U.S. DEPARTMENT OF ENERGY

PNNL-18802

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Technical Support Document for Version 3.6.1 of the COM*check* Software

R Bartlett
LM Connell
K Gowri
MA Halverson
RG Lucas
EE Richman
RW Schultz
DW Winiarski

September 2009

Pacific Northwest NATIONAL LABORATORY

Proudly Operated by Battelle Since 1965

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062;
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov

Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161
ph: (800) 553-6847
fax: (703) 605-6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/ordering.htm

This document was printed on recycled paper.
(9/2003)

PNNL-18802

Technical Support Document for Version 3.6.1 of the COM*check* Software

R Bartlett
LM Connell
K Gowri
MA Halverson
RG Lucas
EE Richman
RW Schultz
DW Winiarski

September 2009

Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

COM*check* provides an optional way to demonstrate compliance with commercial and high-rise residential building energy codes. Commercial buildings include all use groups except single family and multifamily not over three stories in height. COM*check* was originally based on *ANSI/ASHRAE/IES Standard 90.1-1989* (Standard 90.1-1989) requirements and is intended for use with various codes based on Standard 90.1, including the *Codification of ASHRAE/IES Standard 90.1-1989* (90.1-1989 Code) (ASHRAE 1989a, 1993b) and *ASHRAE/IESNA Standard 90.1-1999* (Standard 90.1-1999). This includes jurisdictions that have adopted the 90.1-1989 Code, Standard 90.1-1989, Standard 90.1-1999, or their own code based on one of these. We view Standard 90.1-1989 and the 90.1-1989 Code as having equivalent technical content and have used both as source documents in developing COM*check*.

This technical support document (TSD) is designed to explain the technical basis for the COM*check* software as originally developed based on the *ANSI/ASHRAE/IES Standard 90.1-1989* (Standard 90.1-1989). Documentation for other national model codes and standards and specific state energy codes supported in COM*check* has been added to this report as appendices. These appendices are intended to provide technical documentation for features specific to the supported codes and for any changes made for state-specific codes that differ from the standard features that support compliance with the national model codes and standards.

Communicating with BECP

The U.S. Department of Energy (DOE) and Pacific Northwest National Laboratory (PNNL) intend to refine and enhance the COM*check* materials over time in response to needs expressed by users. Many of the simplifications and enhancements developed for COM*check* have provided the technical basis for code changes submitted to the International Code Council (ICC). PNNL welcomes suggestions for improvements to the COM*check* materials and to this documentation. Suggestions can be communicated to PNNL using any of the methods listed below.

Email: techsupport@becp.pnl.gov
Fax: 1-509-372-4484
Mail: Attn. Pam Cole, MSIN K6-05
Building Energy Codes Program
Pacific Northwest National Laboratory
P.O. Box 999
Richland, WA 99352

Contents

Tables

1.0 Introduction

1.1 About This Report

This technical support document (TSD) is designed to explain the technical basis for the COM*check* (formerly known as COM*check-EZ*) software as originally developed based on the *ANSI/ASHRAE/IES Standard 90.1-1989* (Standard 90.1-1989). Documentation for other national model codes and standards and specific state energy codes supported in *COMcheck* have been added to this report as appendices. These appendices are intended to provide technical documentation for features specific to the supported codes and for any changes made for state-specific codes that differ from the standard features that support compliance with the national model codes and standards.

The primary objectives of this TSD are to identify where COM*check* differs from codes it supports and explain the technical basis and rationale for those differences. The primary intended audience for this report includes groups and individuals considering whether to adopt or approve technical provisions of codes supported by COM*check* or to accept use of the COM*check* software or submissions based on them. Other interested parties directly impacted by these codes or who require a detailed technical understanding of the COM*check* software may also have interest in this document. This document is not intended for use by the direct end-users of the COM*check* software; the Software User's Guide and help information are intended to offer sufficient explanation.

