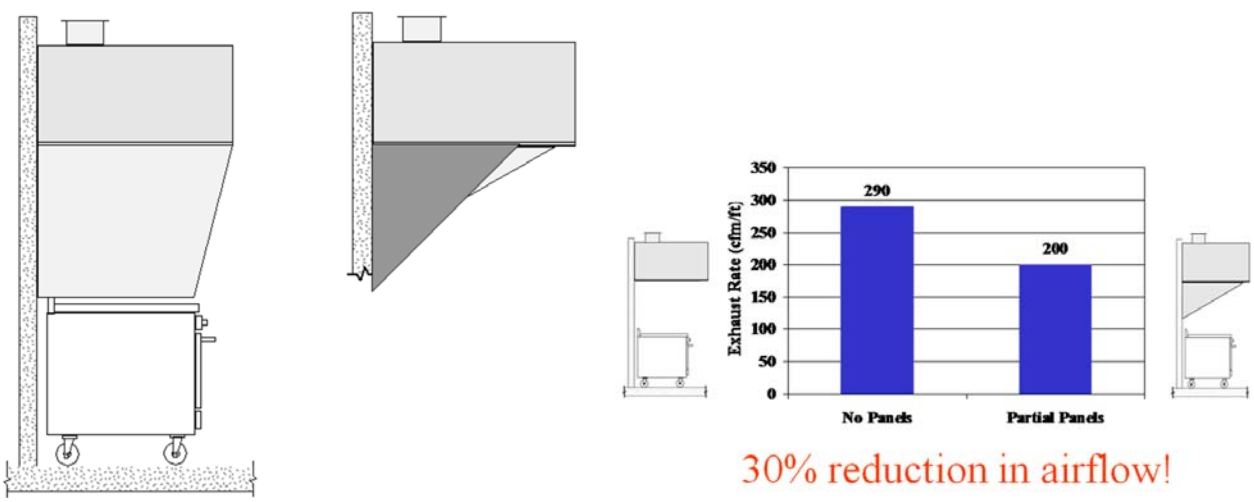


Figure 2-4. Incorporating partial side panels or end walls in different configuration of kitchen hoods allows exhaust flow reduction (www.Fishnick.org)

2.2.3. Outside airflow rate required for building pressurization depends upon the building air tightness. The tighter the building envelope, the smaller airflow rate is required to prevent infiltration of cold/warm air into the building, which reduces the sensible and latent heat load on HVAC systems. ASHRAE is considering implementing in standard 90.1 an overall building air leakage maximum requirement that is that building air leakage is not to exceed 0.4cfm/ft2 at a pressure difference of 75 Pa. The Army has implemented a more stringent requirement for total building air leakage not to exceed 0.25cfm/ft2 at a pressure difference of 75Pa.

In existing buildings air leakage can be determined using the "Blower door" technique in accordance with NFRC 400 and be calculated using the *power law flow* function of the form ($Q = C(\Delta P)^n$. During a blower door test, the two parameters that quantitatively describe the building air leakage, the flow coefficient ,C (CFM/Pa), and the dimensionless flow exponent ,n, can be determined experimentally for a specific building.

The same power law function can be used to estimate the total air flow from infiltration which needs to be overcome to pressurize the building. To accomplish this, the total infiltration rate (Q_{75}) in CFM at 0.3 in w.g. (75Pa) is calculated based on the total wall, floor, and roof area of the building and the assumed overall maximum allowed air leakage rate of .25 CFM/ft2. Assuming that the building is pressurized to 0.02 in w.g. by the building ventilation system, the Power Law flow function can be used to determine the total air leakage rate (Q_5) in CFM at 0.02 in w.g. (5 Pa) assuming a flow coefficient of 0.65:

$$Q_5 = Q_{75} * (5/75)^{.65}$$
$$Q_5 = Q_{75} * .17$$

The mechanical ventilation system has to provide outside air to the building equal to the building exhaust plus Q_5, the air leakage rate at 0.02 in w.g. The infiltration leakage rate is about 10% higher than the outdoor ventilation rates required by ASHRAE Standard 62.1-2004.

2.3. Lighting intensity

Lighting systems are designed based on lighting intensity in buildings recommended to meet OSHA can be found in the IESNA Handbook (IESNA stands for the Illuminating Engineering Society of North America). There are many types of spaces that are overlit for various reasons.

Office spaces are often over-lit as a result of having been installed prior to 1985, when overhead lighting was the only light source and light levels were designed for paper-based reading tasks, using 750-1000 lux as the lighting criteria due to the poor reprographics available at that time; now office lighting designs are based on computer tasks and higher quality printed tasks, so overhead lighting can be reduced to between 300 and 500 lux.

Recent findings show that when the spectral properties of the peripheral lighting are shifted to include more blue, our eyes respond the same as if the lighting levels were increased – the pupils of our eyes get smaller, spaces seem brighter, and we see things more clearly. Thus, additional energy savings can be obtainable through the use of spectrally enhanced lighting and extra-efficient electronic ballasts.

One of the easiest and most cost effective methods for saving energy is to design lighting systems to the correct light level for the tasks being performed, and not over-lighting spaces.

Another parameter used in the lighting systems design is Lighting Power Density which is limited by Section 9 of ASHRAE/IESNA Standard 90.1 2007 with the modifications and additions required by CHAPTER 7 of BSR/ASHRAE/USGBC/IESNA Standard 189.1P ASHRAE Standard 90.1 limits lighting power consumption by defining limits for Lighting Power Densities (LPD) in Watts per sq. Fort The Standard does this by using IESNA lighting recommendations for light levels and calculating the wattage that would be consumed by energy-efficient lighting systems in specific building types. The LPD's in Standard 90.1 are based on standard lamps and ballasts, and do not include the latest in ballast technologies or any spectral contributions.

Table 2-4 provides current requirements for Lighting intensities a for typical Army facilities.

Table 2-4. Examples of design illumination levels for some Army buildings and spaces from EN 12464.

Type of building	Space	Maintained luminance, Ê m, at working areas, lx	UGR	Ra	Remarks
Barracks/Dormitories					
Educational Buildings	Play room, nursery, classroom	300	19	80	
	Lecture hall	500	19	80	
	Computer practice rooms (menu driven)	300	19	80	
Office buildings	Single offices	500	19	80	at 0,8 m
	Open plan offices	500	19	80	at 0,8 m
	Conference rooms	500	19	80	at 0,8 m
Educational buildings	Classrooms	300	19	80	at 0,8 m
	Classrooms for adult education	500	19	80	at 0,8 m
	Lecture hall	500	19	80	at 0,8 m
Hospitals	General ward lighting	100	19	80	at 0,8 m
	Simple examination	300	19	80	at 0,8 m
	Examination and treatment	1000	19	90	at 0,8 m
Hotels and restaurants	Self-service restaurant, dining room	200	22	80	at 0,8 m
	Kitchen	500	22	80	
	Buffet	300	22	80	
Sport facilities	Sports halls	300	22	80	at 0,1 m

Type of building	Space	Maintained luminance, Ê m, at working areas, lx	UGR	Ra	Remarks
Wholesale and retail premises	Sales area	300	22	80	at 0,8 m
	Till area	500	19	80	at 0,8 m
Circulation areas	Corridor	100	28	40	at 0,1 m
	Stairs	150	25	40	at 0,1 m
	Restrooms	100	22	80	
	Cloakrooms, washrooms, bathrooms, toilets	200	25	80	
Industrial	Metal working/ welding	300	25	60	
	Assembly Rough Medium Fine precision	 200 300 500 750	 25 25 22 19	 80 80 80 80	
Central Plant	Boiler house Machine Halls Side rooms, e.g. pump rooms, condenser rooms etc. Control rooms	100 200 200 500	28 25 25 16	40 80 60 80	
Vehicle Construction/ Maintenance	Body work and assembly Painting, spraying and polishing Painting, touch-up, inspection	500 750 1000	22 22 19	80 80 90	
Wood working and processing	Saw frame Work at joiner's bench, gluing, assembly Polishing, painting, fancy joinery Work on wood working machines e.g. turning, fluting, dressing, rebating, grooving, cutting, sawing, sinking	300 300 750 500	25 25 22 19	60 80 80 80	

EN 12464-1 Light and lighting – Lighting of work places – Part 1: Indoor work places. Approved by CEN on 16 October 2002.
http://www.voltimum.it/news/4666//Illumination-levels-for-inside--zones---tasks-and-activity-according-to-EN-12464-1.html

Appendix 3: Building Envelope

3.1. Insulation

The building envelope performs various tasks, which includes weather protection from wind, rain, irradiation, heat and cold, visibility and glare protection, fire protection, noise protection and protection against burglary. At the same time, the building envelope must fulfill internal space requirements, which include thermal conditions, acoustic, and visual comfort along with requirements for humidity conditions for both comfort and mold and mildew growth prevention.

Thermal performance of the building envelope influences the energy demand of a building in two ways. It effects annual energy consumption and thus, operating costs for building heating, cooling and humidity control. It also influences peak loads which consequently determine the size of heating, cooling and energy generation equipment and in this way has an impact on investment costs. In addition to energy saving and investment cost reduction, a better insulated building provides other significant advantages. Higher thermal comfort because of warmer surface temperatures on the interior surfaces in winter and lower temperatures in summer. This also results in a lower risk of mold growth on internal surfaces.

ASHRAE Standard 90.1-2007 prescriptive requirements for building envelope as a function of assembly type, climate zone, and building type are listed in Section 5.5 and Tables 5.5-1 to 5.5-8.

Requirements for building envelopes of small office buildings, small retail buildings, K-12 school buildings and Small Warehouses and Self-Storage Buildings, which allow in combination with other energy conservation measures to achieve 30% energy savings over ANSI/ASHRAE/IESNA Standard 90.1-1999 are listed in respective Advanced Energy Design Guides, which can be obtained from the ASHRAE or downloaded from the following website: http://www.ashrae.org/technology/page/938

Studies conducted by USACE in collaboration with DOE and ASHRAE [B, T, O, DF,CDC] resulted in prescriptive thermal properties (Tables 3-1 to 3-5) of the building envelop components which shall be followed to meet the EPAct 2005 requirement for 30% over the ASHRAE Standard 90.1-2004 building energy performance. These requirements shall be met with all new construction and major renovation projects.

Table 3-1. Barracks – UEPH

Item	Component	Climate Zones							
		1	2	3	4	5	6	7	8
Roof	Attic R (ft^2hF/Btu)	40	40	40	50	50	60	60	60
	Surface reflectance	.27	.27	.27	.27	.27	.27	.27	,.27
Walls	Light Weight Construction R (ft^2hF/Btu)	20	20	20	25	25	30	30	30
Exposed Floors	Mass R (ft^2hF/Btu)	5	10	10	20	20	30	30	30
Slabs	Unheated R (ft^2hF/Btu)	NR	NR	NR	NR	NR	NR	NR	10
Doors	Swinging	NR	NR	NR	NR	NR	NR	NR	NR
	Non-swinging	NR	NR	NR	NR	NR	NR	NR	NR
Vertical Glazing	Window to Wall Area Ratio (%)	20%	20%	20%	20%	20%	20%	20%	20%

Table 3-2. Training barracks

Item	Component	Climate Zones							
		1	2	3	4	5	6	7	8
Roof	Attic R (ft^2hF/Btu)	40	40	40	50	50	60	60	60
	Surface reflectance	.27	.27	.27	.27	.27	.27	.27	,.27
Walls	Light Weight Construction R (ft^2hF/Btu)	20	20	20	25	25	30	30	30
Exposed Floors	Mass R (ft^2hF/Btu)	5	10	10	20	20	30	30	30
Slabs	Unheated R (ft^2hF/Btu)	NR	NR	NR	NR	NR	NR	NR	10
Doors	Swinging	NR	NR	NR	NR	NR	NR	NR	NR
	Non-swinging	NR	NR	NR	NR	NR	NR	NR	NR
Vertical Glazing	Window to Wall Ratio (%)	20%	20%	20%	20%	20%	20%	20%	20%

Table 3-3. Admin buildings

Item	Component	Climate Zones							
		1	2	3	4	5	6	7	8
Roof	Attic R (ft^2hF/Btu)	30	38	38	38	44	44	60	60
	Surface reflectance	.27	.27	.27	.27	.27	.27	.27	,.27
Walls	Light Weight Construction R (ft^2hF/Btu)	13	13	13	13+7.5	13+7.5	13+7.5	13+15	13+20
Exposed Floors	Mass R (ft^2hF/Btu)	NR	NR	NR	NR	NR	NR	NR	NR
Slabs	Unheated R (ft^2hF/Btu)	NR	NR	NR	NR	NR	10	15	20
Doors	Swinging	NR	NR	NR	NR	NR	NR	NR	NR
	Non-swinging	NR	NR	NR	NR	NR	NR	NR	NR
Vertical Glazing	Window to Wall Ratio (%)	40-ns 20-ew	40-ns 20-ew	40-ns 20-ew	40-ns 20-ew	40-ns 20-ew	40-ns 20-ew	40-ns 20-ew	40-ns 20-ew

Table 3-4. Tactical equipment maintenance facilities

Item	Component	Climate Zones							
		1	2	3	4	5	6	7	8
Roof	Attic R (ft^2hF/Btu)	19	19	13+13	13+19	13+19	13+19	13+19	19+13
	Surface reflectance	.27	.27	.27	.27	.27	.08	.09	.08
Walls	Light Weight Construction R (ft^2hF/Btu)	13	13	13	13	13+13	13+13	13+13	13+16
Exposed Floors	Mass R (ft^2hF/Btu)	NR	NR	NR	NR	NR	NR	NR	NR
Slabs	Unheated R (ft^2hF/Btu)	NR	NR	NR	NR	NR	NR	NR	20
Doors	Swinging U (Btu/ft^2hF)	U-.70	U-.70	U-.70	U-.70	U-.70	U-.70	U-.70	U-.70
	Non-swinging U (Btu/ft^2hF)	U-.25	U-.25	U-.25	U-.25	U-.25	U-.25	U-.25	U-.25
Vertical Glazing	Window to Wall Ratio (%)	<10%	<10%	<10%	<10%	<10%	<10%	<10%	<10%

Table 3-5. Dining facilities

Item	Component	Climate Zones							
		1	2	3	4	5	6	7	8
Roof	Roof R (ft^2hF/Btu)	15	15	20	20	20	20	20	30
	Surface reflectance	.65	.65	.65	.3	.3	.3	.3	.3
Walls	Light Weight Construction R (ft^2hF/Btu)	13	13	13+3.8	13+7.5	13+7.5	13+7.5	13+7.5	13+22
Exposed Floors	Mass	NR	NR	NR	NR	NR	NR	NR	NR
Slabs	Unheated R (ft^2hF/Btu)	NR	NR	NR	NR	NR	NR	15	20
Doors	Swinging	NR	NR	NR	NR	NR	NR	NR	NR
	Non-swinging	NR	NR	NR	NR	NR	NR	NR	NR
Vertical Glazing	Window to Wall Ratio	NR	NR	NR	NR	NR	NR	NR	NR

In building retrofit projects, buildings can be insulated from inside or outside. Technically, the best way to insulate a building component is on the outside as this reduces problems with thermal bridges and does not reduce the usable floor area. With the sufficient exterior insulation, the dew point temperature will not fall within the wall cavity - reducing the risk of condensation. With current insulation technologies external insulation offers different color and texture options and improves the look of the façade (Figure 3-1).

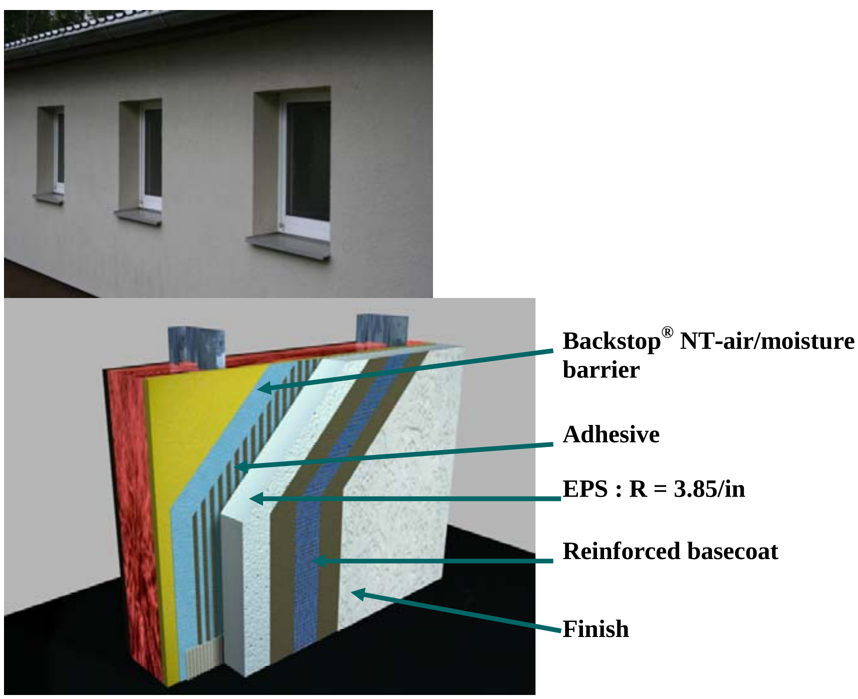


Figure 3-1. Reinsulated Army barrack and schematic of exterior insulation and finish systems

However, with some buildings (e.g., historic buildings) external insulation may be not be approved and, therefore internal insulation shall be used. Internal insulation reduces usable floor area, may have a poorer aesthetics and requires interruption of the space usage (Figure 3-2).

Figure 3-2. Internal insulation of the administrative building at the Rock Island Arsenal.

3.2. Windows

For new designs and major retrofits selecting windows will be selected to improve visual and thermal comfort and provide an opportunity for energy savings. While window replacement for energy conservation reason only is typically not cost efficient, energy efficient windows for new construction and major retrofit projects which include window replacement requirement is cost efficient and shall be specified. The selection of windows for cold climates shall be based on a window's ability to retain heat inside the building and reduce infiltration, whereas in warm climates – on the capacity to block heat gain from the sun and reduced infiltration. The main energy related parameters of a window are its insulation value, transparency to solar radiation, and air tightness.

The **U-factor** expresses a window's insulation value, its resistance to heat flow when there is a difference between inside and outside temperature. The U-factor is measured in Btu/hr-sq ft-°F (W/sq m-°C). The lower the U-factor, the greater a window's resistance to heat flow.

A window's transparency to the heat carried by solar radiation is expressed in the **solar heat gain coefficient (SHGC).** The SHGC is the fraction of solar heat admitted by the window on a range of 0 to 1. A window's transparency to visible light is expressed as its **visible transmittance (VT)** on a range of 0 to 1 (cf. Figure 3-3)**.**

The **air-leakage (AL)** rating of a window indicates its air tightness. It expresses the rate of air-leakage around a window at a specific pressure difference in units of cubic feet per minute per square foot of frame area (cfm/sq ft) or cubic meters per minute per square meter of frame area.(cmm/sq m).

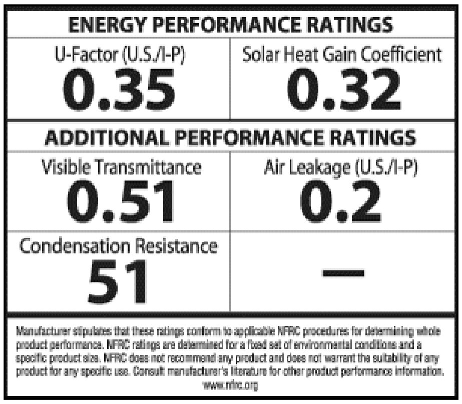


Figure 3-3. Example of the label verifying that the energy properties of windows are rated according to nationally accepted standards and certified by the National Fenestration Rating Council (NFRC).

Table 3-6 shows a range of energy efficient window options (A through F) to be used in barracks located in different climates.

Table 3-6. Window options with default values for barracks buildings

Window Options with Default Performance Values						
#	**Glazing type**	**Frame type**	**U-factor (imp./metric)**	**SHGC**	**VT**	**AL (imp./metric)**
A	2-pane, low-solar-gain low-E	Aluminum, thermal break	0.47 / 2.7	0.33	0.55	0.2 / 0.06
B	2-pane, low-solar-gain low-E	Non-metal	0.34 / 1.9	0.30	0.51	0.2 / 0.06
C	2-pane, high-solar-gain low-E	Non-metal	0.36 / 2.0	0.49	0.54	0.2 / 0.06
D	3-pane, low-solar-gain low-E	Non-metal	0.26 / 1.4	0.25	0.40	0.1 / 0.03
E	3-pane, high-solar-gain low-E	Non-metal	0.27 / 1.5	0.38	0.47	0.1 / 0.03
F	3-pane, high-solar-gain low-E	Non-metal, insulated	0.18 / 1.0	0.40	0.50	0.1 / 0.03

Table 3-7 lists window options for barracks that shall be considered in different climates. Efficient window options are recommended based on the climate-specific considerations —a low SHGC for warm climates and a low U-factor for cold climates. Aluminum-framed window A is among the recommended options for regions where hurricane considerations might require the sturdiness of aluminum (1A, 2A, 2B, 3A).

Table 3-7. Window options recommended for barracks located in different US climates

Zone	Climate	Efficient window options
1A	Very hot	A, B
2A,B	Hot	A, B,
3A,B,C	Warm	A, B
4A,B,C	Mixed	B, C
5A,B	Cool	B, C, D, E
6A,B	Cold	C, D, E
7	Very cold	C, E, F
8	Subarctic	E, F

Operable windows provide building occupants with a connection to the outdoors and can serve to provide additional natural ventilation (under appropriate outdoor conditions) if the mechanical systems are shut down because of problems or servicing. Operable window shall not be used in hot and humid climates (Zones 1a, 2a, and 3a) to prevent mold problems.
The ventilation characteristics of a window that provides a modest connection to the outdoors are different from a window that can provide a portion of the cooling requirements for the interior space. The ventilation function of an operable sash must be incorporated into the total fenestration design. It may not be feasible or necessary to make all windows operable in office or commercial buildings. A small awning or sliding window below a fixed window can provide the desired effect. All operable windows must have appropriate switches to disarm air-conditioning systems controlling sensible load (DOAS controlling latent load shall be operated all the time).

Table 3-8 shows a range of window options (A through D) and their energy related characteristics for administrative buildings which provide energy-efficiency benefits in different climates.

Table 3-8. Window options with default values for administrative buildings

Window Options with Default Performance Values						
#	**Glazing type**	**Frame type**	**U-factor (imp./metric)**	**SHGC**	**VT**	**Incremental cost ($ per ft^2)**
A	2-pane, reflective coating	Aluminum, thermal break	0.54 / 3.1	0.17	0.10	$1.25
B	2-pane, low-E, tinted	Aluminum, thermal break	0.46 / 2.6	0.27	0.43	$1.75
C	2-pane, low-E	Aluminum, thermal break	0.46 / 2.6	0.34	0.57	$1.50
D	3-pane, low-E	Insulated	0.20 / 1.1	0.22	0.37	$8.00

Table 3-9 lists window options for administrative buildings that shall be considered in different climates. Efficient window options are recommended based on the climate-specific considerations —a low SHGC for warm climates and a low U-factor for cold climates. Aluminum-framed window A is among the recommended options for regions where hurricane considerations might require the sturdiness of aluminum (1A, 2A, 2B, 3A).

Table 3-9. Window options recommended for administrative buildings located in different U.S. climates

Zone	Climate	Efficient window options
1A	Very hot – humid	A, B
2A,B	Hot	A, B
3A	Warm -humid	B
3B,C	Warm (dry, marine)	B, C
4A,B,C	Mixed	B, C
5A,B	Cool	B, C
6A,B	Cold	B, C, D
7	Very cold	C, D
8	Subarctic	C, D

3.3. Doors. Exterior doors shall have infiltration rates not exceeding 0.3 cubic feet per minute per square foot (cfm/ft^2) of window area, 0.3 cfm/ft^2 of door area for residential doors, 0.3 cfm/ft^2 of door area for nonresidential single doors (swinging and sliding), and 1.0 cfm/ft^2 for nonresidential double door (swinging) when tested according to NFRC-400 or ASTM E 283 at a pressure differential of 75 Pascals or 1.57 pounds per square foot.

For a solid wood exterior door, the required U-factor is less than or equal to 0.40 Btu/hr-ft^2-F. Weather-stripping along the top, jambs, and bottom sweeps is required to minimize air infiltration around exterior doors. All glass in exterior doors shall have a U-factor or energy efficiency rating less than or equal to 0.65 Btu/hr-ft^2-F.

3.4. Roofs. Roofs are vulnerable to solar gain in summer and heat loss in winter. Dark, non-reflective roofing surfaces create heat island effects by absorbing energy from the sun and radiating it as heat. High-reflectance and high emissivity, roofs (often referred to as “cool roofs”) that can reflect heat instead of absorbing it, thereby reducing the building’s interior temperature and the running time of the air conditioning system. In winter “cool” roofs might have a negative effect on the building energy consumption by increasing load on the heating system compared to standard roofs. Studies conducted under the IEA ECBCS Annex 46 showed that “cool roofs” are cost effective over air-conditioned spaces only for buildings located in climate zones 1-5. In these locations, a minimum of 75% of the entire roof surface not used for roof penetrations, renewable energy power systems (e.g. photovoltaics or solar thermal collectors), harvesting systems for rainwater to be used on-site, buildings shall be covered with roofing products that comply with one or more of the following:

(a) have a minimum initial *SRI* of 0.78 for a low-sloped roof (a slope less than or equal to 2:12) and a minimum initial *SRI* of 0.29 for a steep-sloped roof (a slope of more than 2:12).

(b) comply with the criteria for the USEPA's Energy Star Program Requirements for Roof Products – Eligibility Criteria.

In the case of industrial ventilated and heated, but not air-conditioned buildings, "cool roofs" reduce indoor air temperature during the hot part of the year and therefore improves worker's comfort and productivity and is cost effective in all climates.

The *solar reflective index (SRI)* shall be calculated in accordance with ASTM E1980 for medium-speed wind conditions. The SRI shall be based upon solar reflectance as measured in accordance with ASTM E1918 or ASTM C1549, and the thermal emittance as measured in accordance with ASTM E408 or ASTM C1371. For roofing products, the values for solar reflectance and thermal emittance shall be determined by a laboratory accredited by a nationally recognized accreditation organization, such as the Cool Roof Rating Council CRRC-1 Product Rating Program, and shall be labeled and certified by the manufacturer.

Solar reflectance is the fraction of solar energy that a roof reflects. Thermal emittance is a measure of the roof's ability to radiate any heat absorbed back into the air, rather than the building below. Both properties are measured on a scale of zero to one; the higher the values, the cooler the roof.

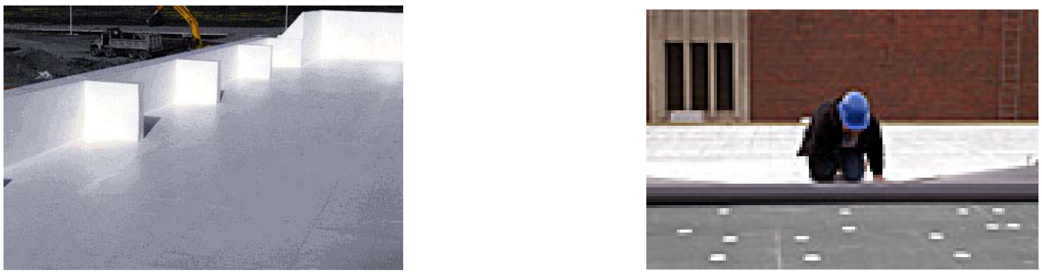
Cool roof options exist for many traditional roofing materials. Each cool roof product offers a different level of reflectance and emissivity, as well as different costs. For flat-roofed industrial buildings membranes are feasible options since based on the NAVFAC Technology evaluation program study there is no difference in first cost between the cool roof and the regular roof options. For sloped residential and non-residential roofs metal roofs, reflective tiles and architectural shingles are feasible.

Metal Roofs: Several metal roof products have earned the ENERGY STAR® label, thanks to the development of pigments that make metal roofs highly reflective. The cost of "cool" and standard painted metal roofing materials is practically the same.
Membranes (single-ply): These flexible or semi-flexible pre-fabricated sheets consist of EPDM (ethylene-propylene-dieneterpolymer), PVC (polyvinyl chloride) or TPO (thermoplastic polyolefin). They can be applied over existing low-slope roofs using heat-sealed seams or caulk. Some are self-cleaning and mold resistant.

Coatings: There elastomeric, polyurethane or acrylic liquids are the consistency of thick paint. They can be applied over existing low-slope roofs with a roller or power sprayer and last from 10 to 20 years.

Reflective Tiles: Clay or concrete tiles can incorporate special pigments that reflect solar energy while mimicking traditional colors, including green, brown and terra cotta. These tiles are extremely durable and especially suitable for new homes or for construction projects where a white roof might be aesthetically unacceptable.

Architectural shingles: These products resemble traditional roofing shingles but have the reflective properties characteristic of other cool roof materials (Figures 3-4 and 3-5). The shingles are available in a variety of colors, and the difference in cost between architectural shingles and conventional asphalt shingles is minimal.



(a) (b)

Figure 3-4. Reflective roof coating (a), and reflective roof membrane (b).

(a) (b) ©

Figure 3-5. White metal roof (a), roof tile coatings (b), and architectural shingles (c) (http://www.elkcorp.com).

Reflective "cool roofs" which reduce the building cooling load, are available in many colors besides white, though roof color, has an impact on energy usage. Table 3-10 shows the reflectance and emittance values by roof type and color for new and aged roofing materials (ORNL).

Table 3-10. Reflectance and emittance values by roof type and color for new and aged roofing materials

Roofing Type	Color	New Solar Reflectance	Aged Solar Reflectance	New Thermal Emittance
Roof Coatings	White	0.70 – 0.85	0.50 –0.65	0.85
Roof Coatings	Grey or Tan	0.70	0.50	0.85
Roof Coatings	Terra Cotta or Brown	0.40	0.30	0.85
Roof Coatings	Aluminized	0.50	0.40	0.50
Metal Paint	Red	0.25	0.25	0.83
Metal Paint	Terra Cotta	0.35	0.35	0.83
Metal Paint	Bright Red	0.35	0.35	0.83

Roofing Type	Color	New Solar Reflectance	Aged Solar Reflectance	New Thermal Emittance
Metal Paint	Beige/Off White	0.55	0.55	0.83
Metal Paint	Tan	0.45	0.45	0.83
Metal Paint	Dark Blue	0.25	0.25	0.83
Metal Paint	Medium to Light Blue	0.32	0.32	0.83
Metal Paint	Dark Brown	0.25	0.25	0.83
Metal Paint	Medium to Light Brown	0.32	0.32	0.83
Metal Paint	Dark Green	0.25	0.25	0.83
Metal Paint	Medium to Light Green	0.32	0.32	0.83
Metal Paint	White	0.65	0.65	0.83
Metal Paint	Bright White	0.70	0.70	0.83
Metal Paint	Black	0.25	0.25	0.83
Metal Paint	Dark Grey	0.25	0.25	0.83
Metal Paint	Medium to Light Grey	0.35	0.35	0.83
Metal Paint	Pearlescent Colors	0.35	0.35	0.75
Galvalume	Unpainted	0.65	0.55	0.05
Copper Metal	Unpainted	0.85	0.18	0.03
Galvanized Steel	Unpainted	0.40	0.20	0.50
EPDM Membrane	Black	0.05	0.10	0.85
TPO Membrane	White	0.80	0.60	0.85
TPO Membrane	Grey	0.50	0.40	0.85
PVC Membrane	White	0.80	0.60	0.85
PVC Membrane	Grey	0.50	0.40	0.85
Asphalt Shingle	Dark Color	0.10	0.10	0.85
Asphalt Shingle	Light Color	0.25	0.25	0.85
Modified Bitumen Cap Sheet	Dark Color	0.10	0.10	0.85
Modified Bitumen Cap Sheet	Light Color	0.25	0.25	0.85
Modified Bitumen Cap Sheet	White	0.50-0.60	0.40 – 0.45	0.85

3.5 Air Tightness. The airtightness of the building enclosure or envelope becomes an increasingly significant factor in the overall energy consumption of buildings. The energy required to heat, cool and maintain humidity control in buildings is increased significantly due to uncontrolled air transfer through the enclosure, as well as by convection. Investigations of building enclosure problems have led many building science consultants, investigators and researchers to conclude that air leakage is the leading cause of moisture problems in exterior building enclosures. These problems include mold and durability problems in exterior walls and other cavities connected to the exterior, excessive rain penetration into wall cavities, poor indoor temperature and humidity control, high heating and air conditioning costs and compromised Noise, fire and smoke control measures. In colder climates the problems of air leakage include icicles on exterior facades, spalling of masonry, premature corrosion of metal parts in exterior walls, high wood moisture contents and rot, excessive rain penetration and indoor temperature and humidity control problems (Figure 3-6). In hot humid climates infiltrating air can cause mold due to condensation on cold air conditioned surfaces.


Figure 3-6. Cold climate exfiltration problems (left) and hot humid air infiltration problems (right)

Where are the leaks? When the building does not have assemblies with a designated layer selected as the airtight layer "an air barrier," and when the airtight layer of adjacent assemblies are not joined together, air leakage is the result. The most common problems show up in between adjacent assemblies, in particular, the wall-to-roof juncture, canopies and soffits, wall to foundation connection and window-to-wall air barrier; these kinds of problems cause "orifice" and "channel" air flow (Figures 3-7 and 3-8). Occasionally building materials are selected that are not tight enough by air barrier standards, causing "diffuse" air flow through them (Figure 3-9). In existing buildings, operable windows and doors generally are a target for either replacement or re-gasketing and weather stripping (Figure 3-10).


Figure 3-7. Examples and unsealed chases between floors and the attic



Figure 3-8. Examples of unsealed pipe penetrations through walls and floors

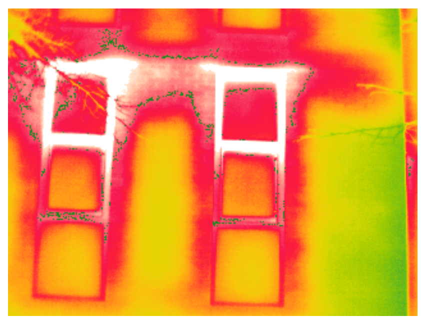



Figure 3-9. Blow-door tests complemented by thermography identify problems with building air tightness and areas with poor insulation where leakage occurs (red and white areas in photos to the right).


Figure 3-10. Penetration through the walls designed to accommodate outdoor air supply to individual room's fan-coil units.

Application of air barrier theory in a building design requires the selection of a component or layer in an assembly to serve as the airtight layer.

Design and construct the building envelopes of office buildings, office portions of mixed office and open space (e.g., company operations facilities), dining, barracks and instructional/training facilities with a continuous air barrier to control air leakage into, or out of, the conditioned space. Clearly identify all air barrier components of each envelope assembly on construction documents and detail the joints, interconnections and penetrations of the air barrier components. Clearly identify the boundary limits of the building air barriers, and of the zone or zones to be tested for building air tightness on the drawings.

Trace a continuous plane of air-tightness throughout the building envelope and make flexible and seal all moving joints. The air barrier material(s) must have an air permeance not to exceed 0.004 cfm / sf at 0.3" wg [0.02 L/s.m2 @ 75 Pa] when tested in accordance with ASTM E 2178. Join and seal the air barrier material of each assembly in a flexible manner to the air barrier material of adjacent assemblies, allowing for the relative movement of these assemblies and components.

Support the air barrier so as to withstand the maximum positive and negative air pressure to be placed on the building without displacement, or damage, and transfer the load to the structure. Seal all penetrations of the air barrier. If any unavoidable penetrations of the air barrier by electrical boxes, plumbing fixture boxes, and other assemblies are not airtight, make them airtight by sealing the assembly and the interface between the assembly and the air barrier or by extending the air barrier over the assembly. The air barrier must be durable to last the anticipated service life of the assembly. Do not install lighting fixtures with ventilation holes through the air barrier

Provide a motorized damper in the closed position and connected to the fire alarm system to open on call and fail in the open position for any fixed open louvers such as at elevator shafts. Damper and control to close all ventilation or make-up air intakes and exhausts, atrium smoke exhausts and intakes, etc when leakage can occur during inactive periods. Compartmentalize garages under buildings by providing air-tight vestibules at building access points. Provide air-tight vestibules at building entrances with high traffic (Figures 3-11, 3-12, and 3-13.)

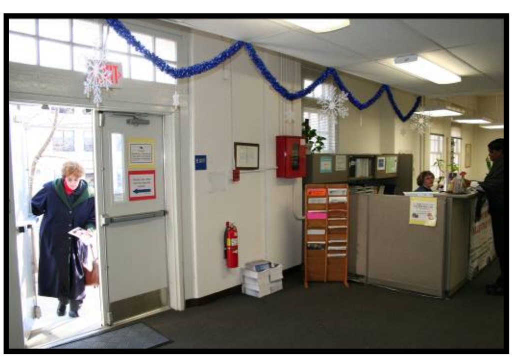


Figure 3-11. Unprotected building entrances with a high traffic.

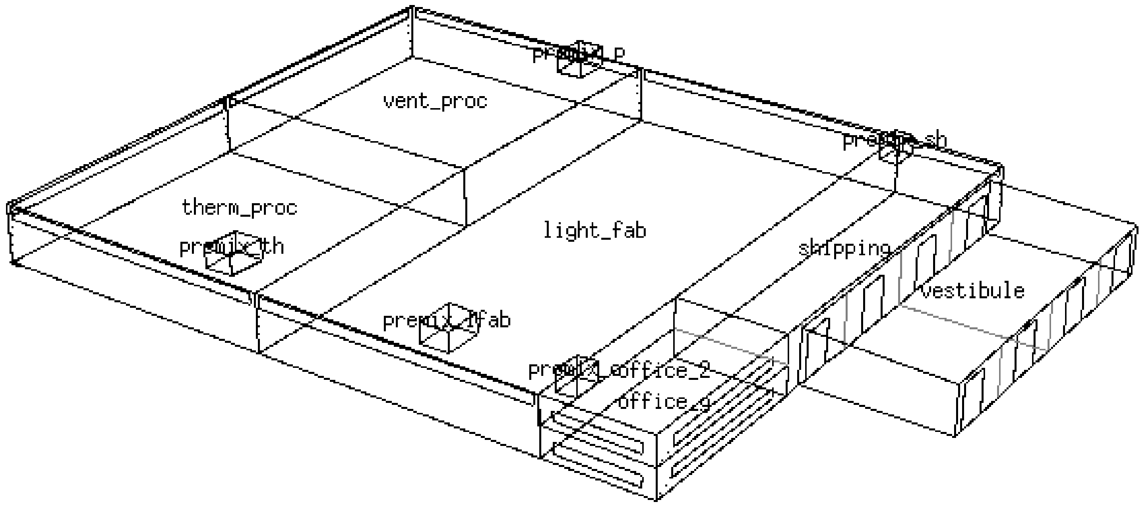


Figure 3-12. Schematic of external vestibule for an industrial building shipping entrance

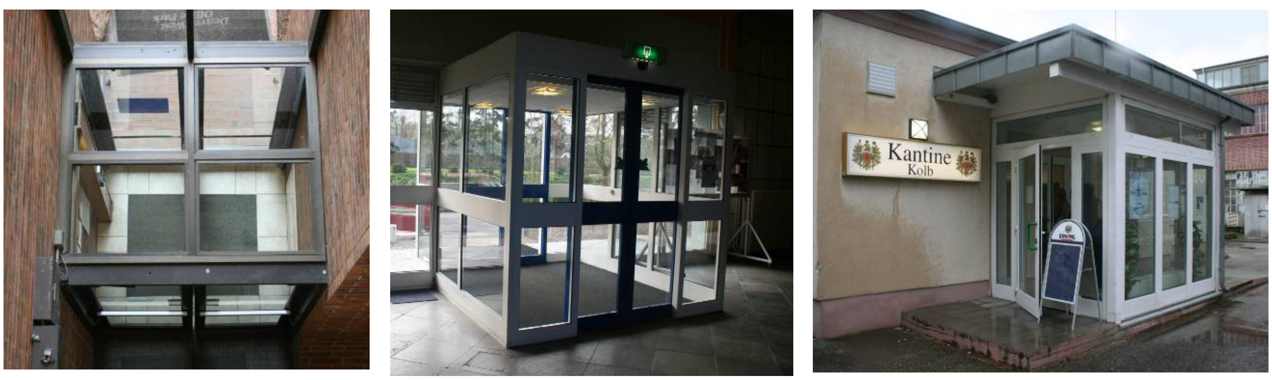


Figure 3-13. Examples of vestibules at the high traffic doors of admin buildings (a,b) and the dining facility (c)

Compartmentalize spaces under negative pressure such as boiler rooms and provide make-up air for combustion.

Performance Criteria and Substantiation: Submit the qualifications and experience of the testing entity for approval. Demonstrate performance of the continuous air barrier for the opaque building envelope by the following tests:

(a) Test the completed building and demonstrate that the air leakage rate of the building envelope does not exceed 0.25cfm/ft2 at a pressure differential of 0.3" w.g.(75 Pa) in accordance with ASTM's E 779 (2003) or E-1827-96 (2002). Accomplish tests using either pressurization or depressurization or both. Divide the volume of air leakage in cfm @ 0.3" w.g. (L/s @ 75 Pa) by the area of the pressure boundary of the building, including roof or ceiling, walls and floor to produce the air leakage rate in cfm/ft2 @ 0.3" w.g. (L/s.m2 @ 75 Pa). Do not test the building until verifying that the continuous air barrier is in place and installed without failures in accordance with installation instructions so that repairs to the continuous air barrier, if needed to comply with the required air leakage rate, can be done in a timely manner.

(b) Test the completed building using Infrared Thermography testing. Use infrared cameras with a resolution of 0.1deg C or better. Perform testing on the building envelope in accordance with ISO 6781:1983 and ASTM C1060-90(1997). Determine air leakage pathways using ASTM E 1186-03 Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems, and perform corrective work as necessary to achieve the whole building air leakage rate specified in (a) above. (c) Notify the Government at least three working days prior to the tests to provide the Government the opportunity to witness the tests. Provide the Government written test results confirming the results of all tests.

Figure 3-14 illustrates some visualization techniques which can be used to identify location or leaks

Figure 3-14. Identification of leakage pathways using smoke pencil (left), theatrical fog and infra-red thermography (right)

Existing buildings undergoing major renovations especially the ones located in cold or hot and humid climates shall be sealed to the same standard as newly constructed ones.

The need for and reasonableness of destructive analysis of the state of exiting air barrier shall be evaluated based on the type of renovation considering related cost issues. This can be challenging due to difficulty in accessing gaps through hard or expensive finishes. Removable ceiling tiles allow easy access to problem areas; walls require destructive access through finishes to expose gaps such as around windows; occasionally if a gap is discovered it may be possible to blind-seal with spray polyurethane foam injected through holes drilled in the drywall. For large holes, bulkheads can be built out of studs and drywall sealed with spray polyurethane foam (SPF); smaller gaps up to 50 mm (2”) can be sealed with one part SPF; larger gaps can be sealed with two-component SPF. Note that stuffing glass-fiber insulation in cracks is not useful, because glass-fiber merely acts as a dust filter and allows air under a pressure differential to pass through it. Air leaks shall be sealed in the following order of priority:

1. Top of building
   - Attics
   - Roof/wall intersections and plenum spaces
   - Mechanical penthouse doors and walls
   - HVAC equipment
   - Other roof penetrations
2. Bottom of Building
   - Soffits and ground floor access doors
   - Underground parking access doors
   - Exhaust and air intake vents
   - Pipe, duct, cable and other service penetrations into core of building
   - Sprinkler hangar penetrations, inspection hatches and other holes
   - Seal core wall to floor slab
   - Crawl spaces
3. Vertical shafts
   - Gasket stairwell fire doors
   - Fire hose cabinets or toilet room recessed accessories connected to shafts
   - Plumbing, electrical, cable and other penetrations within service rooms
   - Elevator rooms, electric rooms- reduce size of cable holes, firestop and seal bus bar openings
4. Exterior Walls
   - Weather-strip windows, doors, including balcony/patio doors and seal window trim
   - Exhaust fans and ducting
   - All service penetrations
   - Baseboard heaters
   - Electrical receptacles
   - Baseboards
5. Compartmentalize
   - Garages
   - Vented mechanical rooms
   - Garbage compactor rooms
   - Emergency generator rooms
   - High voltage rooms
   - Shipping docks
   - Elevator rooms
   - Workshops

Potential energy conservation due to reduced energy used for building heating, cooling and dehumidification is demonstrated by the graph shown in Figure 3-15. The data based on the study of computer simulation of the typical barrack building located in different US climate zones show that air leakage reduction from 1cfm/ft2 at a pressure differential of 0.3” w.g. (75 Pa) to 0.25cfm/ft2 results in the total building energy conservation between 5% and 45% depending on climate zone. In addition, to energy conservation tighter building envelop results in decreased O&M costs for mold problems remediation.

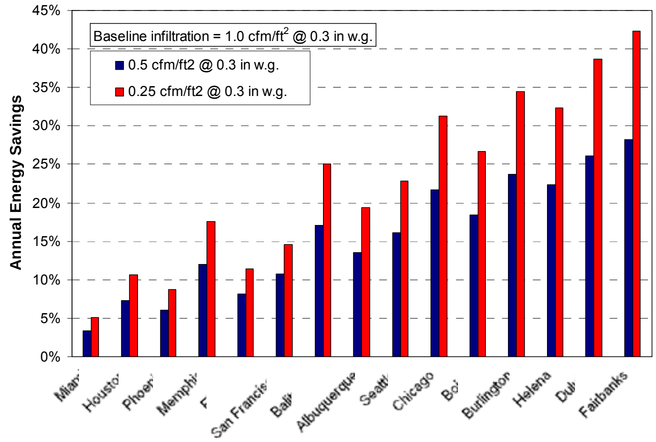


Figure 3-15. Annual energy savings calculated for a typical barrack building for different US climate zones.

A list of air barrier contractors and manufacturers can be found on the Air Barrier Association's website http://www.airbarrier.org

Appendix 4: Ducts and Pipes

4.1. Insulation and seal levels. Duct and pipes convey heated or cooled fluids (air, water, or other fluids) from HVAC or service water heating equipment to the place where that fluid is used in the building. Section 109 of the Energy Policy Act of 2005 sets the absolute minimum duct and piping requirements for commercial buildings at the level of ANSI/ASHRAE/IESNA Standard 90.1-2004. However, Federal agencies are also required to achieve 30% lower energy consumption, if cost-effective, so the levels in Standard 90.1-2004 really only provide the basis for this calculation.

Standard 90.1-2007 provides one type of requirement for ducts and pipes – mandatory:

- Ducts, plenums, and piping must be insulated (Section 6.4.4.1.1).
- Duct should be sealed. (Section 6.4.4.2)
- Service hot water piping insulation should be insulated. (Section 7.4.3)

ASHRAE Advanced Energy Design Guides have developed a set of requirements, including ducts and pipes, for buildings that are considerably more stringent than Standard 90.1-2007, although not necessarily 30% better as required for Federal agencies.

For ducts, the Advanced Energy Design Guides impose four additional requirements on ducts that will all lead to increased energy savings:

1. Low friction rate for ducting (0.08 in. w.c./1000 feet) – this reduces the energy needed to move air through the ducts.
2. Duct seal class B for all ducts – this ensures that ducts deliver the air to where it is needed
3. Ducts located in interior spaces only – this ensures that any duct leakage that does occur takes place in conditioned spaces and not to the outside air. And it reduces the need for insulation.
4. Duct insulated to R-6 – this ensures that heat gain or loss to the air in the ducts is minimized

For piping, the Advanced Energy Design Guide recommends additional service water heating piping insulation beyond what is required for Standard 90.1-2004.

When the building is located in hot and humid climates (zones 1a, 2a, and 3a), in addition to energy conservation consideration, the level of chilled and cold water pipes and supply air ducts insulation shall be designed such, that the surface temperature of the insulated pipe or duct anywhere inside the interior space of the building (including duct and pipe chases) is above the dew point, to prevent condensation and mold problems

4.2. Duct sealing technology

ASHRAE Standard 189 requires that the ducts shall be sealed to a Level A, which surpasses requirements of the ASHRAE Standard 90.1.

Supply and exhaust ducts which don't meet this criteria in the buildings undergoing major retrofits shall be sealed. When the leaky supply duct passes through unconditioned space, air leaks result in a waste of heating and cooling energy. If ductwork is behind barriers, such as within a plenum above suspended ceilings, heating and cooling are not delivered effectively to occupants. In either case, more fan power is required to move air to achieve desired ambient temperatures. Leaks in exhaust ducts result either in ineffective removal of contaminants from the ventilated spaces or in more fan power. Sealing leaks saves both the energy required to heat and cool air, and the energy required to move it to occupants. It may also alleviate occupant comfort problems, if inadequate conditioned air reaches certain locations due to ductwork leakage. Aerosol duct sealing technology seals leaks from the inside out, using a process that is somewhat similar to self-sealing automobile tires.

This technology seals leaks in ductwork from the inside by pressurizing the duct system with a fog of atomized sealant particles. By temporarily blocking all of the normal exits from the duct system (as well as any coils or fans), the fog is forced to the leaks. The acceleration of the air through the leaks causes the sealant particles to leave the air stream and deposit on the leak edges. The right choice of particle size ensures duct flow rate and duct pressure so that the particles remain suspended as they travel through the duct system; thus only a very small fraction of the particles deposit on the duct walls. The Figure 3-16 shows a duct sealing system applied to a small laboratory exhaust system.

The aerosol sealing technology allows leaks that had previously been inaccessible to be sealed. Aerosol sealing has been commercially available for single-family residences since 1999, and became commercially available for large buildings in 2003 with the introduction of a new atomization technology that significantly increases sealing rates, and allows sealant to be atomized inside the ductwork instead of externally.

The technology was developed at Lawrence Berkeley Laboratory (LBNL) by Carrie and Modera (Carrie and Modera 1993, Modera et al. 1996).

The energy savings resulting from implementation of the duct sealing technology can vary considerably depending on the location, length, and condition of the ducts. Tests performed by LBNL on 10 buildings indicated an average leakage of 23% of fan flow, and showed that aerosol sealant injection sealed 87% of that leakage.

The U. S. Navy Technology Validation (TechVal) program conducted evaluation and test installations of duct sealing, and provides the following rules of thumb to help decide whether duct sealing is appropriate for a given facility:

- Laboratory Supply and Laboratory Exhaust systems are worth sealing whenever it can be confirmed that they leak because of the large flow rates, the high fan power, and the heating/cooling loads associated with 100% outside air.

• Large Office Supply systems often benefit from sealing, particularly downstream of terminal boxes, as leakage in these duct sections is often not sealed very well at initial construction.
• Constant Volume Packaged Systems are usually worth sealing as long as the ducts are located above a ceiling, and there is insulation on the ceiling. A lack of additional insulation on the roof, or the existence of vents on the roof, makes these applications even more cost effective.
• Toilet/Shower Exhaust, Ventilation Supply or Exhaust systems are often not very well sealed at initial construction and are usually worth sealing, particularly if there are multiple vertical shafts to be sealed from the same roof or penthouse (Figure 4-1).