This report is a working document that will be revised and extended in the future as necessary to provide the appropriate level of technical detail required by readers.

1.2 About COM*check*

COM*check* provides an optional way to demonstrate compliance with commercial and high-rise residential building energy codes. Commercial buildings include all use groups except single family and multifamily not over three stories in height. COM*check* was originally based on *ANSI/ASHRAE/IES Standard 90.1-1989* (Standard 90.1-1989) requirements and is intended for use with various codes based on Standard 90.1, including the *Codification of ASHRAE/IES Standard 90.1-1989* (90.1-1989 Code) (ASHRAE 1989a, 1993b) and *ASHRAE/IESNA Standard 90.1-1999* (Standard 90.1-1999). This includes jurisdictions that have adopted the 90.1-1989 Code, Standard 90.1-1989, Standard 90.1-1999, or their own code based on one of these. We view Standard 90.1-1989 and the 90.1-1989 Code as having equivalent technical content and have used both as source documents in developing COM*check*.

In developing COM*check*, we attempted to err on the side of stringency to give adopting authorities confidence that when they accept designs developed using COM*check*, the designs can confidently be deemed to comply with the supported codes. However, had we originally been completely rigid in always erring on the side of stringency, the resulting materials would have been significantly more stringent than Standard 90.1-1989 and the 90.1-1989 Code because of the cumulative effects of many provisions. Instead, we used a less rigid approach aimed at equivalency and a reasonable confidence level that a building complying with COM*check* will also comply with the code.

The COM*check* software was developed for the U.S. Department of Energy (DOE) by Pacific Northwest National Laboratory (PNNL) (DOE 1997). These materials are intended to facilitate more effective implementation of commercial building energy code requirements by making it easy for designers and builders to determine and understand the requirements and for building departments to enforce the requirements through plan review and site inspections.

While the original version of COM*check* was designed to be used primarily with simple buildings, the enhancements incorporated since Version 2.0 remove previous building height and HVAC system type restrictions. The software is a self-contained tool that addresses building envelope, HVAC, service water-heating, and lighting system requirements. Each major system must comply on its own; trade-offs between major systems are not permitted, although they are permitted under the Standard 90.1 Building Energy Cost Budget Method or under the Total Building Performance section in the IECC editions. The envelope and lighting sections include short lists of mandatory requirements reflecting Standard 90.1 provisions applicable to all buildings, such areas as window and door infiltration and requirements for caulking and sealing. The mechanical section uses a software "wizard" approach to provide a short, customized list of requirements applicable to the systems identified by the user. The lighting portion of the software automatically calculates the lighting power budget for a building based on building use and enables the user to document the installed lighting by selecting equipment with suggested lamp/ballast wattages. Compliance forms similar to those used in the printed guides are generated by the software for submission with plans and specifications.

Like Standard 90.1, COM*check* materials offer two compliance options for addressing envelope requirements – prescriptive packages and the COM*check* software. The Envelope section of the software is analogous to ENVSTD (Crawley et al. 1989), and the prescriptive packages are analogous to Appendix A in the 90.1-1989 Code and the Alternative Component Package (ACP) tables in Standard 90.1-1989. The software and the prescriptive packages share a common technical basis, and the prescriptive packages are generated using a special version of the COM*check* software.

The COM*check* software incorporates the same equations as those in Attachment 8B of Standard 90.1 and are used in ENVSTD for wall and window trade-offs (Crawley et al. 1989). The ENVSTD program enables Standard 90.1 users to only make trade-offs between above-grade wall and window components. Trade-offs allow the use of components exceeding minimum criteria to be used to offset components that fall below minimum criteria. COM*check* extends the Standard 90.1 trade-offs beyond those that are conveniently available when using Standard 90.1 directly. These trade-offs are clearly consistent with the intent of Standard 90.1 because the principle of unlimited trade-offs based on equivalent energy use is sanctioned under Section 13, *Energy Cost Budget (ECB) Method* in Standard 90.1-1989. As in Standard 90.1-1989, the basis for the trade-offs is equivalent cumulative annual space-conditioning (i.e., heating plus cooling) coil loads. Specific areas where new trade-offs have been added include

- roofs
- skylights
- interior walls
- below-grade walls
- floors
- slab edges.