Figure 4-1. Duct sealing system.

Energy Savings calculated by assuming a duct leakage rate (20%) and a duct sealing rate (85%) showed, that in industrial buildings with ventilation and heating needs and no cooling in summer, 17% of fan power energy and gas can be saved. energy for the industrial building prototype. With the cost of sealing the entire system estimated at $0.45/sq ft floor area, a simple payback period varies between 2.5 and 8.0 years based on the climate (Figure 4-2). In air conditioned buildings, savings in compressor power are typically much greater than fan power use, and electrical savings in hot climates are considerably higher, resulting in a shorter payback (Figure 4-2).

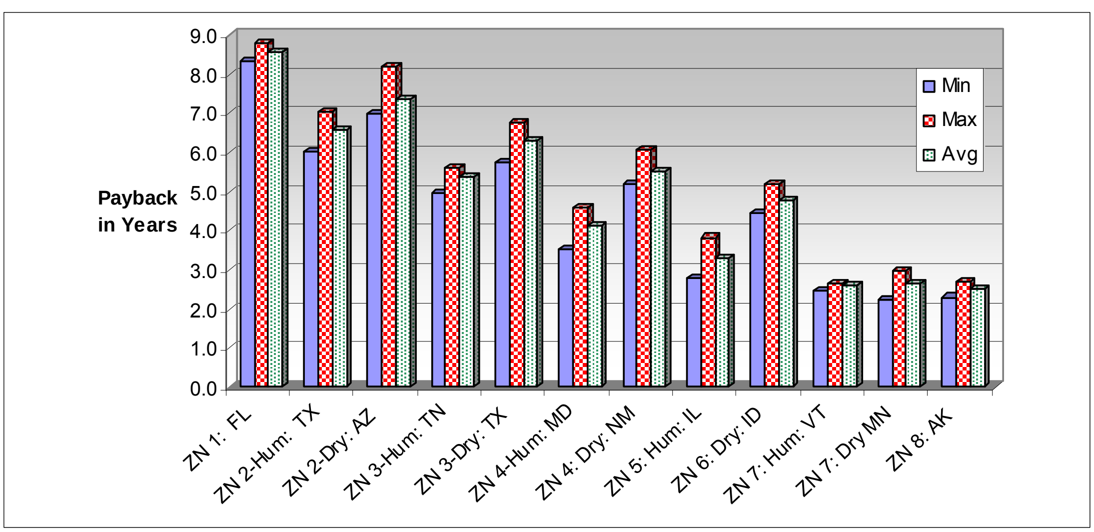


Figure 4-2. Estimated payback due to duct sealing.

The technology was developed for residential application in 1993 and for commercial application in 2003. Duct sealing technology is suitable for all climates.

Contacts and Major Manufacturers: Xetex, RenewAire, Fantech

Appendix 5: Heating and Cooling

5.1 Heating and Cooling Generation and Distribution Systems

5.1.1. Central Vs decentralized Systems. Heating and cooling generation and distribution are among the major contributors to the installations' energy waste and inefficiency. With new construction and major retrofits projects as well as major utility modernization projects central systems are economical and shall be used for the whole installation or a part of it if the heating density is higher than 40,000 MBtu/ (h $\times$ sq. mile), and the cooling density is higher than 68,700 MBtu/ (h $\times$ sq. mi.) or 5,750 tons/ (h $\times$ sq. mile).

When not proven otherwise, central plants shall be designed for combined heat and power (CHP) generation or tri-generation (heating, cooling and power generation), which has an enormous potential for increased thermal efficiency, fuel reliability and reduced environmental impacts.

Central plants with multiple cooling units are preferred, to permit loss of the largest unit while maintaining at least 65% design capacity. Where the master plan calls for multiple buildings in an area, in the design provide for future expansion of the central plant. Water cooled compressors are preferred over air cooled systems and when feasible rejected heat shall be utilized.

5.1.2. Heating Systems. With utility modernization projects, existing heating systems currently using steam as a heating media shall be converted to variable-temperature-variable-flow medium (<270^{o}F) or low temperature (<190^{o}F) hot water. Thus reducing operation and maintenance costs, and allowing the use of less expensive, more efficient piping material. Systems with condensing boilers are to be designed with lower operating return hot water temperatures, i.e. <55 C (130 °F), and use hot water reset to take advantage of the higher efficiencies of condensing boilers.

Steam needs shall be evaluated and, when absolutely necessary, provided by local steam boilers. Use onboard steam generators on equipment requiring steam or a small steam boiler just for the year-round steam load. Hot water system experience fewer problems related to expansion and contraction, have fewer corrosion problems, and are much easier to control, all of which result in low maintenance costs. Use boiler with the thermal efficiency ≥ 90% E_t. Solar-assisted systems shall be considered as alternatives or to compliment conventional boiler systems.

Conversion of steam systems may require some changes in the pipe distribution and new requirements for heat exchange equipment at the customer interface and in the central heating plant. In new construction and steam to hot water conversion projects, a so-called indirect compact substation shall be used. Figure 5-1 shows an example of the building interface installation:

The main parts of the customer interface are:

1. DH control for the secondary side (Figure 5-1, component a)
2. Control valve (Figure 5-1, component b)
3. Differential pressure control, flow rate control (Figure 5-1, component c)

4. Heat meter (Figure 5-1, component d)
5. Plate heat exchanger (Figure 5-1, component e).

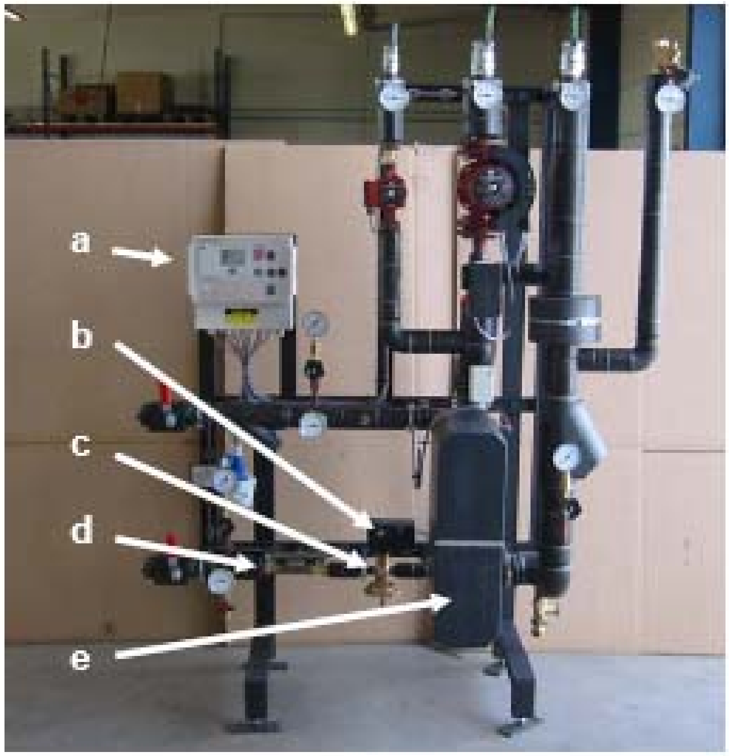


Figure 5-1. Photo of a modern, state-of-the-art DH compact station.

Both the DH control for the secondary side (a) and the control valve (b) regulate the secondary system flow according to the ambient temperature.

Furthermore, the control valve is used to program a time-dependent adjustment, e.g., the day/night shift, the so called night-time heating reduction.

The differential pressure control, flow rate control (c), is used to control the flow rate. Therefore, a certain flow rate limitation is fixed while the differential pressure is variable. When the differential pressure increases, the controller shuts according to its setpoint; similarly when the differential pressure decreases, the controller opens.

The heat meter (d) is used both for billing and to control the flow rate. Typically, at OCONUS installations, the utility owns the heat meter while the customer owns the compact station.

The plate heat exchanger (e) is used to decouple the primary DH distribution system from the secondary building side. This is important since the secondary building piping cannot bear up the relative high temperatures and pressures of the primary DH side.

Hot water in the building can be supplied either to radiators or to coils of the air heating systems. An “admix control” reduces the flow temperature in the secondary loop according to the ambient temperature. The secondary loop can handle different control programs, e.g., for weekend or nighttime heating reduction.

With the central heating system, domestic hot water preparation is also an “admix” operation controlled by the DH control unit for the secondary loop (e). In this loop, the lowest temperature is limited by hygienic conditions. Thus, the lowest flow temperature in the DH system is limited to 160 °F (70 °C) since the domestic hot water must have a temperature higher than 140°F (60 °C). The flow temperature must periodically be raised to 175°F (80 °C) to boost the domestic hot water to 160 °F (70 °C) (the required temperature to kill legionella) for thermal disinfection.

5.1.3. Pipes for Hot Water Distribution Systems. Pre-insulated bounded pipes shall be used for both medium and low temperature hot water systems. These pipes consist of a steel medium pipe and a plastic (i.e., polyethylene) jacket pipe. The insulation between the two pipes is made from a polyurethane (PUR) heat insulation foam. The pipes are pre-insulated in the factory and the PUR foam is a rigid material that bonds the outer jacket with the intermedium pipe.

Using these pipes will reduce the number of manholes and the size of the manholes which are currently about 15×15 Fort In addition, the manholes can be covered by an iron cap. Currently the existing manholes are open due to ventilation. Thus surface water and rain can easily flood the manholes and reduce the lifetime of the pipes due to external corrosion.

Figure 5-2 shows a photo of pre-insulated bounded pipes (pipe on the left is unused and is equipped with a leak detection system; pipe on the right was in use for about 30 years in a DH system with sliding flow temperatures [about 80 °C/130 °C]). The unused pipe is equipped with a leak detection system, indicated by the two wires seen on the far end of the pipe.

The most important limitation of the pipe is its maximum temperature restriction of 285 °F, which minimizes the aging of the PUR foam caused by exposure to the high temperatures.

The pipes are buried in frost-free depth in an open trench (Figure 5-3). After the laying of the pipe with a length of some 15 to 30 ft, the single pipes are connected through welding. Those weld joins are tested with radiation and evacuation tests. Afterwards, the PE jacket pipes are connected with shrinking bushings. Finally, the space between the medium pipe and bushings is foamed in place. Figure 5-4 shows different precast fittings, elbows and branches. Finally, the trench is filled with sand and compressed to bury the pipes. When the pipes are completely buried, the trench is further filled and prepared for the desired surface, which may be a street, pathway or grassland.

Figure 5-2. Pre-insulated bounded pipes (new and used)

Figure 5-3. Trench/canal for a buried pre-insulated pipe.

Figure 5-4. Pre-cast fittings and elbows of pre-insulated bounded pipes.

It is absolutely critical, that QC and QA be provided during the pipe installation to ensure the proper installation. Sensible issues are the bevel seams, the bushings and the foaming in back, the sand bed, the proper connection of the leak detection system and the expansion cushions.

5.1.4. Cooling Systems. ASHRAE Standard 90.1-2007 provides mandatory efficiency

requirements to cooling equipment (section 6.8). Equipment must meet or exceed the seasonal energy efficiency ratio (SEER) or energy efficiency ratio (EER) for the required capacity. The cooling equipment should also meet or exceed the integrated part-load value (IPLV) where applicable. However, requirements to use in Federal Buildings only Energy Star or FEMP designated products are considerably more stringent than Standard 90.1-2007.
(http://www1.eere.energy.gov/femp/procurement/eep_requirements.html)

For central refrigeration air-conditioning systems, provide freeze protection for all exposed piping and components for outdoor packaged chiller units.

Air handling units of the single zone building cooling systems in hot and humid climates (zones 1a, 2a, and 3a) shall be designed with a reheat coil to ensure that the supply air temperature is above the dew point. Variable temperature chilled water single zone units are also not acceptable without a reheat coil.

5.2. Hot Water

The use of hot water has a significant impact on energy consumption. Therefore, it is essential to reduce hot water use. The following should be standard procedure:

Hot Water Temperatures: The following temperatures are the authorized maximum at point of use:

1. Administrative use or general cleaning: 35 °C /95 °F.
2. Shower facilities: 43.3 °C / 110 °F.
3. Automatic dishwashing in dining facilities: 60 °C / 140 °F.
4. Final rinsing of dishes and kitchen utensils in dining and diet kitchen: 82.2 °C / 180 °F.
5. Hot water is not authorized in the following areas:
   a. Retail areas, except for food handling areas.
   b. Warehouses.

For maximum water efficiency and energy conservation:

Shower heads with a flow rate of less than 2.5 gpm shall be used. There are two basic types of low-flow showerheads: aerating and laminar-flow. Aerating showerheads mix air with water, forming a misty spray. Laminar-flow showerheads form individual streams of water. In a humid climate, use of a laminar-flow showerhead is preferable because it won’t create as much steam and moisture as an aerating one;

For dishwashing, use low-flow pre-rinse spray valves with a flow rate of 1.6 gallons per minute or less, and a cleanability performance of 26 seconds per plate or less, based on the ASTM *Standard Test Method for Performance of Pre-Rinse Spray Valves*.
Cold water will be used in lieu of hot water whenever possible.
Report all water leaks to the DPW for immediate repair. A faucet dripping at the rate of one drop per second will waste 3,000 gallons of water per year.

Appendix 6: Lighting systems. (To be completed)

Appendix 7: HVAC Control Systems

7.1. Background. A direct digital control (DDC) system consists of microprocessor based hardware used to control a building's mechanical and electrical systems, particularly the Heating, Ventilating and Air Conditioning (HVAC) system. While a DDC system can function independently (or standalone) at the building-level, it is usually combined with a Utility Monitoring Control System (UMCS) consisting of one or more operator workstation computers used to monitor and manage the connected DDC systems. Within the context of this document, the UMCS along with its connected DDC systems is referred to a building automation system (BAS).

A longstanding goal of most Army installations is to implement a single and cohesive post wide BAS as opposed to multiple separate and independent BASs. Unfortunately most Army Installations procure DDC systems on a case-by-case (building-by-building or system-by-system) basis where the controls are installed under separate contracts and by different contractors and without the planning, preparation and training needed to procure a successful post wide BAS. A successful BAS will:

- Provide a single user interface with a consistent "look and feel" even though it consists of DDC products from different manufacturers installed by different contractors. A key requirement is that the DDC systems must inter-operate with each other and with a UMCS through the use of an Open communications protocol.
- Be expandable without sole-source procurement and supportable over the long term without involvement of the original installing contractors.
- Use standardized and consistent control systems and strategies to achieve a degree of commonality and familiarity for designers, construction quality verification staff, and O&M personnel.
- Support the needs of the building occupants, operations and maintenance (O&M) staff, and management. Therefore it must provide reliable environmental control, be useful to the O&M staff, and provide energy savings capability and functions.

Section 109 of the Energy Policy Act of 2005 sets the absolute minimum building control requirements for commercial buildings at the level of ANSI/ASHRAE/IESNA Standard 90.1-2004. However, Federal agencies are also required to achieve 30% lower energy consumption, if cost-effective, so the levels in Standard 90.1-2004 really only provide the basis for this calculation.

7.2. Requirements and Guidance

Two unified facilities guide specifications (UFGSs) for BASs were released in 2004. The specifications are geared towards multi-vendor, interoperable, and energy efficient DDC systems that integrate with a UMCS (http://www.wbdg.org/):

- The DDC guide spec, UFGS 23 09 23 (previously UFGS 15951): Direct Digital Control for HVAC and Other Building Systems specifies controls at the building level.
- The UMCS guide spec, UFGS 25 10 10 (previously UFGS 13801): Utility Monitoring and Control System (UMCS) specifies the supervisory and post wide system.

These two specifications are intended to work together such that a single UMCS serves as a base wide interface to many building-level DDC systems, regardless of the manufacturer or installer of the building controls. Related design guidance, control system drawings and UMCS drawings are available at: https://eko.usace.army.mil/fa/bAS/

The DDC and UMCS specifications are based on LONWORKS® technology[3] including the use of ANSI/CEA standards 709.1B and 852 (sometimes referred to as LonTalk®) for Open device communications and, LONWORKS® Network Services (LNS®) network operating system in support of Open network management and the LonMark Interoperability Guidelines. These elements and requirements lead to the procurement of an Open system - one where there is no future dependence on the original installing Contractor. For the purposes of procurement, this means that there is no sole source dependence on any Contractor for future system additions, upgrades, or modifications.

The specifications include energy savings requirements in line with the requirements defined in ANSI/ASHRAE/IESNA Standard 90.1-2004.

The goal of a single BAS translates directly into the one-time procurement of a single UMCS from a single vendor. The specifications require the UMCS to be installed and licensed to the Government such that it remains Open, and in concept all future integration of DDC systems into the UMCS can be competitively procured. In practice, however, the UMCS manufacturer/installer will be best able to perform the integration of DDC systems so in many cases installations will seek to procure integration services through the installing contractor. Regardless of who is performing the integration the building-level DDC systems can and should be procured competitively. A method for procuring and then expanding the UMCS must be identified and is discussed in ERDC/CERL Technical Report TR-07-16.

Figure 7-1 illustrates a UMCS/DDC system where multiple building DDC systems have been integrated into a single UMCS that provides multiple operator workstations ("UMCS Client"). Figure 7-2 also shows the UMCS/DDC system and further distinguishes between the UMCS and DDC elements specified by the two guide specifications.

Some of the benefits and capabilities of an Open multi-vendor BAS include:

- Competitive procurement, most notably at the building and sub-system level.
- Management of base-wide system operations such as: remote alarm reporting, remote scheduling (on/off control), remote set point override, data logging and reports, energy management including load shedding, utilities monitoring/measurement for the purpose of monitoring energy performance contracts, and initial diagnosis of service calls. Section 109 of the Energy Policy Act of 2005 sets the absolute minimum building control requirements for commercial buildings at the level of ANSI/ASHRAE/IESNA Standard 90.1-2004. However, Federal agencies are also required to achieve 30% lower energy consumption, if cost-effective, so the levels in Standard 90.1-2004 really only provide the basis for this calculation.
- A graphical user interface that provides for the same look and feel for monitoring and control regardless of which vendor's DDC system or sub-system an operator is viewing. As a result, system operators and managers need only become proficient with one user interface to efficiently and effectively manage base-wide operations..

[3] The term LONWORKS® is used to loosely describe a collection of technologies (including hardware, and software), vendors and installers relating to or based on the ANSI/CEA-709.1 communications protocol

- A “whole-building” or “intelligent-building” approach to systems integration where multiple building systems are integrated into one, including the efficient inter-connection of HVAC control sub-systems. For example, terminal unit equipment such as VAV boxes can be readily interfaced to the servicing air handler to turn the air handler on when needed. In addition, the whole-building approach provides the capability for integrating HVAC and non-HVAC systems such as lighting. For example, the same occupancy sensor that tells a VAV box to cool a room can also turn on the lights in the room.

BACnet® is an alternative communications protocol that may be used where implementation planning has been completed and an implementation strategy has been documented. There is no Army-approved UFGS for BACnet, so design of BACnet systems should use the requirements found in the MILCON Transformation Model RFP and ERDC/CER TR-07-03 as described in ECB 2007-8.

Related BAS implementation guidance and information is available in Engineering Construction Bulletin (ECB) 2004-11, ECB 2005-17, ECB 2007-8, and ERDC/CERL Technical Reports TR-05-14 and TR-07-03, and TR-07-16.

Summary

Army Installation BAS design standards include the use of LONWORKS® technology, LONWORKS® Network Services, ANSI/CEA 709.1 communications protocol, and ANSI/CEA-852 communications protocol, and ANSI/ASHRAE/IESNA Standard 90.1-2004. This approach applies to all HVAC control system and energy monitoring system projects including additions and retrofits. Designers should also strive to include these standards in lighting control projects notably including those where occupancy sensors are used. Designers should consider the use of these standards for water and sanitary sewer systems, electrical systems, and other utility systems. BACnet® is an alternative communications protocol that may be used where implementation planning has been completed and an implementation strategy has been documented. There is no Army-approved UFGS for BACnet, so design of BACnet systems should use the requirements found in the MILCON Transformation Model RFP and ERDC/CER TR-07-03 as described in ECB 2007-8.

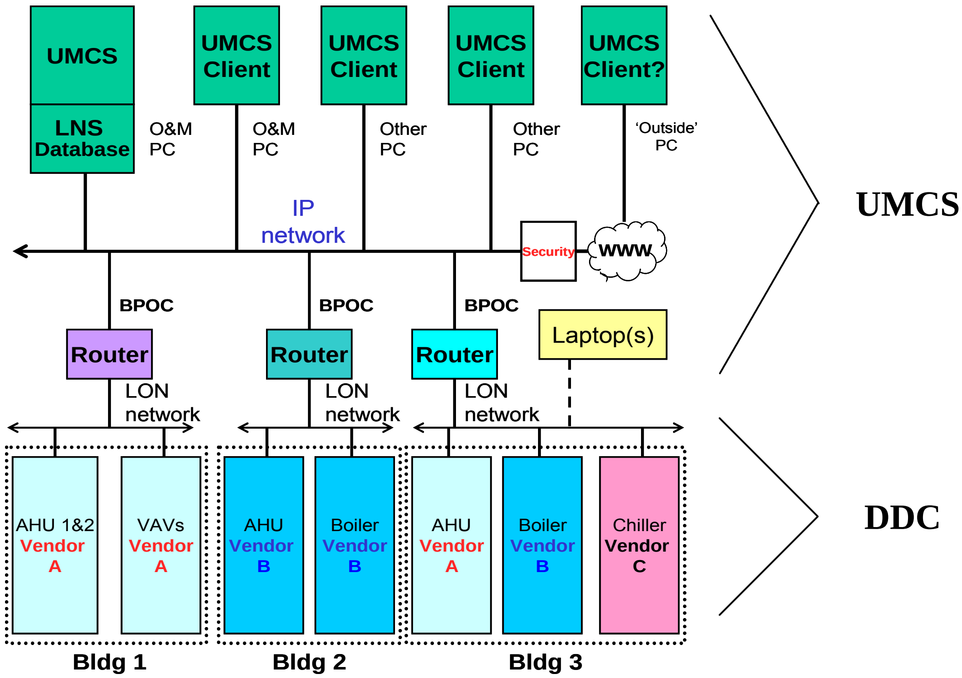


Figure 7-1. Basewide LONWORKS® BAS—including a UMCS and multiple-vendor DDC systems.

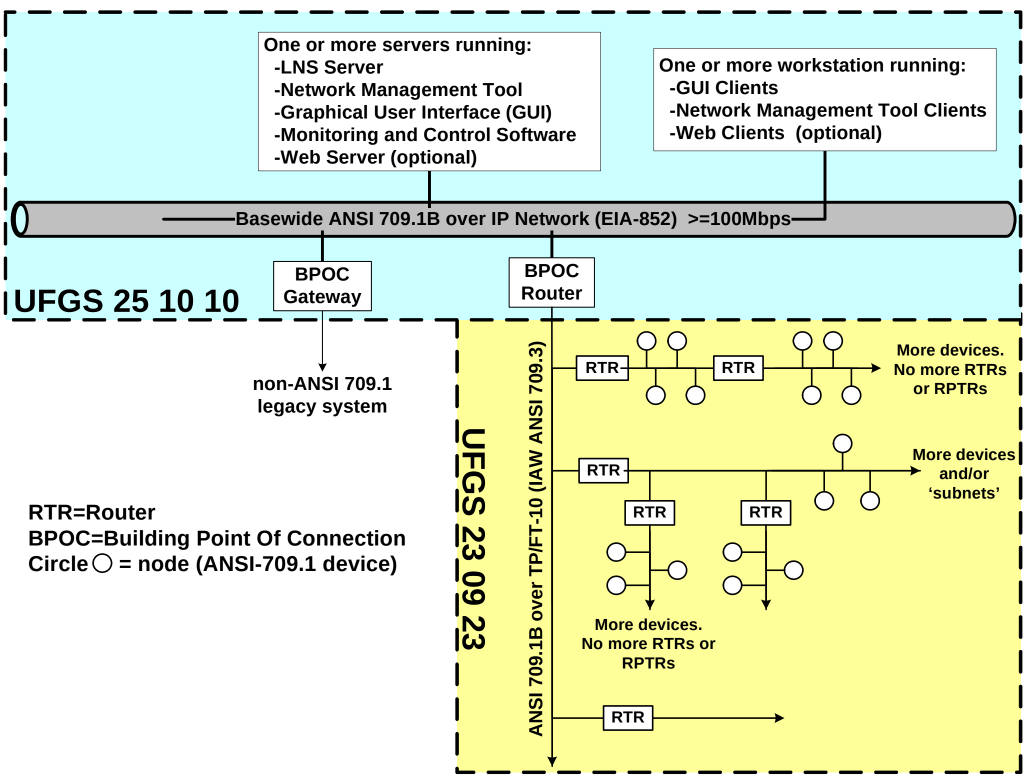


Figure 7-2. BAS comprised of UMCS and DDC systems.

Appendix 8: Appliances

In all new Army facilities and all major renovations only Energy Star or FEMP designated appliances shall be used. The term “Energy Star product” means a product that is rated for energy efficiency under an Energy Star program. The term “FEMP designated product” means a product that is designated under the Federal Energy Management Program of the Department of Energy as being among the highest 25 percent of equivalent products for energy efficiency. When selecting integral sized electric motors, choose NEMA PREMIUM type motors that conform to NEMA MG 1, minimum Class F insulation system. Motors with efficiencies lower than the NEMA PREMIUM standard may only be used in unique applications that require a high constant torque speed ratio (e.g., inverter duty or vector duty type motors that conform to NEMA MG 1, Part 30 or Part 31).

Transformers represent large electrical consumption sources and should be unplugged when not required.

Dryers represent large electricity expenditure. Dryers should only be used with full loads. Dryers should not be set to operate in excess of 60 minutes (overheating can also degrade clothing). The use of clothes racks or lines is encouraged for drying clothes and will extend their useful life.

No appliances or transformers shall be left on when rooms are unoccupied, except for ovens, dryers, washers and refrigerators. Appliances with a spliced or damaged cord will not be used.

Appendix 9: HVAC Equipment Performance Efficiencies Considerations

9.1. Regulatory requirements for HVAC Systems. HVAC system requirements address the heating, ventilating, and air-conditions in the building. These systems typically are the largest energy users in most buildings and the proper design of these systems is necessary to achieve minimal energy usage. Section 109 of the Energy Policy Act of 2005 sets the absolute minimum HVAC system requirements for commercial buildings at the level of ANSI/ASHRAE/IESNA Standard 90.1-2004. However, Federal agencies are also required to achieve 30% lower energy consumption, if cost-effective, so the levels in Standard 90.1-2004 really only provide the basis for this calculation.

ASHRAE Standard 90.1-2007 provides two types of requirements for HVAC systems – mandatory and simplified, prescriptive, some of them are more stringent than the ones in the previous, 2004, addition. Standard has different requirements for systems installed in new buildings and to additions and replacements of HVAC systems in existing buildings, *Standard 90.1-2007 Mandatory HVAC Requirements include minimum* HVAC equipment performance efficiencies (Section 6.4.1). *Standard 90.1-2007 Prescriptive HVAC Requirements* discussed in Section 6.5 are a function of HVAC system.

ASHRAE Advanced Energy Design Guides include requirements to HVAC systems, that are considerably more stringent than Standard 90.1-2007, although not necessarily 30% better as required for Federal agencies by EPAct 2005. These requirements are also a function of HVAC system. The guides recommend higher HVAC efficiencies for air conditioners, gas furnaces, and heat pumps. (THESE EFFICIENCIES NEED TO BE CHECKED AGAINST FEMP-DESIGNATED AND ENERGY STAR AS REQUIRED FOR FEDERAL AGENCIES). For HVAC systems, the guides recommend economizers for air conditioners and heat pumps if the cooling capacity is greater than 54 kBtuh.

HVAC equipment must meet or exceed the seasonal energy efficiency ratio (SEER) or energy efficiency ratio (EER) values of Energy Star or FEMP designated products, which are considerably more stringent than Standard 90.1-2007 (http://www1.eere.energy.gov/femp/procurement/eep_requirements.html)

US Army Corps of Engineers Prescriptive Requirements to HVAC equipment which are listed in design guides to achieve 30 percent energy savings over a baseline built to the minimum requirements of ANSI/ASHRAE/IESNA Standard 90.1-2004 for new buildings to be constructed under Military Transformation Program. These requirements are listed in Tables ???

Appendix 10: Heating Systems Efficiencies. (to be developed)

Appendix 11: Cooling Systems Efficiencies (to be developed)

Appendix 12: HVAC Motor Considerations (to be developed)

Appendix 13: Energy Metering (to be developed)

Appendix 14: Prescriptive and optional energy saving technologies for barracks

14.1 Prescriptive Technology Solution Sets

As part of the EPACT 2005 energy study discussed in Appendix 1, a prescriptive technology solution set was developed for the UEPH barracks for each climate zone to achieve at least a 30% energy consumption reduction compared to an ASHRAE 90.1-2004 minimum baseline building. The general energy conservation measures used to achieve the 30% reduction are listed in Table 14-1.

Table 14-1. General energy conservation measures used to achieve the 30% reduction

ECM	Baseline Models	Efficient Models
Wall Insulation	Standard 90.1-2004	Higher R-Values (see Tables 3-1 to 3-5).
Roof Insulation	Standard 90.1-2004	Higher R-Values (see Tables 3-1 to 3-5).
Roof Solar Reflectance	0.08	0.27
Window-to-Wall Ratio	20%	20%
Window Construction	Standard 90.1-2004	ASHRAE AEDG 30% Small Offices
Infiltration	0.4 cfm/ft^2 @ 75 Pa	0.25 cfm/ft^2 @ 75 Pa
Ventilation	Exhaust plus make-up air for infiltration at 5 Pa	Same as baseline but reduced make-up air for the tighter building
Lighting	1.1 W/ft^2 in rooms, 0.5 in corridors, 0.6 in stairwells	0.9 W/ft^2 in rooms, 0.45 in corridors, 0.54 in stairwells
SWH Boiler Efficiency	80%	95%
Grey water heat recovery	None	Assumed 30% savings on shower hot water
HVAC Systems	Packaged Single Zone with DX coil (3.05 COP) for cooling and natural gas coil (80% efficient) for heating	DOAS with DX coil (3.5 COP) and ERV (75%-70% sensible effectiveness) and hot water coil, 4-pipe fan coil with central chiller and boiler

The specific prescriptive technology solution set for UEPH in each climate zone is shown below:

Climate Zone 1A, Prescriptive Technology Solution Table

Item	Component	Baseline (1)	30% Solution
Roof	Attic	R-30	R-40
	Surface reflectance	0.08	0.27
Walls	Light Weight Construction	R-13	R-20
Exposed Floors	Mass	R-4.2 c.i.	R-5 c.i.
Slabs	Unheated	NR (2)	NR (2)
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-1.45
Infiltration		0.4 cfm/ft^2 @ 75 Pa	0.25 cfm/ft^2 @ 75 Pa (3)
Vertical Glazing	Window to Wall Ratio (WWR)	10% - 20%	10% - 20%
	Thermal transmittance	U-1.22	U-0.45
	Solar heat gain coefficient (SHGC)	0.25	0.31
Interior Lighting	Lighting Power Density (LPD)	1.1 W/ft^2	0.9 W/ft^2
	Ballast		Electronic ballast
HVAC	Air Conditioner	PSZ-AC 12.0 SEER (3.05 COP)	4-Pipe Fan Coil with central chiller and boiler plus DOAS (4) with 14.0 SEER DX coil (3.52 COP) and HHW coil on central boiler SAT control 55ºF – 62ºF with OAT 75º – 54ºF
	Gas Furnace	80% E_t	none
	ERV	None	70% - 75% sensible effectiveness
Economizer		no	no
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Laundry Room		Decoupled (5)
Ducts	Friction Rate		0.08 in. w.c./100 feet
	Sealing		Seal class B
	Location		Interior only
	Insulation level		R-6 (6)
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 2A, Prescriptive Technology Solution Table

Item	Component	Baseline (1)	30% Solution
Roof	Attic	R-30	R-40
	Surface reflectance	0.08	0.27
Walls	Light Weight Construction	R-13	R-20
Exposed Floors	Mass	R-4.2 c.i.	R-10 c.i.
Slabs	Unheated	NR (2)	NR (2)
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-1.45
Infiltration		0.4 cfm/ft^2 @ 75 Pa	0.25 cfm/ft^2 @ 75 Pa (3)
Vertical Glazing	Window to Wall Ratio (WWR)	10% - 20%	10% - 20%
	Thermal transmittance	U-1.22	U-0.45
	Solar heat gain coefficient (SHGC)	0.25	0.31
Interior Lighting	Lighting Power Density (LPD)	1.1 W/ft^2	0.9 W/ft^2
	Ballast		Electronic ballast
HVAC	Air Conditioner	PSZ-AC 12.0 SEER (3.05 COP)	4-Pipe Fan Coil with central chiller and boiler plus DOAS (4) with 14.0 SEER DX coil (3.52 COP) and HHW coil on central boiler SAT control 55ºF – 62ºF with OAT 75º – 54ºF
	Gas Furnace	80% E_t	none
	ERV	None	70% - 75% sensible effectiveness
Economizer		no	no
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Laundry Room		Decoupled (5)
Ducts	Friction Rate		0.08 in. w.c./100 feet
	Sealing		Seal class B
	Location		Interior only
	Insulation level		R-6 (6)
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 2B, Prescriptive Technology Solution Table

Item	Component	Baseline (1)	30% Solution
Roof	Attic	R-30	R-40
	Surface reflectance	0.08	0.27
Walls	Light Weight Construction	R-13	R-20
Exposed Floors	Mass	R-4.2 c.i.	R-10 c.i.
Slabs	Unheated	NR (2)	NR (2)
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-1.45
Infiltration		0.4 cfm/ft^2 @ 75 Pa	0.25 cfm/ft^2 @ 75 Pa (3)
Vertical Glazing	Window to Wall Ratio (WWR)	10% - 20%	10% - 20%
	Thermal transmittance	U-1.22	U-0.45
	Solar heat gain coefficient (SHGC)	0.25	0.31
Interior Lighting	Lighting Power Density (LPD)	1.1 W/ft^2	0.9 W/ft^2
	Ballast		Electronic ballast
HVAC	Air Conditioner	PSZ-AC 12.0 SEER (3.05 COP)	4-Pipe Fan Coil with central chiller and boiler plus DOAS (4) with 14.0 SEER DX coil (3.52 COP) and HHW coil on central boiler SAT control 55ºF – 62ºF with OAT 75º – 54ºF
	Gas Furnace	80% E_t	none
	ERV	None	70% - 75% sensible effectiveness
Economizer		yes	yes
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Laundry Room		Decoupled (5)
Ducts	Friction Rate		0.08 in. w.c./100 feet
	Sealing		Seal class B
	Location		Interior only
	Insulation level		R-6 (6)
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 3A, Prescriptive Technology Solution Table

Item	Component	Baseline (1)	30% Solution
Roof	Attic	R-30	R-40
	Surface reflectance	0.08	0.27
Walls	Light Weight Construction	R-13	R-20
Exposed Floors	Mass	R-4.2 c.i.	R-10 c.i.
Slabs	Unheated	NR (2)	NR (2)
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-1.45
Infiltration		0.4 cfm/ft^2 @ 75 Pa	0.25 cfm/ft^2 @ 75 Pa (3)
Vertical Glazing	Window to Wall Ratio (WWR)	10% - 20%	10% - 20%
	Thermal transmittance	U-0.57	U-0.45
	Solar heat gain coefficient (SHGC)	0.37	0.31
Interior Lighting	Lighting Power Density (LPD)	1.1 W/ft^2	0.9 W/ft^2
	Ballast		Electronic ballast
HVAC	Air Conditioner	PSZ-AC 12.0 SEER (3.05 COP)	4-Pipe Fan Coil with central chiller and boiler plus DOAS (4) with 14.0 SEER DX coil (3.52 COP) and HHW coil on central boiler SAT control 55ºF – 62ºF with OAT 75º – 54ºF
	Gas Furnace	80% E_t	none
	ERV	None	70% - 75% sensible effectiveness
Economizer		no	no
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Laundry Room		Decoupled (5)
Ducts	Friction Rate		0.08 in. w.c./100 feet
	Sealing		Seal class B
	Location		Interior only
	Insulation level		R-6 (6)
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 3B, Prescriptive Technology Solution Table

Item	Component	Baseline (1)	30% Solution
Roof	Attic	R-30	R-40
	Surface reflectance	0.08	0.27
Walls	Light Weight Construction	R-13	R-20
Exposed Floors	Mass	R-4.2 c.i.	R-10 c.i.
Slabs	Unheated	NR (2)	NR (2)
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-1.45
Infiltration		0.4 cfm/ft^2 @ 75 Pa	0.25 cfm/ft^2 @ 75 Pa (3)
Vertical Glazing	Window to Wall Ratio (WWR)	10% - 20%	10% - 20%
	Thermal transmittance	U-0.57	U-0.45
	Solar heat gain coefficient (SHGC)	0.37	0.31
Interior Lighting	Lighting Power Density (LPD)	1.1 W/ft^2	0.9 W/ft^2
	Ballast		Electronic ballast
HVAC	Air Conditioner	PSZ-AC 12.0 SEER (3.05 COP)	4-Pipe Fan Coil with central chiller and boiler plus DOAS (4) with 14.0 SEER DX coil (3.52 COP) and HHW coil on central boiler SAT control 55ºF – 62ºF with OAT 75º – 54ºF
	Gas Furnace	80% E_t	none
	ERV	None	70% - 75% sensible effectiveness
Economizer		yes	yes
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Laundry Room		Decoupled (5)
Ducts	Friction Rate		0.08 in. w.c./100 feet
	Sealing		Seal class B
	Location		Interior only
	Insulation level		R-6 (6)
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 3C, Prescriptive Technology Solution Table

Item	Component	Baseline (1)	30% Solution
Roof	Attic	R-30	R-40
	Surface reflectance	0.08	0.27
Walls	Light Weight Construction	R-13	R-20
Exposed Floors	Mass	R-4.2 c.i.	R-10 c.i.
Slabs	Unheated	NR (2)	NR (2)
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-1.45
Infiltration		0.4 cfm/ft^2 @ 75 Pa	0.25 cfm/ft^2 @ 75 Pa (3)
Vertical Glazing	Window to Wall Ratio (WWR)	10% - 20%	10% - 20%
	Thermal transmittance	U-1.22	U-0.45
	Solar heat gain coefficient (SHGC)	0.39	0.31
Interior Lighting	Lighting Power Density (LPD)	1.1 W/ft^2	0.9 W/ft^2
	Ballast		Electronic ballast
HVAC	Air Conditioner	PSZ-AC 12.0 SEER (3.05 COP)	4-Pipe Fan Coil with central chiller and boiler plus DOAS (4) with 14.0 SEER DX coil (3.52 COP) and HHW coil on central boiler SAT control 55ºF – 62ºF with OAT 75º – 54ºF
	Gas Furnace	80% E_t	none
	ERV	None	70% - 75% sensible effectiveness
Economizer		yes	yes
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Laundry Room		Decoupled (5)
Ducts	Friction Rate		0.08 in. w.c./100 feet
	Sealing		Seal class B
	Location		Interior only
	Insulation level		R-6 (6)
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 4A, Prescriptive Technology Solution Table

Item	Component	Baseline (1)	30% Solution
Roof	Attic	R-30	R-50
	Surface reflectance	0.08	0.27
Walls	Light Weight Construction	R-13	R-20
Exposed Floors	Mass	R-4.2 c.i.	R-20
Slabs	Unheated	NR (2)	NR (2)
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-1.45
Infiltration		0.4 cfm/ft^2 @ 75 Pa	0.25 cfm/ft^2 @ 75 Pa (3)
Vertical Glazing	Window to Wall Ratio (WWR)	10% - 20%	10% - 20%
	Thermal transmittance	U-0.57	U-0.45
	Solar heat gain coefficient (SHGC)	0.39	0.31
Interior Lighting	Lighting Power Density (LPD)	1.1 W/ft^2	0.9 W/ft^2
	Ballast		Electronic ballast
HVAC	Air Conditioner	PSZ-AC 12.0 SEER (3.05 COP)	4-Pipe Fan Coil with central chiller and boiler plus DOAS (4) with 14.0 SEER DX coil (3.52 COP) and HHW coil on central boiler SAT control 55ºF – 62ºF with OAT 75º – 54ºF
	Gas Furnace	80% E_t	none
	ERV	None	70% - 75% sensible effectiveness
Economizer		no	no
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Laundry Room		Decoupled (5)
Ducts	Friction Rate		0.08 in. w.c./100 feet
	Sealing		Seal class B
	Location		Interior only
	Insulation level		R-6 (6)
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 4B, Prescriptive Technology Solution Table

Item	Component	Baseline (1)	30% Solution
Roof	Attic	R-30	R-50
	Surface reflectance	0.08	0.27
Walls	Light Weight Construction	R-13	R-25
Exposed Floors	Mass	R-4.2 c.i.	R-20
Slabs	Unheated	NR (2)	NR (2)
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-1.45
Infiltration		0.4 cfm/ft^2 @ 75 Pa	0.25 cfm/ft^2 @ 75 Pa (3)
Vertical Glazing	Window to Wall Ratio (WWR)	10% - 20%	10% - 20%
	Thermal transmittance	U-0.57	U-0.42
	Solar heat gain coefficient (SHGC)	0.39	0.46
Interior Lighting	Lighting Power Density (LPD)	1.1 W/ft^2	0.9 W/ft^2
	Ballast		Electronic ballast
HVAC	Air Conditioner	PSZ-AC 12.0 SEER (3.05 COP)	4-Pipe Fan Coil with central chiller and boiler plus DOAS (4) with 14.0 SEER DX coil (3.52 COP) and HHW coil on central boiler SAT control 55ºF – 62ºF with OAT 75º – 54ºF
	Gas Furnace	80% E_t	none
	ERV	None	70% - 75% sensible effectiveness
Economizer		yes	yes
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Laundry Room		Decoupled (5)
Ducts	Friction Rate		0.08 in. w.c./100 feet
	Sealing		Seal class B
	Location		Interior only
	Insulation level		R-6 (6)
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 4C, Prescriptive Technology Solution Table

Item	Component	Baseline (1)	30% Solution
Roof	Attic	R-30	R-50
	Surface reflectance	0.08	0.27
Walls	Light Weight Construction	R-13	R-25
Exposed Floors	Mass	R-4.2 c.i.	R-20
Slabs	Unheated	NR (2)	NR (2)
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-1.45
Infiltration		0.4 cfm/ft^2 @ 75 Pa	0.25 cfm/ft^2 @ 75 Pa (3)
Vertical Glazing	Window to Wall Ratio (WWR)	10% - 20%	10% - 20%
	Thermal transmittance	U-0.57	U-0.42
	Solar heat gain coefficient (SHGC)	0.39	0.46
Interior Lighting	Lighting Power Density (LPD)	1.1 W/ft^2	0.9 W/ft^2
	Ballast		Electronic ballast
HVAC	Air Conditioner	PSZ-AC 12.0 SEER (3.05 COP)	4-Pipe Fan Coil with central chiller and boiler plus DOAS (4) with 14.0 SEER DX coil (3.52 COP) and HHW coil on central boiler SAT control 55ºF – 62ºF with OAT 75º – 54ºF
	Gas Furnace	80% E_t	none
	ERV	None	70% - 75% sensible effectiveness
Economizer		yes	yes
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Laundry Room		Decoupled (5)
Ducts	Friction Rate		0.08 in. w.c./100 feet
	Sealing		Seal class B
	Location		Interior only
	Insulation level		R-6 (6)
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 5A, Prescriptive Technology Solution Table

Item	Component	Baseline (1)	30% Solution
Roof	Attic	R-30	R-50
	Surface reflectance	0.08	0.27
Walls	Light Weight Construction	R-13 + 3.8 c.i.	R-25
Exposed Floors	Mass	R-4.2 c.i.	R-20
Slabs	Unheated	NR (2)	NR (2)
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-1.45
Infiltration		0.4 cfm/ft^2 @ 75 Pa	0.25 cfm/ft^2 @ 75 Pa (3)
Vertical Glazing	Window to Wall Ratio (WWR)	10% - 20%	10% - 20%
	Thermal transmittance	U-0.57	U-0.42
	Solar heat gain coefficient (SHGC)	0.39	0.46
Interior Lighting	Lighting Power Density (LPD)	1.1 W/ft^2	0.9 W/ft^2
	Ballast		Electronic ballast
HVAC	Air Conditioner	PSZ-AC 12.0 SEER (3.05 COP)	4-Pipe Fan Coil with central chiller and boiler plus DOAS (4) with 14.0 SEER DX coil (3.52 COP) and HHW coil on central boiler SAT control 55ºF – 62ºF with OAT 75º – 54ºF
	Gas Furnace	80% E_t	none
	ERV	None	70% - 75% sensible effectiveness
Economizer		yes	yes
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Laundry Room		Decoupled (5)
Ducts	Friction Rate		0.08 in. w.c./100 feet
	Sealing		Seal class B
	Location		Interior only
	Insulation level		R-6 (6)
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 5B, Prescriptive Technology Solution Table

Item	Component	Baseline (1)	30% Solution
Roof	Attic	R-30	R-50
	Surface reflectance	0.08	0.27
Walls	Light Weight Construction	R-13 + 3.8 c.i.	R-25
Exposed Floors	Mass	R-4.2 c.i.	R-20
Slabs	Unheated	NR (2)	NR (2)
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-1.45
Infiltration		0.4 cfm/ft^2 @ 75 Pa	0.25 cfm/ft^2 @ 75 Pa (3)
Vertical Glazing	Window to Wall Ratio (WWR)	10% - 20%	10% - 20%
	Thermal transmittance	U-0.57	U-0.42
	Solar heat gain coefficient (SHGC)	0.39	0.46
Interior Lighting	Lighting Power Density (LPD)	1.1 W/ft^2	0.9 W/ft^2
	Ballast		Electronic ballast
HVAC	Air Conditioner	PSZ-AC 12.0 SEER (3.05 COP)	4-Pipe Fan Coil with central chiller and boiler plus DOAS (4) with 14.0 SEER DX coil (3.52 COP) and HHW coil on central boiler SAT control 55ºF – 62ºF with OAT 75º – 54ºF
	Gas Furnace	80% E_t	none
	ERV	None	70% - 75% sensible effectiveness
Economizer		yes	yes
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Laundry Room		Decoupled (5)
Ducts	Friction Rate		0.08 in. w.c./100 feet
	Sealing		Seal class B
	Location		Interior only
	Insulation level		R-6 (6)
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 6A, Prescriptive Technology Solution Table

Item	Component	Baseline (1)	30% Solution
Roof	Attic	R-30	R-60
	Surface reflectance	0.08	0.27
Walls	Light Weight Construction	R-13 + 3.8 c.i.	R-30
Exposed Floors	Mass	R-4.2 c.i.	R-30
Slabs	Unheated	NR (2)	NR (2)
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-1.45
Infiltration		0.4 cfm/ft^2 @ 75 Pa	0.25 cfm/ft^2 @ 75 Pa (3)
Vertical Glazing	Window to Wall Ratio (WWR)	10% - 20%	10% - 20%
	Thermal transmittance	U-0.57	U-0.42
	Solar heat gain coefficient (SHGC)	0.39	0.46
Interior Lighting	Lighting Power Density (LPD)	1.1 W/ft^2	0.9 W/ft^2
	Ballast		Electronic ballast
HVAC	Air Conditioner	PSZ-AC 12.0 SEER (3.05 COP)	4-Pipe Fan Coil with central chiller and boiler plus DOAS (4) with 14.0 SEER DX coil (3.52 COP) and HHW coil on central boiler SAT control 55ºF – 62ºF with OAT 75º – 54ºF
	Gas Furnace	80% E_t	none
	ERV	None	70% - 75% sensible effectiveness
Economizer		yes	yes
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Laundry Room		Decoupled (5)
Ducts	Friction Rate		0.08 in. w.c./100 feet
	Sealing		Seal class B
	Location		Interior only
	Insulation level		R-6 (6)
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 6B, Prescriptive Technology Solution Table

Item	Component	Baseline (1)	30% Solution
Roof	Attic	R-30	R-60
	Surface reflectance	0.08	0.27
Walls	Light Weight Construction	R-13 + 3.8 c.i.	R-30
Exposed Floors	Mass	R-4.2 c.i.	R-30
Slabs	Unheated	NR (2)	NR (2)
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-0.50
Infiltration		0.4 cfm/ft^2 @ 75 Pa	0.25 cfm/ft^2 @ 75 Pa (3)
Vertical Glazing	Window to Wall Ratio (WWR)	10% - 20%	10% - 20%
	Thermal transmittance	U-0.57	U-0.42
	Solar heat gain coefficient (SHGC)	0.39	0.46
Interior Lighting	Lighting Power Density (LPD)	1.1 W/ft^2	0.9 W/ft^2
	Ballast		Electronic ballast
HVAC	Air Conditioner	PSZ-AC 12.0 SEER (3.05 COP)	4-Pipe Fan Coil with central chiller and boiler plus DOAS (4) with 14.0 SEER DX coil (3.52 COP) and HHW coil on central boiler SAT control 55ºF – 62ºF with OAT 75º – 54ºF
	Gas Furnace	80% E_t	none
	ERV	None	70% - 75% sensible effectiveness
Economizer		yes	yes
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Laundry Room		Decoupled (5)
Ducts	Friction Rate		0.08 in. w.c./100 feet
	Sealing		Seal class B
	Location		Interior only
	Insulation level		R-6 (6)
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 7A, Prescriptive Technology Solution Table

Item	Component	Baseline (1)	30% Solution
Roof	Attic	R-30	R-60
	Surface reflectance	0.08	0.27
Walls	Light Weight Construction	R-13 + 7.5 c.i.	R-3 0
Exposed Floors	Mass	R-4.2 c.i.	R-30.
Slabs	Unheated	NR (2)	NR (2)
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-0.50
Infiltration		0.4 cfm/ft^2 @ 75 Pa	0.25 cfm/ft^2 @ 75 Pa (3)
Vertical Glazing	Window to Wall Ratio (WWR)	10% - 20%	10% - 20%
	Thermal transmittance	U-0.57	U-0.33
	Solar heat gain coefficient (SHGC)	0.49	NR
Interior Lighting	Lighting Power Density (LPD)	1.1 W/ft^2	0.9 W/ft^2
	Ballast		Electronic ballast
HVAC	Air Conditioner	PSZ-AC 12.0 SEER (3.05 COP)	4-Pipe Fan Coil with central chiller and boiler plus DOAS (4) with 14.0 SEER DX coil (3.52 COP) and HHW coil on central boiler SAT control 55ºF – 62ºF with OAT 75º – 54ºF
	Gas Furnace	80% E_t	none
	ERV	None	70% - 75% sensible effectiveness
Economizer		yes	yes
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Laundry Room		Decoupled (5)
Ducts	Friction Rate		0.08 in. w.c./100 feet
	Sealing		Seal class B
	Location		Interior only
	Insulation level		R-6 (6)
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 8A, Prescriptive Technology Solution Table

Item	Component	Baseline (1)	30% Solution
Roof	Attic	R-30	R-60
	Surface reflectance	0.08	0.27
Walls	Light Weight Construction	R-13 + 7.5 c.i.	R-30
Exposed Floors	Mass	R-4.2 c.i.	R-30
Slabs	Unheated	10	10
Doors	Swinging	U-0.46	U-0.70
	Non-Swinging	NR	U-0.50
Infiltration		0.4 cfm/ft^2 @ 75 Pa	0.25 cfm/ft^2 @ 75 Pa (3)
Vertical Glazing	Window to Wall Ratio (WWR)	10% - 20%	10% - 20%
	Thermal transmittance	U-0.46	U-0.33
	Solar heat gain coefficient (SHGC)	NR	0.31
Interior Lighting	Lighting Power Density (LPD)	1.1 W/ft^2	0.9 W/ft^2
	Ballast		Electronic ballast
HVAC	Air Conditioner	PSZ-AC 12.0 SEER (3.05 COP)	4-Pipe Fan Coil with central chiller and boiler plus DOAS (4) with 14.0 SEER DX coil (3.52 COP) and HHW coil on central boiler SAT control 55ºF – 62ºF with OAT 75º – 54ºF
	Gas Furnace	80% E_t	none
	ERV	None	70% - 75% sensible effectiveness
Economizer		yes	yes
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Laundry Room		Decoupled (5)
Ducts	Friction Rate		0.08 in. w.c./100 feet
	Sealing		Seal class B
	Location		Interior only
	Insulation level		R-6 (6)
Service Water Heating	Gas storage	80% E_t	90% E_t

Prescriptive Technology Solution Table Notes (#):

1. Baseline requirements are from ANSI/ASHRAE/IESNA Standard 90.1-2004.
2. NR means there is no requirement or recommendation for a component in this climate.
3. **Increased Building Air tightness.** Building air leakage (measured in cfm/ft^2) is the average volume of air(measured in cubic feet per minute) that passes through a unit area of the *building envelope* (measured in square feet) when the building is maintained at a specified internal pressure (measured in Pascals). Testing requirements are specified in Chapter 5..
4. **Dedicated Outdoor Air System**. A central dedicated outdoor air system (DOAS) providing the following:
   a. outside air for building indoor air quality and humidity control, (the amount needed is typically less than the amount exhausted from the bathroom and kitchen)
   b. make-up air for bathroom and kitchen exhausts
   c. Building pressurization to prevent infiltration which allows for reduction of heating/cooling and moisture loads on the system.
   NOTE: The Central DOAS does not provide sensible heating or cooling. Sensible loads are provided by a complementing heating and cooling system
5. **Decoupling exhaust and supply systems for laundry rooms**. To reduce unneeded energy use for heating and cooling of the make-up air and for air transportation of supply and exhausted air from the dryers, laundry exhaust and supply systems are separated in the efficient building model from the rest of the building exhaust and supply systems. Laundry exhaust system and corresponding make-up systems operate only when dryers are operating.
6. The duct and pipe insulation values are from the ASHRAE Advanced Energy Design Guide for Small Offices.

14.2 Energy Savings Results Achieved

Table 14-2 shows the energy consumption reductions (without plug/process loads) achieved using the above prescriptive technology solution sets compared to a minimum ASHRAE 90.1-2004 compliant UEPH.

Table 14-2. Energy consumption reductions achieved using prescriptive technology solution sets described.

Zone	City	Baseline (kBtu/ft^2)	Prescriptive Technology Solution Set (kBtu/ft^2)	Prescriptive Technology Solution Set Savings
1A	Miami, FL	82	40	51%
2A	Houston, TX	82	37	55%
2B	Phoenix, AZ	45	32	30%

3A	Memphis, TN	71	35	51%
3B	El Paso, TX	42	30	30%
3C	San Francisco, CA	47	26	45%
4A	Baltimore, MD	75	32	57%
4B	Albuquerque, NM	48	29	40%
4C	Seattle, WA	60	27	55%
5A	Chicago, IL	77	32	58%
5B	Colorado Springs, CO	54	28	48%
6A	Burlington, VT	83	32	61%
6B	Helena, MT	68	29	57%
7A	Duluth, MN	91	33	64%
8A	Fairbanks, AK	123	42	66%

The following are descriptions of some of the technologies used in the prescriptive solution sets described above:

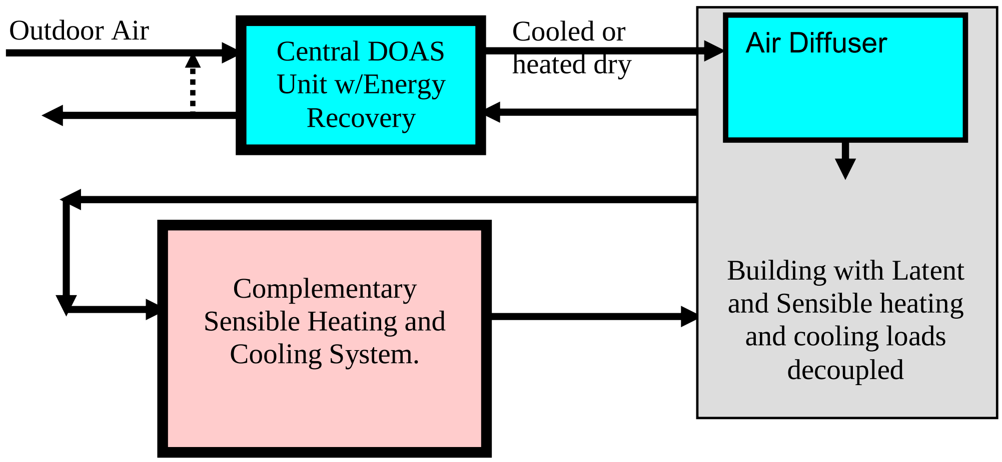
14.3 Dedicated outdoor air system

Three fundamental requirements for elimination of mold in Army facilities are:

- Minimize air leakage through the building envelope (discussed in a separate section of this document)
- Control the dew point temperature/relative humidity of the space with a central Dedicated Outdoor Air System (DOAS)
- Provide only room dry bulb temperature control with the in-room air conditioning system.

Figure 14-1 shows a central dedicated outdoor air system (DOAS). The DOAS will provide the following:

- outside air for building indoor air quality and humidity control, (the amount needed is typically less than the amount exhausted from the bathroom and kitchen)
- make-up air for bathroom and kitchen exhausts
- building pressurization to prevent infiltration which allows for reduction of heating/cooling and moisture loads on the system.



DOAS Schematic

Figure 14-1. Central dedicated outdoor air system (DOAS).

Central DOAS does not provide heating or sensible cooling. This is provided by a complementing heating and cooling system, which will be taking care of only sensible loads. Complementing system can be radiant ceiling system or a conventional convective HVAC system. If a convective HVAC system is used, the system must not deliver conditioned air to any space in the building at a dry bulb temperature which is below the dew point temperature in the space. All chilled water piping in the building must be properly insulated and all air conditioning units with ANY potential for condensation on the unit must have full coverage condensate drain systems.

Dedicated outdoor air system shall operate and provided the dew point temperature/relative humidity and a positive building pressure when building spaces are occupied or non-occupied for a short or long periods of time. Indoor conditions to be maintained in all spaces in all climate zones are shown in Appendix 2..

DOAS can have different configurations capable of providing deep outdoor air dehumidification. Figure 14-2 shows a detailed schematic of all-electric DX/desiccant DOAS unit installed in the Building 637 at Fort Stewart. In the figure, the leaving dew point temperature (DPT) from the DX coils is shown to be 50 F (10.0 C). This assumes that the air leaving the DX coils is saturated. The desiccant wheel further dehumidifies and reheats the air, resulting in a supply air dry bulb temperature (DBT) of 64.9 F (18.3 C) and a supply air relative humidity of 39.8% (which is equivalent to a supply air dew point temperature of 39.9 F (4.4 C). This dry air is then delivered to the occupant rooms via air distribution ductwork. This system delivers 4500 CFM, about 25 percent more ventilation air than the original system in an effort to maintain positive pressurization of the occupant rooms and prevent infiltration of hot, humid outdoor air.

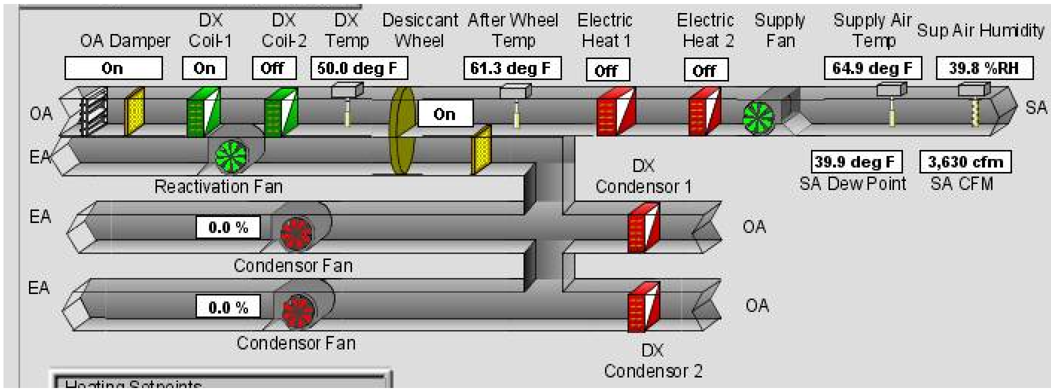


Figure 14-2. All-electric DX/desiccant DOAS unit installed in the Building 637 at Fort Stewart

Figure 14-3 shows schematic of a DOAS system used in a retrofit project of the Barrack 631 at Fort Stewart with a York Solutions AHU. Downstream of air filters, a preheat coil and a chilled water cooling coil, the AHU includes a DX cooling coil and an air-cooled condenser. The leaving dew point temperature (DPT) from the chilled water cooling coil is about 58 F (14.4 C). The DX cooling coil further dehumidifies the air, with a leaving DPT of approximately 40 F (4.4 C). This dry air is then reheated by the air-cooled condenser coil before being delivered to the occupant rooms at approximately 62 F (16.7 C) dry bulb temperature (DBT) and 40 F (4.4 C) DPT. As in the case with the system installed in the Building 637, this system delivers 4500 CFM, about 25 percent more ventilation air than the original system in an effort to maintain positive pressurization of the occupant rooms and prevent infiltration of hot, humid outdoor air.

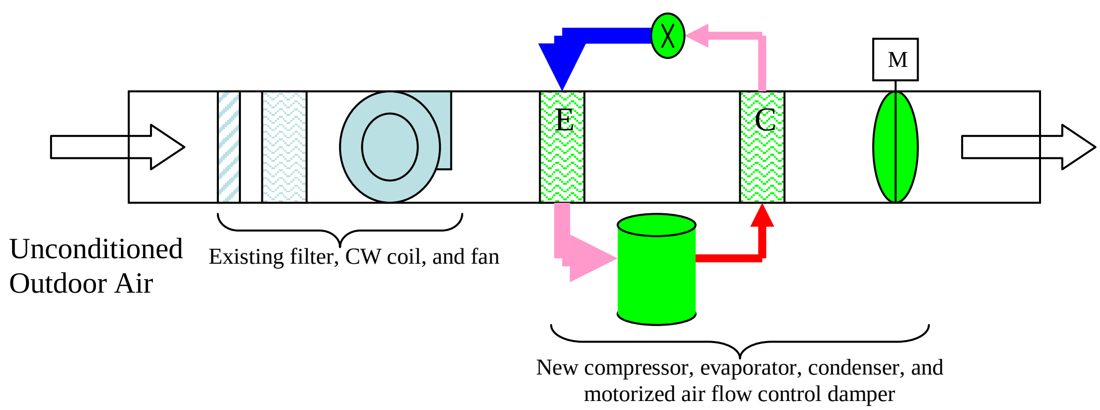


Figure 14-3. DOAS system used in a retrofit project of the Barrack 631 at Fort Stewart with a York Solutions AHU

14.4 Grey Water Heat Recovery

Domestic hot water (DHW) is one of the major heating energy users in the Army barrack buildings. Approximately 80-90% of hot water energy goes down the drain. Gravity Film heat eXchanger (GFX) technology was developed on a US Department of Energy (DOE) grant to capture heat carried by hot water and in 2002 received a Green Product Award. This technology is compatible with all types of water heating systems, including solar water heating systems. While shower water usage per a single shower head in

Permanent Party Barracks may be comparable with a shower water usage in residential buildings, it may be significantly higher in training barracks. Same applies to billets with common shower area. Thus, one can expect a payback period for such barracks to be shorter.

Gravity-Film Heat Exchanger (GFX) is a vertical counterflow heat exchanger that extracts heat out of drain water and applies it to preheat the cold water be mixed with hot water to be used in the shower (Figure 14-4). The CFX consists of a 2 to 4-inch central cooper pipe (that carries the warm wastewater) with ½-in.cooper coils wound around the central pipe. Heat is transferred from the wastewater passing through the large, central pipe to the cold water simultaneously moving upward through the coils on the outside of the pipe. The coils are flattened a little to increase the contact area and improve heat transfer. The system is beneficial for use with showers where the use of hot and cold water and the production of waste-water from the shower occur at the same time.

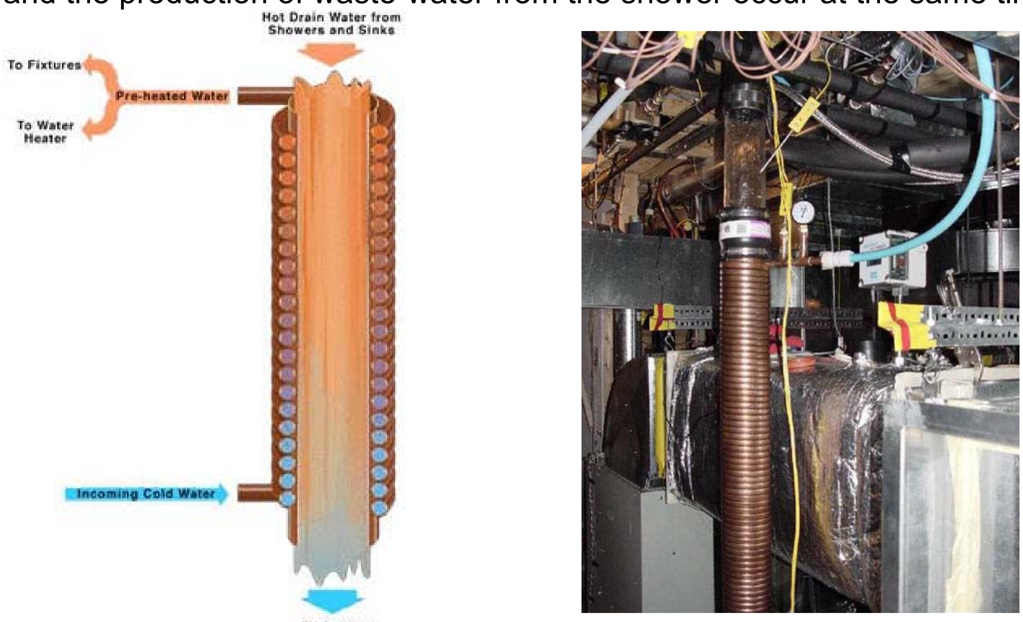


Figure 14-4. GFX system schematics and installation example

Energy savings occur due to use of waste water heat to preheat the cold water be mixed with hot water to be used in the shower. Cold water preheating results in reduction of the hot water usage. In addition to energy conservation GFX allows size reduction of the hot water storage tanks and (in the case of solar water heating) size reduction of solar water heaters.

According to Oak Ridge National Laboratory, this technology has been found to save 25–30 percent of total water-heating energy needed for showers. With an average usage rate of 30gal/day per occupant at 110^{o}F (43^{o}C), depending upon location and climate, DHW can consume more up to 60% of the total annual heating energy supplied to barrack buildings and be the dominant hot water consumer during the non-heating season.

An annual energy use and savings were analyzed for a barrack/dormitory baseline building built to meet the minimum requirements of ASHRAE Standard 90.1-1989. The prototype building is three stories high, has an area of 30,465 ft^2, 40 2-bedroom apartment units, lobby on the main floor, and laundry rooms on each floor. For the payback calculations, it was assumed, that each GFX system serves 20 apartments and the average cost of each of two systems' retrofit including the cost of 4" heat recovery unit and drain lines, its transportation and installation is about $850.

Energy savings (Figure 14-5) differ between climates varying between 3% and 7% of the total barrack building energy use (at 25% energy recovery). While placing of GFX system for each shower is not cost efficient, installation of one heat exchanger for a group of showers produce a reasonable pay-back of 2 to 5 years (Figure 14-6).

Gravity Film heat eXchanger (GFX) technology has been developed over the last 7 years.

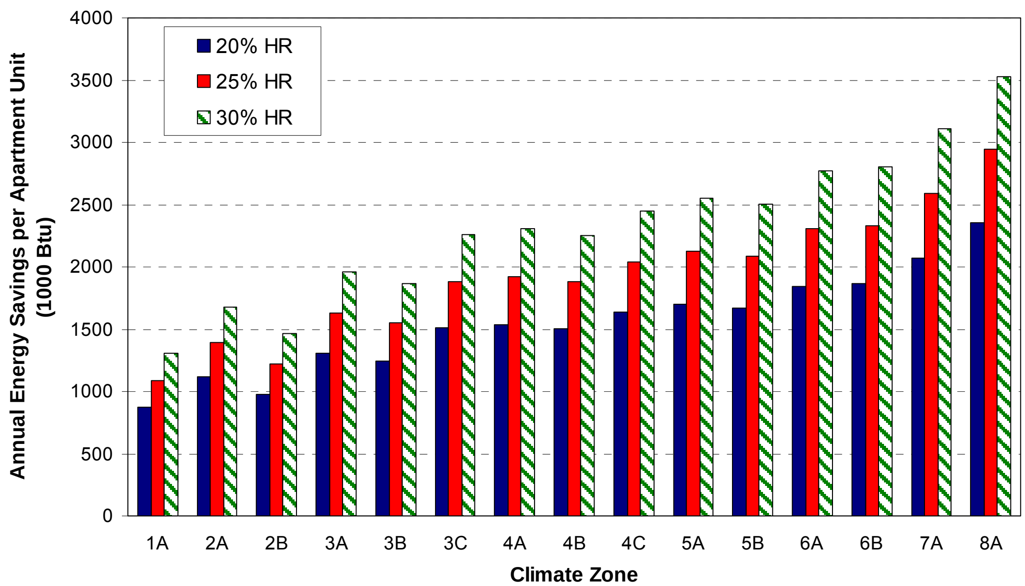


Figure 14-5. Annual energy savings per apartment unit with different heat recovery efficiency.

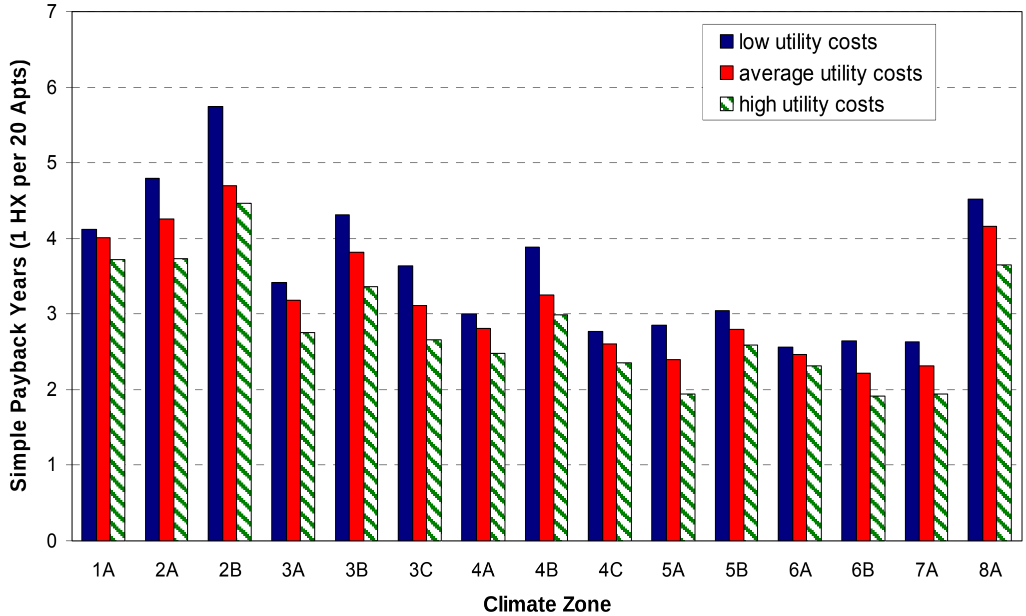


Figure 14-6. Simple payback, years with low, average and high utility rates for the heat recovery system servicing 20 apartments.

Appendix 15: Prescriptive and optional energy saving technologies for administrative facilities (To be completed)

Appendix 16: Prescriptive and optional energy saving technologies for Tactical Equipment maintenance Facilities

16.1 Prescriptive Technology Solution Sets

As part of the EPACT 2005 energy study discussed in Appendix 1, a prescriptive technology solution set was developed for the TEMF for each climate zone to achieve at least a 30% energy consumption reduction compared to an ASHRAE 90.1-2004 minimum baseline building. The general energy conservation measures used to achieve the 30% reduction are shown below:

Building Component	Baseline Building Model	Efficient Building Model
Area	49,920 ft^2 (4,638 m^2)	Same as baseline
Floors	2	Same as baseline
Aspect ratio	4.4	Same as baseline
Fenestration type	Standard 90.1-2004	Improved
Wall construction	steel frame	Metal building
Wall insulation	Standard 90.1-2004 steel frame	Improved
Roof construction	Flat built up roof	Metal building roof
Roof insulation	Standard 90.1-2004 equal to the "insulation entirely above deck"	Improved
Roof albedo	0.3	0.65 (CZ 1-5) 0.3 (CZ 6-8)
Infiltration	0.5 ACH	0.5 ACH
Temp set points	70°F heating; 75°F cooling – set back when unoccupied to 55°F heating; 91°F cooling Repair bays, vehicle corridor, and storage 1: 55°F heating, no cooling	Same as baseline
HVAC	PSZ with DX-AC (3.05 COP) and gas furnace (0.8 E_t); packaged make-up air units for exhaust make-up air and gas fired unit heaters for the repair bays, vehicle corridor, and consolidated bench	Increased efficiency of the baseline HVAC system to 3.52 COP, 0.9 E_t, and efficient fans. Energy recovery on repair bay, vehicle corridor, and consolidated bench exhaust systems. Assumed sensible heat recovery at 70% to 75% effectiveness. Reduced ventilation requirement using demand controlled ventilation.
DHW	Natural gas boiler (0.8 E_t)	Natural gas boiler (0.9 E_t)

The specific prescriptive technology solution set for TEMF in each climate zone is shown below:

Climate Zone 1A, Prescriptive Technology Solution Table

Item	Component	Baseline1	Recommendation
Roof	Insulation above deck	R-15 ci	
	Metal building roof		R-19
	Surface reflectance	0.3	0.65
Walls	Steel-framed	R-13	
	Metal building		R-13
Slabs	Unheated	NR[2]	NR
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-0.25
Infiltration		0.5 ACH	0.5 ACH
Vertical Glazing	Window to Wall Ratio (WWR)	< 10%	< 10%
	Thermal transmittance	U-1.22	U-0.56
	Solar heat gain coefficient (SHGC)	0.25	0.49 – N; 0.35 – S, E, W
	South Overhangs	None	NR
Skylights	Percent roof area	None	2%
	Thermal transmittance		U-1.36
	SHGC		0.19
Interior Lighting	Lighting Power Density	See note 3	See note 3
	Ballast		Electronic ballast
	Daylighting controls [4]	none	Yes
	Occupancy controls	NR	all unoccupied spaces
HVAC	Make up Air Unit Fans	See Fan Efficiency Table	See Fan Efficiency Table
	Air Conditioner	PSZ-AC 12.0 SEER	PSZ-AC 14.0 SEER
	Gas Coil	80% E_t	90% E_t
	Hydronic radiant floor heat	None	None
	ERV	None	None
Economizer		NR	NR
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Transpired Solar Coll.	None	None
Ducts	Sealing		Seal class B
	Location		Interior only
	Insulation level [5]		R-6
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 2A, Prescriptive Technology Solution Table

Item	Component	Baseline[1]	Recommendation
Roof	Insulation above deck	R-15 ci	
	Metal building roof		R-19
	Surface reflectance	0.3	0.65
Walls	Steel-framed	R-13	
	Metal building		R-13
Slabs	Unheated	NR[2]	NR
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-0.25
Infiltration		0.5 ACH	0.5 ACH
Vertical Glazing	Window to Wall Ratio (WWR)	< 10%	< 10%
	Thermal transmittance	U-1.22	U-0.45
	Solar heat gain coefficient (SHGC)	0.25	0.44 – N; 0.31 – S, E, W
	South Overhangs	None	NR
Skylights	Percent roof area	None	2%
	Thermal transmittance		U-1.36
	SHGC		0.19
Interior Lighting	Lighting Power Density	See Note 3	See Note 3
	Ballast		Electronic ballast
	Daylighting controls [4]	none	Yes
	Occupancy controls	NR	all unoccupied spaces
HVAC	Make up Air Unit Fans	See Fan Efficiency Table	See Fan Efficiency Table
	Air Conditioner	PSZ-AC 12.0 SEER	PSZ-AC 14.0 SEER
	Gas Coil	80% E_t	90% E_t
	Hydronic radiant floor heat	None	Ground floor
	ERV	None	None
Economizer		NR	NR
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Transpired Solar Coll.	None	None
Ducts	Sealing		Seal class B
	Location		Interior only
	Insulation level[5]		R-6
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 2B, Prescriptive Technology Solution Table

Item	Component	Baseline[1]	Recommendation
Roof	Insulation above deck	R-15 ci	
	Metal building roof		R-19
	Surface reflectance	0.3	0.65
Walls	Steel-framed	R-13	
	Metal building		R-13
Slabs	Unheated	NR[2]	NR
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-0.25
Infiltration		0.5 ACH	0.5 ACH
Vertical Glazing	Window to Wall Ratio (WWR)	< 10%	< 10%
	Thermal transmittance	U-1.22	U-0.45
	Solar heat gain coefficient (SHGC)	0.25	0.44 – N; 0.31 – S, E, W
	South Overhangs	None	NR
Skylights	Percent roof area	None	2%
	Thermal transmittance		U-1.36
	SHGC		0.19
Interior Lighting	Lighting Power Density	See Note 3	See Note 3
	Ballast		Electronic ballast
	Daylighting controls [4]	none	Yes
	Occupancy controls	NR	all unoccupied spaces
HVAC	Make up Air Unit Fans	See Fan Efficiency Table	See Fan Efficiency Table
	Air Conditioner	PSZ-AC 12.0 SEER	PSZ-AC 14.0 SEER
	Gas Coil	80% E_t	90% E_t
	Hydronic radiant floor heat	None	Ground floor
	ERV	None	None
Economizer		NR	NR
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Transpired Solar Coll.	None	None
Ducts	Sealing		Seal class B
	Location		Interior only
	Insulation level[5]		R-6
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 3A, Prescriptive Technology Solution Table

Item	Component	Baseline[1]	Recommendation
Roof	Insulation above deck	R-15 ci	
	Metal building roof		R-13 + R-13
	Surface reflectance	0.3	0.65
Walls	Steel-framed	R-13	
	Metal building		R-13
Slabs	Unheated	NR[2]	NR
	Heated	R-7.5 for 12 in	R-10
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-0.25
Infiltration		0.5 ACH	0.5 ACH
Vertical Glazing	Window to Wall Ratio (WWR)	< 10%	< 10%
	Thermal transmittance	U-0.57	U-0.45
	Solar heat gain coefficient (SHGC)	0.37	0.44 – N; 0.31 – S, E, W
	South Overhangs	None	NR
Skylights	Percent roof area	None	2%
	Thermal transmittance		U-0.69
	SHGC		0.19
Interior Lighting	Lighting Power Density	See Note 3	See Note 3
	Ballast		Electronic ballast
	Daylighting controls [4]	none	Yes
	Occupancy controls	NR	all unoccupied spaces
HVAC	Make up Air Unit Fans	See Fan Efficiency Table	See Fan Efficiency Table
	Air Conditioner	PSZ-AC 12.0 SEER	PSZ-AC 14.0 SEER
	Gas Coil	80% E_t	90% E_t
	Hydronic radiant floor heat	None	Ground floor
	ERV	None	Yes
Economizer		NR	NR
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Transpired Solar Coll.	None	Yes
Ducts	Sealing		Seal class B
	Location		Interior only
	Insulation level [5]		R-6
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 3B, Prescriptive Technology Solution Table

Item	Component	Baseline[1]	Recommendation
Roof	Insulation above deck	R-15 ci	
	Metal building roof		R-13 + R-13
	Surface reflectance	0.3	0.65
Walls	Steel-framed	R-13	
	Metal building		R-13
Slabs	Unheated	NR[2]	NR
	Heated	R-7.5 for 12 in	R-10
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-0.25
Infiltration		0.5 ACH	0.5 ACH
Vertical Glazing	Window to Wall Ratio (WWR)	< 10%	< 10%
	Thermal transmittance	U-0.57	U-0.45
	Solar heat gain coefficient (SHGC)	0.37	0.44 – N; 0.31 – S, E, W
	South Overhangs	None	NR
Skylights	Percent roof area	None	2%
	Thermal transmittance		U-0.69
	SHGC		0.19
Interior Lighting	Lighting Power Density	See Note 3	See Note 3
	Ballast		Electronic ballast
	Daylighting controls [4]	none	Yes
	Occupancy controls	NR	all unoccupied spaces
HVAC	Make up Air Unit Fans	See Fan Efficiency Table	See Fan Efficiency Table
	Air Conditioner	PSZ-AC 12.0 SEER	PSZ-AC 14.0 SEER
	Gas Coil	80% E_t	90% E_t
	Hydronic radiant floor heat	None	Ground floor
	ERV	None	Yes
Economizer		NR	NR
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Transpired Solar Coll.	None	Yes
Ducts	Sealing		Seal class B
	Location		Interior only
	Insulation level [5]		R-6
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 3C, Prescriptive Technology Solution Table

Item	Component	Baseline[1]	Recommendation
Roof	Insulation above deck	R-15 ci	
	Metal building roof		R-13 + R-13
	Surface reflectance	0.3	0.65
Walls	Steel-framed	R-13	
	Metal building		R-13
Slabs	Unheated	NR[2]	NR
	Heated	R-7.5 for 12 in	R-10
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-0.25
Infiltration		0.5 ACH	0.5 ACH
Vertical Glazing	Window to Wall Ratio (WWR)	< 10%	< 10%
	Thermal transmittance	U-1.22	U-0.45
	Solar heat gain coefficient (SHGC)	0.39	0.6
	South Overhangs	None	NR
Skylights	Percent roof area	None	2%
	Thermal transmittance		U-1.36
	SHGC		0.19
Interior Lighting	Lighting Power Density	See Note 3	See Note 3
	Ballast		Electronic ballast
	Daylighting controls[4]	none	Yes
	Occupancy controls	NR	all unoccupied spaces
HVAC	Make up Air Unit Fans	See Fan Efficiency Table	See Fan Efficiency Table
	Air Conditioner	PSZ-AC 12.0 SEER	PSZ-AC 14.0 SEER
	Gas Coil	80% E_t	90% E_t
	Hydronic radiant floor heat	None	Ground floor
	ERV	None	Yes
Economizer		NR	NR
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	NR
	Transpired Solar Coll.	None	None
Ducts	Sealing		Seal class B
	Location		Interior only
	Insulation level [5]		R-6
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 4A, Prescriptive Technology Solution Table

Item	Component	Baseline[1]	Recommendation
Roof	Insulation above deck	R-15 ci	
	Metal building roof		R-13 + R-19
	Surface reflectance	0.3	0.65
Walls	Steel-framed	R-13	
	Metal building		R-13
Slabs	Unheated	NR[2]	NR
	Heated	R-7.5 for 24 in	R-10
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-0.25
Infiltration		0.5 ACH	0.5 ACH
Vertical Glazing	Window to Wall Ratio (WWR)	< 10%	< 10%
	Thermal transmittance	U-0.57	U-0.42
	Solar heat gain coefficient (SHGC)	0.39	0.46
	South Overhangs	None	NR
Skylights	Percent roof area	None	2%
	Thermal transmittance		U-0.69
	SHGC		0.34
Interior Lighting	Lighting Power Density	See Note 3	See Note 3
	Ballast		Electronic ballast
	Daylighting controls [4]	none	Yes
	Occupancy controls	NR	all unoccupied spaces
HVAC	Make up Air Unit Fans	See Fan Efficiency Table	See Fan Efficiency Table
	Air Conditioner	PSZ-AC 12.0 SEER	PSZ-AC 14.0 SEER
	Gas Coil	80% E_t	90% E_t
	Hydronic radiant floor heat	None	Ground floor
	ERV	None	Yes
Economizer		NR	NR
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	Yes
	Transpired Solar Coll.	None	Yes
	Transpired Solar Coll.	None	Yes
Ducts	Sealing		Seal class B
	Location		Interior only
	Insulation level [5]		R-6
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 4B, Prescriptive Technology Solution Table

Item	Component	Baseline[1]	Recommendation
Roof	Insulation above deck	R-15 ci	
	Metal building roof		R-13 + R-19
	Surface reflectance	0.3	0.65
Walls	Steel-framed	R-13	
	Metal building		R-13
Slabs	Unheated	NR[2]	NR
	Heated	R-7.5 for 24 in	R-10
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-0.25
Infiltration		0.5 ACH	0.5 ACH
Vertical Glazing	Window to Wall Ratio (WWR)	< 10%	< 10%
	Thermal transmittance	U-0.57	U-0.42
	Solar heat gain coefficient (SHGC)	0.39	0.46
	South Overhangs	None	NR
Skylights	Percent roof area	None	2%
	Thermal transmittance		U-0.69
	SHGC		0.34
Interior Lighting	Lighting Power Density	See Note 3	See Note 3
	Ballast		Electronic ballast
	Daylighting controls [4]	none	Yes
	Occupancy controls	NR	all unoccupied spaces
HVAC	Make up Air Unit Fans	See Fan Efficiency Table	See Fan Efficiency Table
	Air Conditioner	PSZ-AC 12.0 SEER	PSZ-AC 14.0 SEER
	Gas Coil	80% E_t	90% E_t
	Hydronic radiant floor heat	None	Ground floor
	ERV	None	Yes
Economizer		NR	NR
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	Yes
	Transpired Solar Coll.	None	Yes
	Transpired Solar Coll.	None	Yes
Ducts	Sealing		Seal class B
	Location		Interior only
	Insulation level [5]		R-6
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 4C, Prescriptive Technology Solution Table

Item	Component	Baseline[1]	Recommendation
Roof	Insulation above deck	R-15 ci	
	Metal building roof		R-13 + R-19
	Surface reflectance	0.3	0.65
Walls	Steel-framed	R-13	
	Metal building		R-13
Slabs	Unheated	NR[2]	NR
	Heated	R-7.5 for 24 in	R-10
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-0.25
Infiltration		0.5 ACH	0.5 ACH
Vertical Glazing	Window to Wall Ratio (WWR)	< 10%	< 10%
	Thermal transmittance	U-0.57	U-0.42
	Solar heat gain coefficient (SHGC)	0.39	0.46
	South Overhangs	None	NR
Skylights	Percent roof area	None	2%
	Thermal transmittance		U-0.69
	SHGC		0.34
Interior Lighting	Lighting Power Density	See Note 3	See Note 3
	Ballast		Electronic ballast
	Daylighting controls [4]	none	Yes
	Occupancy controls	NR	all unoccupied spaces
HVAC	Make up Air Unit Fans	See Fan Efficiency Table	See Fan Efficiency Table
	Air Conditioner	PSZ-AC 12.0 SEER	PSZ-AC 14.0 SEER
	Gas Coil	80% E_t	90% E_t
	Hydronic radiant floor heat	None	Ground floor
	ERV	None	Yes
Economizer		NR	NR
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	Yes
	Transpired Solar Coll.	None	Yes
	Transpired Solar Coll.	None	Yes
Ducts	Sealing		Seal class B
	Location		Interior only
	Insulation level [5]		R-6
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 5A, Prescriptive Technology Solution Table

Item	Component	Baseline[1]	Recommendation
Roof	Insulation above deck	R-15 ci	
	Metal building roof		R-13 + R-19
	Surface reflectance	0.3	0.3
Walls	Steel-framed	R-13 + 3.8 c.i.	
	Metal building		R-13 + R-13
Slabs	Unheated	NR[2]	NR
	Heated	R-10 for 24 in	R-10
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-0.25
Infiltration		0.5 ACH	0.5 ACH
Vertical Glazing	Window to Wall Ratio (WWR)	< 10%	< 10%
	Thermal transmittance	U-0.57	U-0.42
	Solar heat gain coefficient (SHGC)	0.39	0.6
	South Overhangs	None	NR
Skylights	Percent roof area	None	2%
	Thermal transmittance		U-0.69
	SHGC		0.39
Interior Lighting	Lighting Power Density	See Note 3	See Note 3
	Ballast		Electronic ballast
	Daylighting controls[4]	none	Yes
	Occupancy controls	NR	all unoccupied spaces
HVAC	Make up Air Unit Fans	See Fan Efficiency Table	See Fan Efficiency Table
	Air Conditioner	PSZ-AC 12.0 SEER	PSZ-AC 14.0 SEER
	Gas Coil	80% E_t	90% E_t
	Hydronic radiant floor heat	None	Ground floor
	ERV	None	Yes
Economizer		NR	NR
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	Yes
	Transpired Solar Coll.	None	Yes
Ducts	Sealing		Seal class B
	Location		Interior only
	Insulation level [5]		R-6
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 5B, Prescriptive Technology Solution Table

Item	Component	Baseline[1]	Recommendation
Roof	Insulation above deck	R-15 ci	
	Metal building roof		R-13 + R-19
	Surface reflectance	0.3	0.3
Walls	Steel-framed	R-13 + 3.8 c.i.	
	Metal building		R-13 + R-13
Slabs	Unheated	NR[2]	NR
	Heated	R-10 for 24 in	R-10
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-1.45	U-0.25
Infiltration		0.5 ACH	0.5 ACH
Vertical Glazing	Window to Wall Ratio (WWR)	< 10%	< 10%
	Thermal transmittance	U-0.57	U-0.42
	Solar heat gain coefficient (SHGC)	0.39	0.6
	South Overhangs	None	NR
Skylights	Percent roof area	None	2%
	Thermal transmittance		U-0.69
	SHGC		0.39
Interior Lighting	Lighting Power Density	See Note 3	See Note 3
	Ballast		Electronic ballast
	Daylighting controls[4]	none	Yes
	Occupancy controls	NR	all unoccupied spaces
HVAC	Make up Air Unit Fans	See Fan Efficiency Table	See Fan Efficiency Table
	Air Conditioner	PSZ-AC 12.0 SEER	PSZ-AC 14.0 SEER
	Gas Coil	80% E_t	90% E_t
	Hydronic radiant floor heat	None	Ground floor
	ERV	None	Yes
Economizer		NR	NR
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	Yes
	Transpired Solar Coll.	None	Yes
Ducts	Sealing		Seal class B
	Location		Interior only
	Insulation level [5]		R-6
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 6A, Prescriptive Technology Solution Table

Item	Component	Baseline[1]	Recommendation
Roof	Insulation above deck	R-15 ci	
	Metal building roof		R-13 + R-19
	Surface reflectance	0.3	0.3
Walls	Steel-framed	R-13 + 3.8 c.i.	
	Metal building		R-13 + R-13
Slabs	Unheated	NR[2]	R-10, 24 in. horizontal
	Heated	R-10 for 36 in	R-10
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-0.50	U-0.25
Infiltration		0.5 ACH	0.5 ACH
Vertical Glazing	Window to Wall Ratio (WWR)	< 10%	< 10%
	Thermal transmittance	U-0.57	U-0.42
	Solar heat gain coefficient (SHGC)	0.39	0.6
	South Overhangs	None	NR
Skylights	Percent roof area	None	2%
	Thermal transmittance		U-0.69
	SHGC		0.49
Interior Lighting	Lighting Power Density	See Note 3	See Note 3
	Ballast		Electronic ballast
	Daylighting controls [4]	none	Yes
	Occupancy controls	NR	all unoccupied spaces
HVAC	Air Conditioner	PSZ-AC 12.0 SEER	PSZ-AC 14.0 SEER
	Gas Coil	80% E_t	90% E_t
	Hydronic radiant floor heat	None	Ground floor
	ERV	None	Yes
Economizer		NR	NR
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	Yes
	Transpired Solar Coll.	None	Yes
Ducts	Sealing		Seal class B
	Location		Interior only
	Insulation level [5]		R-6
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 6B, Prescriptive Technology Solution Table

Item	Component	Baseline[1]	Recommendation
Roof	Insulation above deck	R-15 ci	
	Metal building roof		R-13 + R-19
	Surface reflectance	0.3	0.3
Walls	Steel-framed	R-13 + 3.8 c.i.	
	Metal building		R-13 + R-13
Slabs	Unheated	NR[2]	R-10, 24 in. horizontal
	Heated	R-10 for 36 in	R-10
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-0.50	U-0.25
Infiltration		0.5 ACH	0.5 ACH
Vertical Glazing	Window to Wall Ratio (WWR)	< 10%	< 10%
	Thermal transmittance	U-0.57	U-0.42
	Solar heat gain coefficient (SHGC)	0.39	0.6
	South Overhangs	None	NR
Skylights	Percent roof area	None	2%
	Thermal transmittance		U-0.69
	SHGC		0.49
Interior Lighting	Lighting Power Density	See Note 3	See Note 3
	Ballast		Electronic ballast
	Daylighting controls [4]	none	Yes
	Occupancy controls	NR	all unoccupied spaces
HVAC	Air Conditioner	PSZ-AC 12.0 SEER	PSZ-AC 14.0 SEER
	Gas Coil	80% E_t	90% E_t
	Hydronic radiant floor heat	None	Ground floor
	ERV	None	Yes
Economizer		NR	NR
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	Yes
	Transpired Solar Coll.	None	Yes
Ducts	Sealing		Seal class B
	Location		Interior only
	Insulation level [5]		R-6
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 7A, Prescriptive Technology Solution Table

Item	Component	Baseline[1]	Recommendation
Roof	Insulation above deck	R-15 ci	
	Metal building roof		R-13 + R-19
	Surface reflectance	0.3	0.3
Walls	Steel-framed	R-13 + 7.5 c.i.	
	Metal building		R-13 + R-13
Slabs	Unheated	NR[2]	R-15, 24 in. horizontal
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-0.50	U-0.25
Infiltration		0.5 ACH	0.5 ACH
Vertical Glazing	Window to Wall Ratio (WWR)	< 10%	< 10%
	Thermal transmittance	U-0.57	U-0.33
	Solar heat gain coefficient (SHGC)	0.49	NR
	South Overhangs	None	NR
Skylights	Percent roof area	None	2%
	Thermal transmittance		U-0.69
	SHGC		0.64
Interior Lighting	Lighting Power Density	See Note 3	See Note 3
	Ballast		Electronic ballast
	Daylighting controls [4]	none	Yes
	Occupancy controls	NR	all unoccupied spaces
HVAC	Air Conditioner	PSZ-AC 12.0 SEER	PSZ-AC 14.0 SEER
	Gas Coil	80% E_t	90% E_t
	Hydronic radiant floor heat	None	Ground floor
	ERV	None	Yes
Economizer		NR	NR
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	Yes
	Transpired Solar Coll.	None	None
Ducts	Sealing		Seal class B
	Location		Interior only
	Insulation level [5]		R-6
Service Water Heating	Gas storage	80% E_t	90% E_t

Climate Zone 8A, Prescriptive Technology Solution Table

Item	Component	Baseline[1]	Recommendation
Roof	Insulation above deck	R-20 ci	
	Metal building roof		R-19 + R-19
	Surface reflectance	0.3	0.3
Walls	Steel-framed	R-13 + 7.5 c.i.	
	Metal building		R-13 + R-16
Slabs	Unheated	R-10, 24 in. horizontal	R-20, 24 in. horizontal
Doors	Swinging	U-0.70	U-0.70
	Non-Swinging	U-0.50	U-0.25
Infiltration		0.5 ACH	0.5 ACH
Vertical Glazing	Window to Wall Ratio (WWR)	< 10%	< 10%
	Thermal transmittance	U-0.46	U-0.33
	Solar heat gain coefficient	NR[2]	NR
	South Overhangs	None	NR
Skylights	Percent roof area	None	2%
	Thermal transmittance		U-0.58
	SHGC		NR
Interior Lighting	Lighting Power Density	See Note 3	See Note 3
	Ballast		Electronic ballast
	Daylighting controls[4]	none	Yes
	Occupancy controls	NR	all unoccupied spaces
HVAC	Air Conditioner	PSZ-AC 12.0 SEER	PSZ-AC 14.0 SEER
	Gas Coil	80% E_t	90% E_t
	Hydronic radiant floor heat	None	Ground floor
	ERV	None	Yes
Economizer		NR	NR
Ventilation	Outdoor Air Damper	Motorized control	Motorized control
	Demand Control	NR	Yes
	Transpired Solar Coll.	None	None
Ducts	Sealing		Seal class B
	Location		Interior only
	Insulation level [5]		R-8
Service Water Heating	Gas storage	80% E_t	90% E_t

Notes about prescriptive technology solution sets:

Baseline requirements are from ANSI/ASHRAE/IESNA Standard 90.1-2004.

1. NR means there is no requirement or recommendation for a component in this climate.
2. Lighting levels in accordance with the following table:

Zone	Baseline	Recommendation
Repair Bay	0.7 W/ft^2 (7.5 W/m^2)	0.7 W/ft^2 (7.5 W/m^2)
Vehicle Corridor	0.7 W/ft^2 (7.5 W/m^2)	0.7 W/ft^2 (7.5 W/m^2)
Showers	0.6 W/ft^2 (6.5 W/m^2)	0.6 W/ft^2 (6.5 W/m^2)
Storage 1	0.9 W/ft^2 (9.7 W/m^2)	0.9 W/ft^2 (9.7 W/m^2)
Consolidated Bench	1.9 W/ft^2 (20.5 W/m^2)	1.3 W/ft^2 (14.0 W/m^2)
Storage 2	0.9 W/ft^2 (9.7 W/m^2)	0.9 W/ft^2 (9.7 W/m^2)
Office	1.0 W/ft^2 (10.8 W/m^2)	0.9 W/ft^2 (9.7 W/m^2)

3. Daylighting should be included in the repair bays, vehicle corridor, and office.
4. The duct and pipe insulation values are from the ASHRAE Advanced Energy Design Guide for Small Offices.

16.2 Energy Savings Results Achieved

The following table shows the energy consumption reductions (without plug/process loads) achieved using the above prescriptive technology solution sets compared to a minimum ASHRAE 90.1-2004 compliant UEPH:

Table 16-1. Energy consumption reductions using prescription technology tables (without plug loads)

CZ	City	Baseline (kBtu/ft^2)	Final Energy Efficient Solution (kBtu/ft^2)	Energy Savings
1A	Miami, FL	36	15	59%
2A	Houston, TX	45	19	58%
2B	Phoenix, AZ	42	17	59%
3A	Memphis, TN	56	25	56%
3B	El Paso, TX	47	20	58%
3C	San Francisco, CA	43	17	59%
4A	Baltimore, MD	75	35	53%
4B	Albuquerque, NM	61	27	56%
4C	Seattle, WA	64	29	54%
5A	Chicago, IL	93	45	52%
5B	Colorado Springs, CO	80	36	55%
6A	Burlington, VT	108	54	50%
6B	Helena, MT	99	49	50%
7A	Duluth, MN	134	65	51%
8A	Fairbanks, AK	207	105	49%

Descriptions of technologies used in the prescriptive technology solution sets follow:

16.3 Cool Roofs

In TEMF, which are conditioned in warm season only by ventilation, cool roofs do not save energy. However they can improve comfort conditions (and hence productivity) in the space (Figure 16-1). In cold climates, a cool roof can increase the heating load, since the solar radiation reflected by the cool roof would otherwise be absorbed, resulting in a warmer roof. Cool roof materials are available as

- white coatings
- single-ply white membrane or
- painted metal (white, cool colored).

The EPA and DOE established the ENERGY STAR Roof Products Program to distinguish those products that are energy efficient. The criteria for an ENERGY STAR labeled roof product are based on the initial and aged total solar reflectance (TSR) the initial and aged total solar reflectance (TSR). The ENERGY STAR criteria vary for low and steep slope applications. Table 16-2 lists the Total Solar Reflectance (TSR) required.

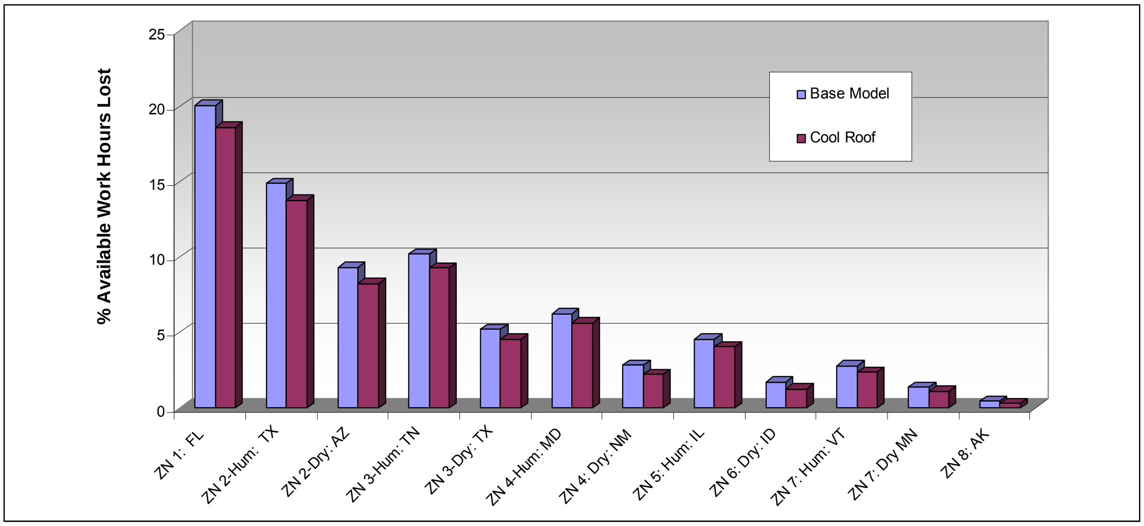


Figure 16-1. Percent of work hours lost in the base industrial building and in the building with a "cool roof" (based on the analysis under the Annex 46 study).

Table 16-2. Total Solar Reflectance (TSR) required.

	Minimum initial TSR	3-year Aged TSR
Low slope roofing (≤ 2:12)	0.65	0.50
Steep slope roofing (>2:12)	0.25	0.15

Based on the analysis conducted by CERL and NAVFAC, the first cost of most of Energy Star Roof Products that can be used for TEMF does not exceed the cost of regular (not "cool" roofing materials). For TEMF roofs with high reflectivity (0.65) are recommended for climate zones 1–5.

16.4 Lighting Density Reduction and Daylighting

The lighting power density in the office and consolidated bench spaces and daylighting controls were included in the office, repair bay, and in the east half of the vehicle corridor. Repair bays and warehouses are good candidates for hybrid lighting systems, which include a combination of electrical lighting and daylighting (Figure 16-2). Installing skylights to reducing lighting costs is not a new concept. Skylight technology, however, has advanced significantly in recent years (Figure 16-3). Modern 'passive' skylights include a reflective tube that channels the light into the work area and a lens that diffuses the light evenly to produce a uniformly illuminated area (Figure 16-4). 'Active' systems may include a rotating mirror assembly that tracks the sun.

Figure 16-2. Maintenance facility with a daylighting system.

Figure 16-3. Warehouse application without (left) and with (right) skylights.

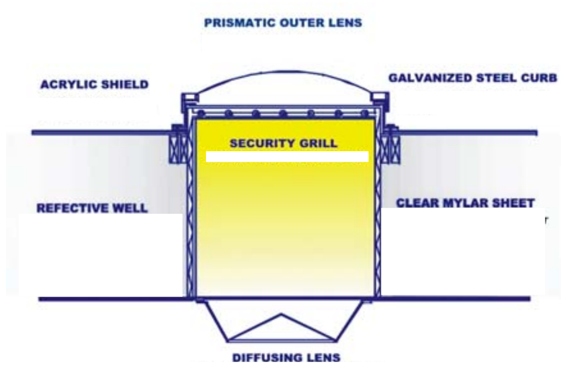


Figure 16-4. Schematic of modern skylight installation details (Source: www.daylighttechnology.com).

To automatically dim the lights, a photoelectric sensor measures the amount of light in a zone. If the specified amount of light has been reached, the controller turns off a bank of lights. Systems can be obtained to control only lights near windows or an entire building.

Small controllers can control the banks of lights near windows and larger systems can control an entire building that is illuminated by natural lighting. The controls can be set to dim the lights once a certain level of light has been achieved. Proper lighting levels can be found in the IESNA Lighting Ready Reference. Controls systems can typically either perform “step” dimming, which simply turns off certain banks of lights or linear dimming, and which linearly dims the lights until a minimum power level has been reached. Linear dimming, however, requires special dimming ballasts that are quite expensive and less efficient than standards ballasts above 50 percent. Figure 16-5 shows energy savings for a hybrid system. Based on the simulation results from the Annex 46 study, for the ventilated industrial building with no air conditioning, average pay-back ranges from 4–9 years (Figure 16-5).

16.5 Close Capture Evacuation System for Vehicle Exhaust Fumes

Vehicle exhaust ventilation system can mitigate and reduce exposure to Diesel and gasoline fumes generated by moving vehicles. Vehicle exhaust ventilation systems can be adapted to specific conditions of the maintenance facility (e.g., maintenance bay, drive-through corridor) and allow a range of exhausted air volume and withstand temperature ranges specific to variety of vehicles/tactical equipment serviced or repaired in these facilities. For the biggest vehicles the military needs to service, exhaust flow varies from 1700 to 3300cfm at temperatures of 650 up to 1200 °F.

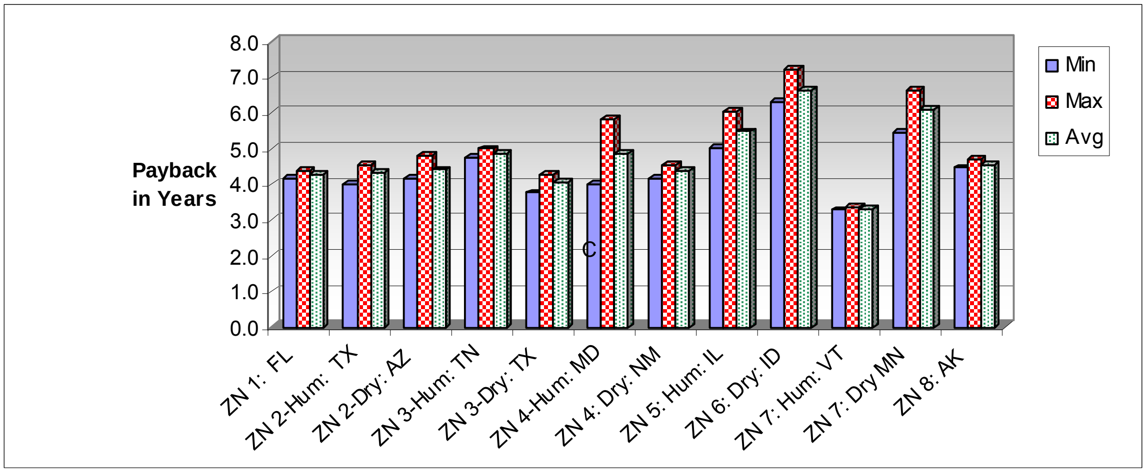


Figure 16-5. Estimated payback in years for hybrid lighting system.

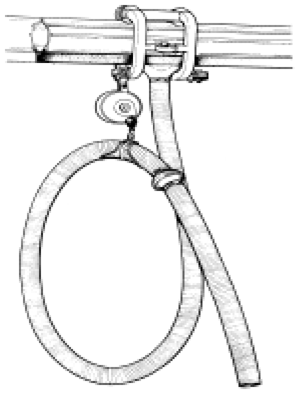
Vehicle exhaust capture systems trap and remove by-products of the engine combustion process (gas or Diesel) without contaminating the building air. Vehicle exhaust fumes contain hydrocarbons (HC), nitrogen oxides (NOx), carbon monoxide (CO), sulfur dioxides (SOx), carbon dioxide (CO_2) and approximately 100 other volatile organic and acidic compounds.

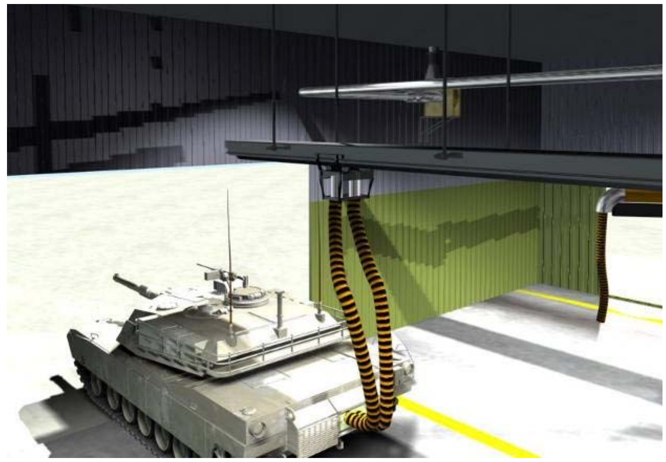
Traditional ventilation systems for maintenance facilities include a general dilution system sized for approximately 1.5 cfm of outside air per sq ft of floor area. This flow rate is based on ASHRAE Std. 62 and assumes that running vehicles are entering the building prior to attachment of the stationary close capture exhaust system. If the close capture system is attached before the vehicle enters the building, the general dilution rate can be assumed to be similar to mechanical or assembly shops (~0.75 cfm/sq ft) (Ventilation Guide for Automotive Industry, HPAC Engineering, 2000). The reduction could be achieved through demand controlled exhaust and make-up air systems and using the exhaust air from the office space as part of the make-up air. Conditioning the make-up air is the largest single energy use in the TEMF. This ECM results in the most significant energy savings in all climate zones.

Figure 16-6 shows a stationary hose reel type system (requiring ~1.5 cfm/sq ft of outside air).

Figure 16-6. Stationary hose reel type system.

Reduction in the general dilution rate can be achieved by means of well designed suction rail or pivoting boom systems (Figure 16-7). Vehicles are connected to these systems prior to entering the facility and remain attached while moving in and out of the facility.





Suction Rail Systems

Boom Systems

Figure 16-7. Well designed suction rail or pivoting boom systems.

Vehicle Exhaust Extraction systems can be classified as non-enclosing or enclosing. Enclosing type exhaust systems typically have a flexible hose with a tail-pipe adapter. The hose can be mounted on a stationary reel, an overhead rail extraction system or a swinging boom. Enclosing systems are normally classified as ‘sealed’ or ‘non-sealed’.

Sealed type exhaust systems use a tailpipe adapter, which makes an airtight seal between the exhaust tailpipe and the flexible exhaust ventilation hose. The attachment of this nozzle is usually through the use of an air-filled bladder made of synthetic rubber, which conforms to the size of the vehicle’s tailpipe. This eliminates the escape of exhaust gases when the vehicle is being accelerated or run at high idle. This system has a low operating air volume flow rate. Table 16-3 lists approximate airflow rates to be extracted per vehicle from the exhaust pipe using a sealed-fit tailpipe adapter. The capture effectiveness of sealed exhaust systems is high and for design purposes can be considered 90 percent or higher.

Table 16-3. Airflow rates to be extracted per vehicle from the tail pipe using a sealed fit tailpipe adapter (Source: Ventilation Guide for Automotive Industry, HPAC Engineering, 2000).

Sealed Fit Tailpipe Adapter			
Veh. Type **	**Engine Power (h.p.)**	**Airflow rate cfm (m3 /h)**	**Hose size (in.)**
LDGV	<130	300 (510)	3
LDGT	< 175	450 (765)	4
HDGV	< 250	500 (850)	4
LDDV	< 325	500 (850)	4
LDDT	< 400	500 (850)	4
HDDV	< 500	750 (1275)	5
ORV	< 600	1000 (1700)	6-8

Non-sealed systems use a loosely fitting tailpipe adapter. This system requires a higher air flow rate than a sealed system to maintain negative pressure control of the exhaust gases emitted by the vehicle. The nozzle is usually attached by means of a mechanical device such as a vice-grip clamp or spring clip.

For non-sealed exhaust systems, the capture effectiveness is below 75 percent. Table 16-4 lists approximate airflow rates to be extracted per vehicle from the exhaust pipe using a non-sealed fit tailpipe adapter.

Table 16-4. Airflow rates to be extracted per vehicle from the exhaust pipe using an open-fit non-sealing tailpipe adapter (Source Ventilation Guide for Automotive Industry, HPAC Engineering, 2000).

Non-sealed Fit Tailpipe Adapter			
Veh. Type*	**Engine Power (h.p.)**	**Airflow rate cfm (m3 /h)**	**Hose size (in.)**
LDGV	< 130	450 (765)	4
LDGT	< 175	600 (900)	5
HDGV	< 250	750 (1250)	5
LDDV	< 325	750 (1275)	5
LDDT	< 400	750 (1275)	5
HDDV	< 500	1125 (1910)	6
ORV	< 600	1500 (2500)	8

*Notes:
LDGV: Light-duty gasoline-fueled vehicles, up to 6000 lb GVW
LDGT: Light-duty gasoline-fueled trucks, up to 8500 lb GVW
HDGV: Heavy-duty gasoline-fueled vehicles, 8501+ lb GVW
LDDV: Light-duty Diesel vehicles, up to 6000 lb GVW
LDDT: Light-duty Diesel trucks, up to 8500 lb GVW
HDDV: Heavy-duty Diesel vehicles, 8501+ lb GVW

Selection of the hose for a particular application depends on exhaust temperature and flow rate. Selection of the nozzle depends on the size and configuration of the tail-pipe or exhaust grill (cf. Appendix D).

In most small vehicle maintenance and repair facilities, it is uncommon for several vehicles to drive in or out of the facility simultaneously. Likewise, it is uncommon to run all the engines in the facility at the same time. Typically a demand controlled local exhaust system is sized for a maximum duty cycle of 50 percent of the total available capacity thereby reducing the size of the exhaust duct, fan as well as its operating airflow rate. The exhaust airflow rate is controlled using a variable frequency drive (VFD) and a pressure sensor installed in the main duct.

Demand based control of the local exhaust system is initiated by a mechanical damper that opens when the hose is pulled down from the reel. Each of these mechanical dampers initiates the activation of air flow from a specific hose reel during maintenance operations. The system fan ramps up or down to accommodate the number of hose reels activated without affecting the airflow through other reels.

Figures 16-8 and 16-9 show the simple payback for both the rail and boom systems based on the simulation results conducted under the Annex 46 study. For both systems in all climates, the payback is less than 4.5 years. The significant reduction in outside air flow rate is responsible for the savings.

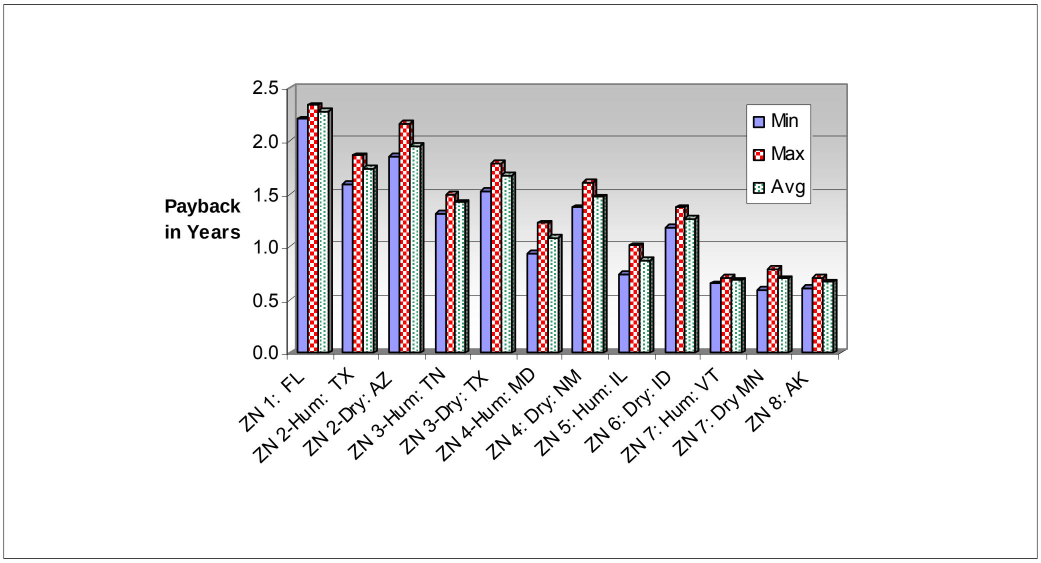


Figure 16-8. Estimated simple payback for rail system.

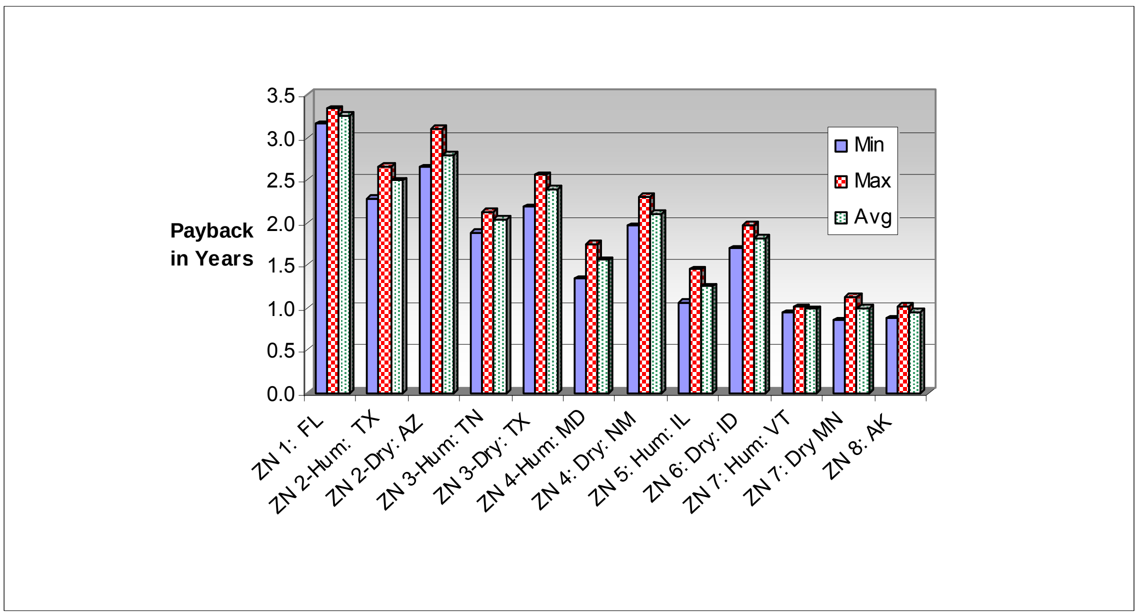


Figure 16-9. Estimated simple payback for boom system.

16.6 General Ventilation

General supply and exhaust ventilation shall be designed to respond maintain indoor air quality and provide a make-up air for local exhaust systems. Demand controlled ventilation with variable frequency drives (VFD) and CO and NOx sensors to control residual fumes from gasoline, can be implemented following the indoor air quality (IAQ) procedure in ASHRAE Standard 62.1-2007.

Cascading air from offices to maintenance bays and vehicle corridor pressurizes office areas and prevents odors/contaminants from more polluted zones to office spaces. It also provides heated or cooled air for the repair bays area and results in energy conservation. Since vehicle exhaust fume are heavier that the air and tend to stay close to the floor, two-thirds of air shall be exhausted by general exhaust system from within 1 ft from the floor level, and the rest from the upper zone. If TEMF has a pit, it shall be ventilated by supplying air directly into the pit and have an exhaust from its bottom.

16.7 HVAC equipment efficiency improvement

Compared to the ASHRAE Standard 90.1 minimum requirement, the cooling equipment efficiencies were increased by 20 percent, the gas burner efficiencies were increased to 0.9, and the fan efficiencies were improved (Table 16-5).

The improved efficiency fan performance numbers are based on available high efficiency fans. The last column shows the pressure increase in the fan system for the inclusion of the energy recovery ventilator (ERV). The fan pressure was increased by 50 Pa when the transpired solar collector was included. For the cases with reduced ventilation, the pressures were reduced by 15 percent for the repair bays, vehicle corridor, and the consolidated bench.

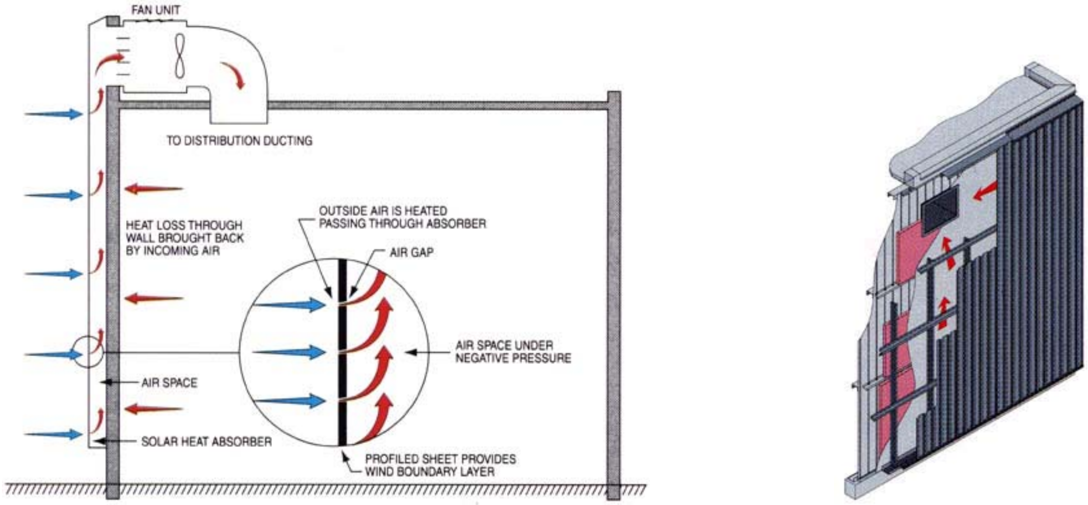
Table 16-5. Improved fan model assumptions.

System	Flow (m^3/s)	Pressure Rise (Pa)	Baseline Efficiency		Improved Efficiency		ERV Pressure Drop (Pa)
			Fan Motor	Total Fan	Fan Motor	Total Fan	
Repair bay	15.52	400	0.8	0.27	0.9	0.45	200
Vehicle corridor	4.28	300	0.8	0.19	0.9	0.45	150
Showers	0.78	250	0.8	0.20	0.85	0.34	
Storage 1	0.54	250	0.8	0.20	0.85	0.34	
Consolidated bench	2.14	300	0.8	0.19	0.9	0.45	150
Storage 2	1.19	250	0.8	0.20	0.85	0.34	
Office	2.49	250	0.8	0.20	0.85	0.34	
Fan coil units	Varies	75	0.8	0.30	0.85	0.34	

The fan improvements had the larges affect in the climate zones 1 to 3.

16.8 Ventilation air preheating in transpired solar collector

A transpired solar collector or a “solar wall” preheats ventilation air by drawing make-up air through a perforated steel or aluminum plate that is warmed by solar radiation. The solar wall consists of perforated steel or aluminum cladding attached to the south façade of a building with an air gap between the existing wall and the cladding. The solar wall 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 (Figure 16-10). The warm air rises to the top of the wall and is drawn into the building’s ventilation system as shown in the figure below. Figure 16-11 shows a solar wall installed on the maintenance facility at Fort Drum, NY.



a. **b.**

Figure 16-10. Schematic of air flows through (a) a solar wall and (b) typical installation.

a. **b.**

Figure 16-11. Solar wall installed on (a) the maintenance facility at Fort Drum, detail showing (b) perforated panel element

The performance of a “solar wall” depends primarily on four parameters: the solar reflectance of the wall, the orientation of the wall, the size and spacing of the perforations in the wall, and the pressure drop maintained by the ventilation system across the wall. The solar reflectance is primarily affected by the coating applied to the solar wall. In general, darker colors have a lower reflectance, and thus absorb a greater fraction of incident solar radiation.

The orientation of the wall also greatly affects its performance The intensity of the incident solar radiation is dependent on the cosine of the ‘angle of incidence’, the angle between the outward facing normal of the surface and the ‘line of sight’ to the sun. Walls that more directly face the sun will receive more solar radiation. In winter months in the northern hemisphere, south facing walls perform best. The cost effectiveness of applying solar collectors to East and West facing walls (to catch morning and afternoon sun) must be analyzed on a case by case basis.

The size and spacing of the perforations along with the pressure drop across the wall due to the operation of the ventilation system largely determines the impact of wind speed and wind direction on the solar wall performance. For a properly designed wall with small closely spaced perforations and a relatively high pressure drop, the laminar boundary layer created by suction at the wall will largely negate the effects of changing wind speed and wind direction. For the improved model building a 2,280 sq ft transpired solar collector on the south wall of the repair bays was simulated. This collector occupies the top 10 ft of the wall and is slightly undersized for the exhaust air requirements of this zone. The collector should be sized for the flow to be 7 to 10 cfm/sq ft.

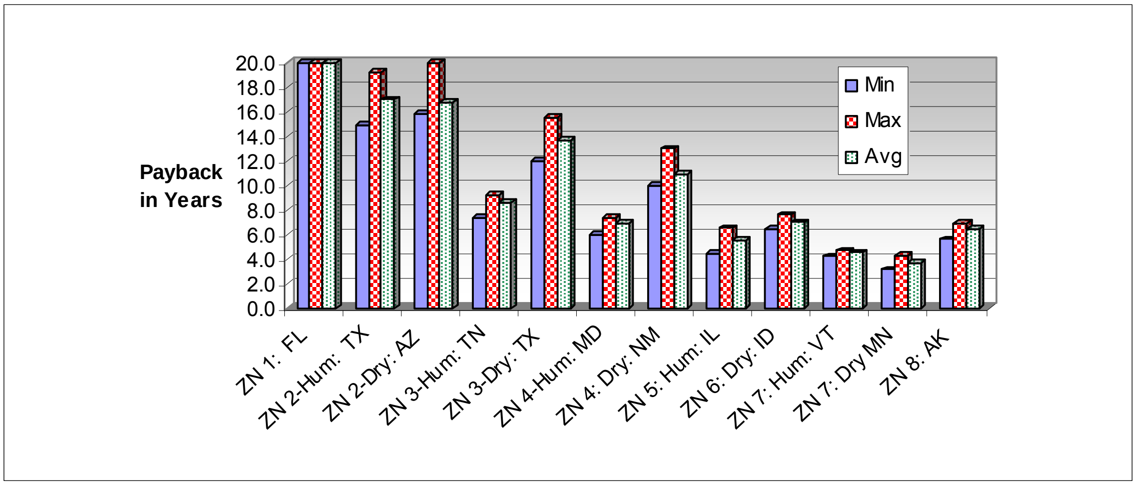


Figure 16-12. Transpired solar wall estimated payback shown for high, medium and low energy rates.

Figure 16-12 shows a simple payback from installation of the “solar wall.” The data was received through simulation of “solar wall” conducted under the IEA Annex 46 study. The simple pay back is under 6 years for all heating dominated climates.

16.9 Energy recovery ventilators

Heating energy recovery from the stream of air exhausted from repair bays, vehicle corridor, and consolidated bench can be used to preheat supply air. Use of ERV results in the increased pressure drop in the supply air system. There is also a need for better duct insulation to reduce heat losses in the return duct. Given these additional costs and losses, according to Airways [2002] ERVs are not cost efficient in mild climates (with HDD < 2500). Considering that exhaust air may contain sticky particulates, ERVs were selected with a plate heat exchangers (Figure 16-13), which are 75 to 70 percent effective for flows ranging from 70 to 100 percent.

Figure 16-13. Plate heat exchanger.

16.10 Hydronic radiant floor heating

Low intensity hydronic radiant floor heating systems are commonly used in industrial facilities, hangars, warehouses, garages, gymnasiums, hospitals, kindergartens, apartments, and in different other types of buildings. Heat to the space is provided by hot water supplied through pipes embedded in floors. Thermal energy is exchanged by at least 50% by radiation between the room and people present in the space and the heated floor surface. Transfer from the hot water pipes to the surface of the floor is the important consideration. Figure 16-14 shows the installation of plastic piping for a radiant floor heating system, and Figure 16-15 shows a radiant floor heating system installed in a TEMF at Fort Lewis, WA.

The uniform temperature distribution from floor heating increases comfort and reduces room air temperature stratification especially in high ceiling buildings. Low intensity radiant heating provides greater comfort for mechanics working near or on the floor. Radiant energy transmitted to the cold (sometimes snow-covered) vehicles results in rapid conditioning of the vehicles for service, which improves workers' productivity and adds to their comfort.

Figure 16-14. Installation of plastic piping for the radiant floor heating system (Uponor, 2007)

Figure 16-15. Radiant floor heating system installed in a TEMF at Fort Lewis, WA.

Radiant floor systems are more energy efficient.

1. Compared to warm air heating systems traditionally used in TEMF, a radiant floor system provides the same comfort level in the working zone at a lower room air temperature during the heating season. This results in reduced ventilation and infiltration losses.
2. In hydronic radiant floor systems, energy is transported by water instead of air. Auxiliary energy for circulation pumps is less than for fans.
3. The system uses lower water temperature for heating, than the warm air heating systems. This allows for using return water for radiant floor system, which increases energy performance of boilers (condensing boilers) and heat pumps.
4. Reduced air temperature stratification along the room height results in heating energy saving, typically at least by 25 to 30 percent.

With the introduction of polybutelene tubing and new design techniques, as well as reduced energy losses due elimination of room air temperature stratification, the first cost of radiant floor system became comparable or even lower than the warm air system.

Application of radiant floor systems requires under the slab insulation with 2 in. of EPS insulation (R-10) for climate zones 1 to 7 and 3 in. (R-15) for climate zone 8 (Figure 16-16).

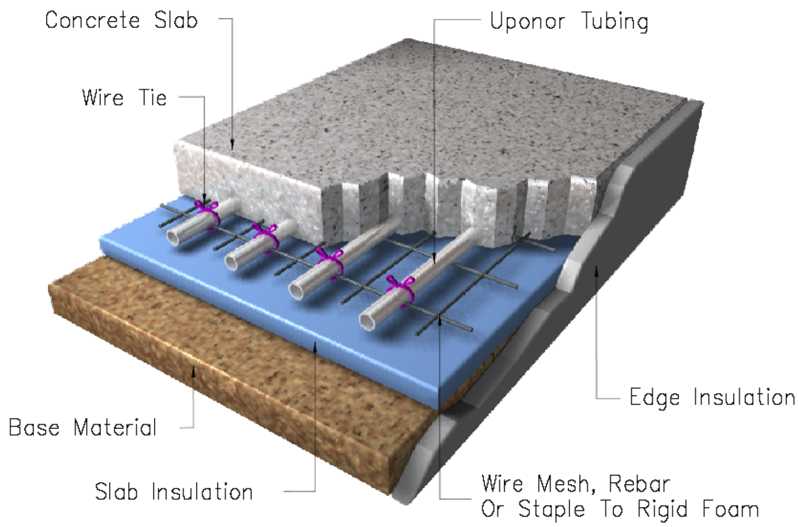


Figure 16-16. Concrete floor radiant heating system with edge and slab insulation (Uponor 2008).

16.11 Optional ECMs

16.11.1 Vestibules with airlocks

Vestibule with an air lock (Figure 16-17) prevents cold air drafts into the building and allows heating the vehicle prior to bringing it in. The building is protected from outdoor air by two sequentially installed doors with an enclosed space ("air lock"). There is only one door open at a time to let a vehicle in or out the building. After the vehicle enters the "air lock" the first door closes and the second one opens.

Figure 16-18 shows a simple payback from installation of the vestibule. The data was received through simulation of "vehicle vestibules" conducted under the IEA Annex 46 study. The simple pay back is under 4 years for all heating dominated climates.

Figure 16-17. Example vestibule at auto manufacturing plant.

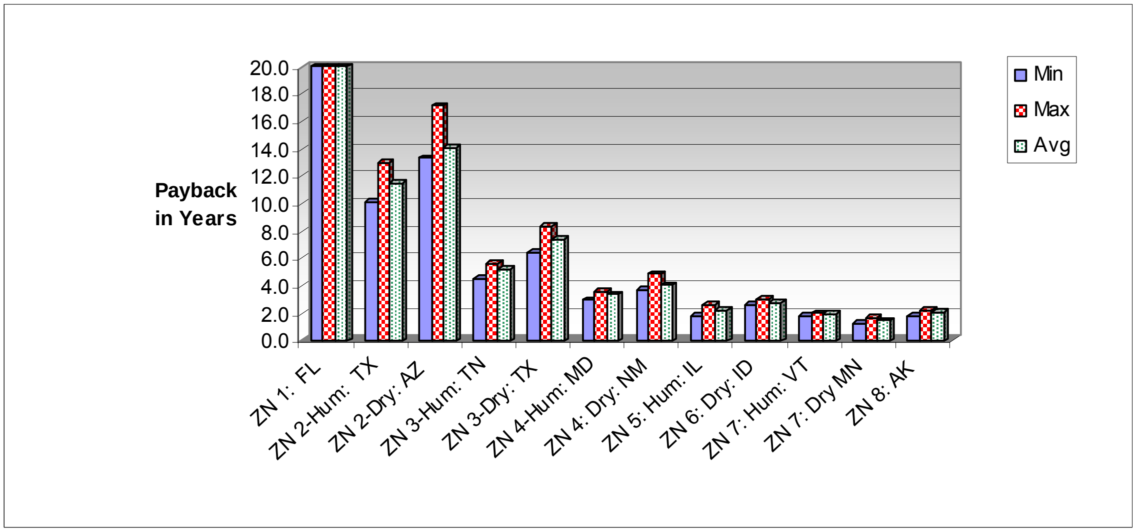


Figure 16-18. Simple payback from installation of the vestibule.

16.11.2 Evaporative Cooling

The Wet Bulb Globe Temperature (WBGT) offers a useful first order index of the environmental contribution to heat stress. It is influenced by air temperature, radiant heat, and humidity. WBGT values are calculated using one of the following equations: with direct exposure to sunlight:

$$WGBT_{out} = 0.7\ T_{nwb} + 0.2\ T_g + 0.1\ T_{db}$$

without direct exposure to the sun:

$$WBGT_{in} = 0.7\ T_{nwb} + 0.3\ T_g$$

where:

T_{nwb} = natural wet bulb temperature (sometimes called NWB)
T_g = globe temperature (sometimes called GT)
T_{db}= dry bulb (air) temperature (sometimes called DB).

Because WBGT is only an index of the environment, the screen criteria are adjusted for the contributions of work demands and clothing as well as state of acclimatization. Table 16-6 lists ACGIH (American Conference of Governmental Industrial Hygienists) rest-work guidelines for hot-humid climates. It provides screening criteria for heat stress exposure (WBGT values in °F).

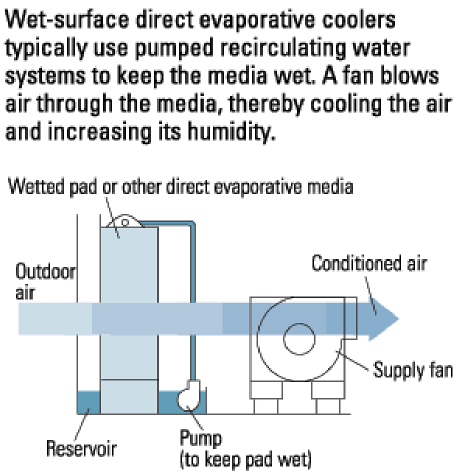
Table 16-6. ACGIH rest-work guidelines for hot-humid climates.

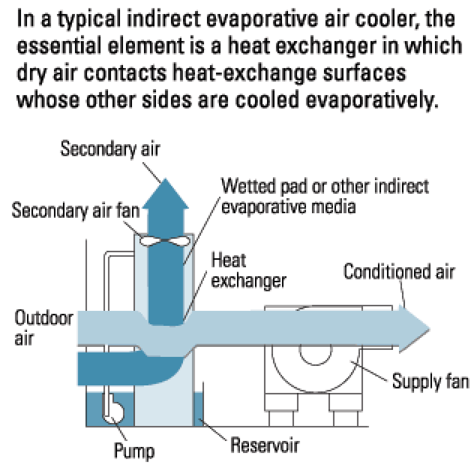
	Acclimatized Employee		Unacclimatized Employee	
Work Demands	**Light (WBGT °F)**	**Moderate (WBGT, °F)**	**Light (WBGT, °F)**	**Moderate (WBGT, °F)**
100% Work	85.1	81.5	81.5	77
75% Work 25% Rest	86.9	83.3	84.2	79.7
50% Work 50% Rest	88.7	85.1	86	82.4
25% Work 75% Rest	90.5	87.8	87.8	84.2

Based on the information provided in Table 16-6, to avoid heat stress in an environment where the humidity and temperature exceeds 85 °F wet bulb globe temperature, workers should be given rest time of 15 minutes per hour or more. Thus, height WBGT results not only in workers discomfort but in a reduced productivity.

For TEMF cooled only by ventilation, an evaporative cooler installed in the outside air duct can improve indoor working conditions during the cooling season. For this type of system, a comfort analysis allows to see the effect of the technology. Evaporative coolers can also be used to pre-cool outside air used by a mechanical cooling system. For this type of system, an energy analysis shows the cost/benefit of the system.

There are two main categories of evaporative coolers; direct and indirect (Figure 16-19). Direct coolers spray water through the incoming air stream, cooling the air to a temperature much closer to the wet bulb temperature. The largest draw back of a direct evaporative cooler is that it dramatically increases the relative humidity of the incoming air. In hot, working conditions, a direct evaporative cooler can lower the thermal comfort by creating a warm, humid environment. Indirect coolers, on the other hand, operate much more like a common heat exchanger. Water is sprayed on a water-proof membrane letting outside air evaporate on it, while the intake air is passed on the other side of the membrane. Unlike a direct cooler, the humidity of the inlet air is unchanged. Figure 16-19 shows the two types of evaporative coolers. Many companies produce roof-top evaporators to temper incoming air. The indirect evaporative cooler shown in Figure 16-19 is an evaporative heat recovery heat exchanger.





a. Direct Evaporative Cooler **b. Indirect Evaporative Cooler**

Figure 16-19. Two types of evaporative coolers (source: http://www.xcelenergy.com).

During the cooling season, water misters in the relief air stream evaporatively cool the relief air before it leaves the system. The Fresh air is drawn through a counterflow heat exchanger and heat is transferred from the fresh air stream to the evaporatively cooled relief air stream. Evaporative coolers do not save energy if the building is cooled by ventilation only. More than that, application of evaporative cooling results in increased water and electrical energy usage.

However, significant cost reduction results from improved thermal environment and respective increase in worker productivity. The indirect evaporative cooler lowers the dry bulb temperature in the space resulting in a corresponding improvement in both worker comfort and productivity. The annual savings in man-hours is shown in the plot below for the indirect evaporative cooler.

The data received through simulation of indirect evaporative cooling conducted under the IEA Annex 46 study, shows, it is cost efficient in every climate except for the climate zones 7 and 8 with a simple payback under 2 years (Figure 16-20).

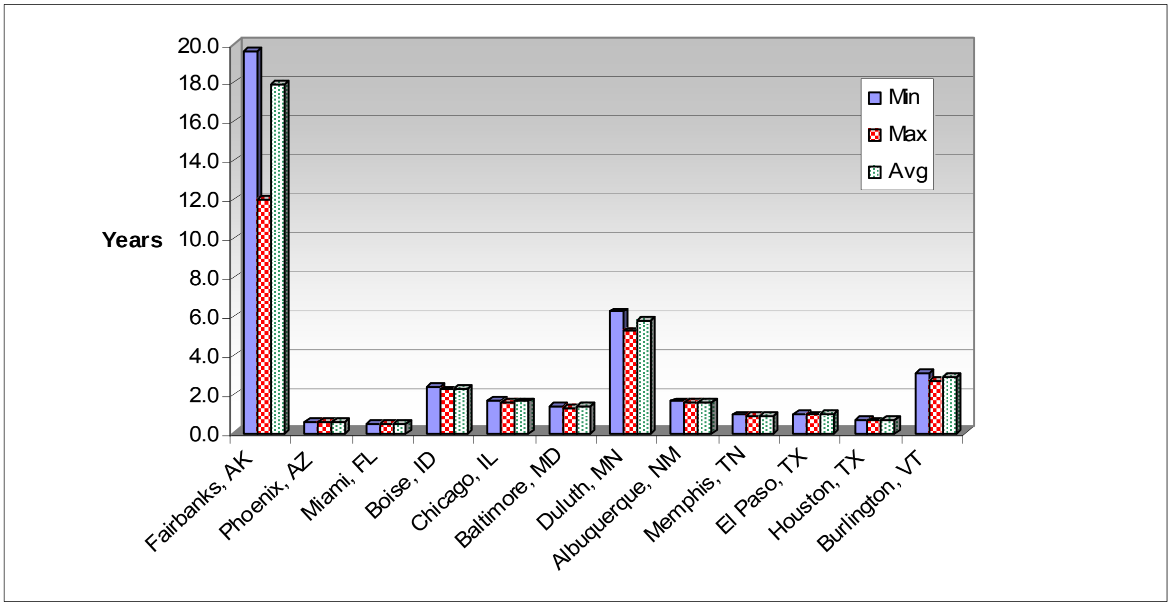


Figure 16-20. Simple payback for indirect evaporative cooling in various climate zones.

Appendix 17: Prescriptive and optional energy saving technologies for dining facilities

17.1. Prescriptive Technology Solution Sets

As part of the EPACT 2005 energy study discussed in Appendix 1, a prescriptive technology solution set is being developed for dining facilities for each climate one to achieve at least a 30% energy consumption reduction compared to an ASHRAE 90.1-2004 minimum baseline building. These prescriptive sets will be included here when completed. The general prescriptive energy saving technologies for dining facilities include:

Building envelope air tightness: 0.25 cfm/ft^2 at 0.3 in w.g. The savings from this measure are significant in climate zones 6 to 8.

Building envelope insulation: buildings located in climate zones 1 and 2 have the same insulation values as required by the ASHRAE Standard 90.1-2004, in other location – per the ASHRAE 30% Small Office Advanced Energy Design Guide. This measure produces insignificant savings in the climate zone 3 and significant energy savings in colder climates.

The windows are per the ASHRAE 30% Small Office Advanced Energy Design Guide. They have a lower U-value and a higher SHGC than Standard 90.1-2004 windows.

"Cool Roof" with a solar reflectance = 0.65 for buildings in climate zones 1, 2, 3A and 4B. There are no requirements to use "cool roof" in other climate zones due to negative energy savings.

Reduced LPD: in buildings located in all climates zones

Table 17-1. Daylighting and reduced LPD in the dining, servery, carryout, and office areas.

Zone	Baseline		Efficient Model		90.1-2004 Space Type
	W/ft^2	W	W/ft^2	W	
Dining	0.9	7,183	0.8	6,383	Dining area
Storage/Receiving	0.8	2,098	0.8	2,098	Active Storage
Dishwash	1.2	1,344	1.0	1,120	Food Preparation
Kitchen	1.2	3,315	1.1	3,039	Food Preparation
Servery	1.2	5,131	1.0	4,276	Food Preparation
Entry/Circulation	1.3	4,277	1.0	3,290	Lobby
Carryout	1.2	1,253	1.0	1,044	Food Preparation
Office	1.1	1,588	0.9	1,300	Office
Utility	1.5	1,580	1.0	1,053	Elec/Mech
Total		**27,759**		**23,596**	

This measure results in energy savings in all climate zones; however, the savings gets smaller as the climate gets colder.

Install partial end panels on the kitchen hood and all wall-mounted hoods in the servery, bake shop, and carryout areas. This measure shows significant energy savings in all climate zones, especially in the cold climates.

Replace Single-Island Hoods with Wall-Mounted Hoods in Servery. This measure ECM shows smaller energy savings in the warm climates and significant savings in the cold climates.

Use Demand Controlled Ventilation Hoods in the Servery and Carryout. Use of DCV technology in hoods located in the Servery and Carryout allows reduction of the airflow by half and fan power by one fourth (e.g., for 2 hours in the morning and 2 hours in the afternoon.) This technology saves energy in every climate, especially in warm and the cold climates. Savings associated with this measure strongly depend on the number of hours with reduced flow and the rate of the airflow reduction.

Use Demand Controlled Ventilation Hoods in the Kitchen allows reduction of the airflow by half and the fan power by one fourth (e.g., for three hours in the morning, two hours midmorning, and two hours in the afternoon.). This technology shows significant energy savings in climate zones 3 through 8 and smaller savings in climate zones 1 and 2.

High Efficiency HVAC. : PSZ-AC, 12.0 EER (3.52 COP); 0.9 E_t gas heater; 0.94 E_t gas boiler Vs PSZ-AC, 9.7 EER (2.84 COP); 0.8 E_t gas heater; 0.8 E_t gas boiler in the baseline case per the ASHRAE Standard 90.1-2004 requirements. This measure shows significant energy savings in all climates. It shows the highest savings for climate zones 1 through 3 and 4B.

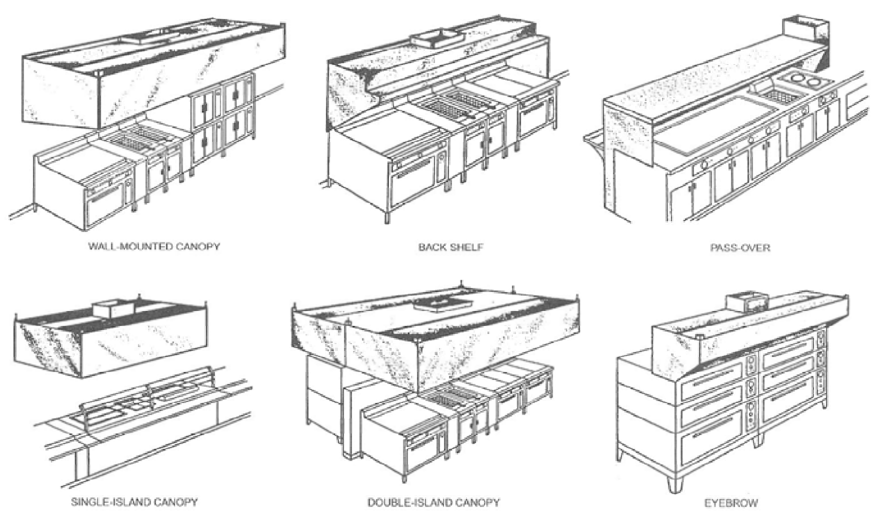
Low-Flow Pre-Rinse Nozzles. Use 1.2 gpm rinsing nozzles in each of the storage and receiving, dish wash, and kitchen zones. This ECM is very easy to implement and shows energy savings in all climates.

17.2. Energy Efficient Kitchen Ventilation

17.2.1. Optimized Selection and Installation of UL Listed Exhaust Hoods

Description

The design exhaust rate for kitchen ventilation systems depends on the hood style along with subtle construction features and enhancements (e.g., return flanges along the inside edge of the hood, integral side skirts). Wall-mounted canopy hoods, island (single or double) canopy hoods, and proximity (backshelf, pass-over, or eyebrow) hoods all have different capture areas and are mounted at different heights and horizontal positions relative to the cooking equipment (see Figure 17-1). Generally, for the identical (thermal plume) challenge, a single-island canopy hood requires more exhaust than a wall-mounted canopy hood, and a wall-mounted canopy hood requires more exhaust than a proximity (backshelf) hood. The performance of a double-island canopy tends to emulate the performance of two back-to-back wall-canopy hoods, although the lack of a physical barrier between the two hood sections makes the configuration more susceptible to cross drafts.



Source: ASHRAE Standard 154

Figure 17-1. Types of kitchen ventilation systems

Building codes distinguish between cooking processes that create smoke and grease (e.g., frying, griddling, or charbroiling) and those that produce only heat and moisture (e.g., dishwashing and some baking and steaming operations). Cooking that produces smoke and grease requires liquid-tight construction with a built-in fire suppression system (Type I hood), while operations such as dishwashers that produce only heat and moisture do not require liquid-tight construction or a fire suppression system (Type II hood).

ASHRAE Standard 154 categorizes cooking appliances as light-, medium-, heavy-, and extra heavy-duty, depending on the strength of the thermal plume and the quantity of grease, smoke, heat, water vapor, and combustion products produced. The strength of the thermal plume is a major factor in determining the exhaust rate. By their nature, these thermal plumes rise by natural convection, but they are turbulent and different cooking processes have different "surge" characteristics.

Mechanical codes recognize exceptions for hoods that have been tested against a recognized standard, such as Underwriters Laboratories (UL) Standard 710. Part of the UL standard is a "cooking smoke and flair up" test. This test is essentially a cooking effluent capture and containment (C&C) test where "no evidence of smoke or flame escaping outside the exhaust hood" must be observed. Hoods bearing a recognized laboratory mark are called *listed* hoods, while those constructed to the prescriptive requirements of the building code are called *unlisted* hoods.

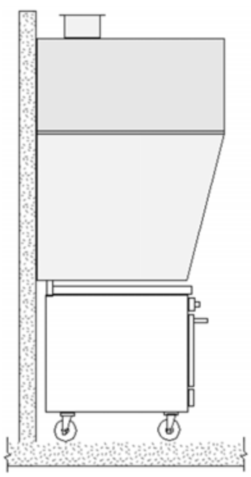
As reflected by the range in exhaust rates in the Table 7-1, a *listed* hood can be operated at a lower exhaust rate than an *unlisted* hood of comparable style and size over the same cook line. Lower exhaust rates may be proven by laboratory testing with specific hood(s) and appliance lineup using the test protocol described in ASTM Standard F-1704, *Test Method for Performance of Commercial Kitchen Ventilation Systems*. This process is sometimes referred to as "custom-engineering" a hood and is the foundation of this ECM. Within the specification to maximize hood performance and minimize exhaust rate are construction or installation details that include the addition of partial side panels, minimizing the gap between the appliances and the back wall and, in the case of canopy hoods, increasing the amount of overhang (e.g., from 6 to 18 in). These detailed specifications can permit a listed hood to operate satisfactorily at the lower end of the cfm range show (e.g., 200 cfm vs. 300 cfm) for a 30% or more saving over the Code values and or standard design practice).

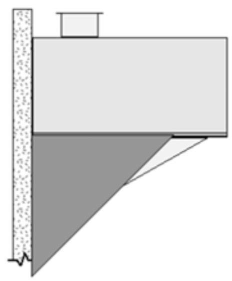
Energy Efficiency Specifications

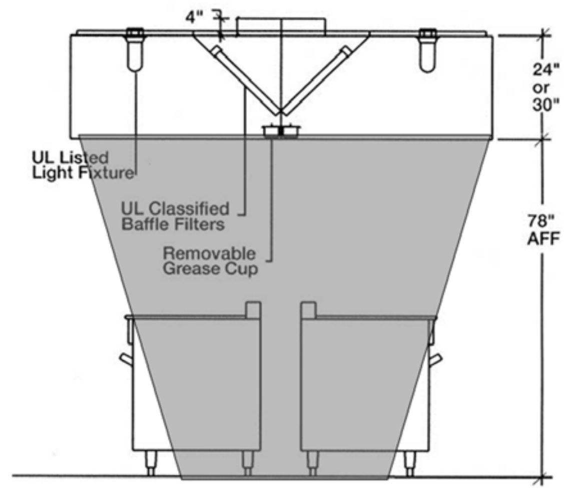
Specify exhaust hoods based on performance data provided by the manufacturer of a *listed* hood that will minimize the exhaust ventilation rate for a given cooking equipment line or duty (as reflected in the above table). In general, this will permit exhaust ventilation rates that are at least 30% below the prescriptive code requirements with proportional energy savings.

Where applicable, the following best-design practices should be incorporated within the exhaust system design and specifications to ensure that capture and containment performance of the hood is satisfactorily at the reduced exhaust rate:

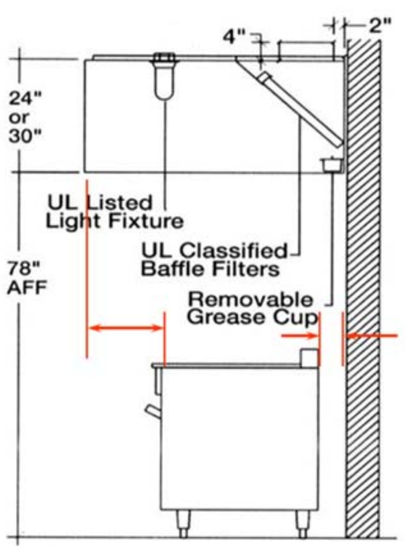
1. Incorporate partial side panels or end walls.







2. Maximize overhang and minimize clearance between appliance and rear wall.



3. Positioning heavy duty equipment (e.g., broilers) in middle of the hood and light duty (e.g., ovens, kettles) at the end of the cook line.
4. Specifying walk-mounted canopy hoods instead of single-island canopies.
5. Specifying back-shelf (i.e., proximity hoods) over short-order equipment such as griddles and fryers.

6. Low-velocity introduction of makeup air near hoods (e.g., no 4-way diffusers in kitchens).
7. Maximize transfer air (detailed within 17.2.3.).
8. Incorporate demand ventilation controls (detailed within 17.2.4.).

17.2.2 – Maximize transfer air/minimize dedicated makeup air *(to be completed)*

17.2.3 – Demand Ventilation Controls for Exhaust Hoods *(to be completed)*

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