Under Standard 90.1, these trade-offs are available only if you use the ECB Method. COM*check* makes these trade-offs available to anyone using the compliance software.

The impact of allowing trade-offs with additional building envelope components is that designs violating some of the Standard 90.1 prescriptive requirements (e.g., for roofs, below-grade walls, or slabs) may now comply if other envelope requirements are exceeded. To assist in code enforcement, the

COM*check* Envelope Compliance Certificate lists the features used in the design and on which the determination of compliance is based.

1.2.1 Source of COM*check* Criteria

The major sources for COM*check* criteria were the 90.1-1989 Code and Standard 90.1-1989. Tables 1.1 and 1.2 & 1.3 correlate code sections with sections in this TSD. A secondary but important source of technical content for COM*check* was the envelope trade-off equations from BSR/ASHRAE/IESNA Standard 90.1-1989R (Standard 90.1-1989R), First Public Review Draft. Section 3.2.1 explains in greater detail the rationale for using these equations.

The mechanical section contains a trade-off of economizer requirements for more efficient equipment. It allows a designer to substitute a high efficiency air-conditioner for an economizer. The basis for this trade-off was analytical work done at PNNL in support of Standard 90.1-1989R. This provision offers additional flexibility in specific climates where equivalent efficiency from the trade-off could be ensured.

The lighting section was substantially simplified from Standard 90.1 using an approach that mirrored work done in the development of California's Title 24 and Standard 90.1-1989R. Manual switching requirements were simplified and whole building types and area categories and power budgets were selected. Because the Standard 90.1-1989R work was still in draft version, the Title 24 categories were chosen for COM*check*. These categories were well defined and were reasonably comprehensive.

Table 1.1. Envelope Requirements

90.1-1989 Code Requirement		
90.1 Section No.	Section Topic	Section Reference in TSD
Envelope Requirements		
402.1	Calculations and Supporting Information	3.2.1
402.2.1	Air Leakage for Fenestration and Doors	3.2.2
402.2.2	Exterior Envelope Joints	3.2.3
402.2.3	Moisture Migration	3.2.4
402.3	Thermal Performance Criteria	3.3
402.3.1	Roof Thermal Performance	3.4.3
402.3.1	Floor Thermal Performance	3.10.3
402.3.1	Wall Adj. to Uncond. Space Thermal Performance	3.7.2
402.3.1	Skylight Thermal Performance	3.5.2
402.3.2	Below-Grade Wall Thermal Performance	3.12.4
402.3.2	Slab-on-Grade Thermal Performance	3.11.2
402.4	Wall Thermal Performance	3.6.5
402.4	Door Thermal Performance	3.9.2
402.4	Window Thermal Performance	3.8.5

Table 1.2. Lighting Requirements

90.1-1989 Code Requirement		COM*check*/*IECC* Requirement	
90.1 Section No.	Section Topic	How Requirement is Addressed	Section Reference in TSD
Lighting Requirements			
401.1.1	Check Metering Provisions	None—no requirement in 90.1	5.4.1
401.1.2	Electrical Schematic	None—included in building code	5.4.2
401.2.1	Motor Efficiency	None--motors covered by '92 EPAct[a] legislation	5.4.3
401.3.1	Building Exteriors	Use permitted lighting source types	5.4.4
401.3.2	Building Interiors	Use COM*check-EZ* software or lighting worksheet	5.1
401.3.3	Lighting Control Credits	None--control credits eliminated	5.1.1
401.3.4.2	Manual Controls	Meet minimum mandatory control requirements	5.4.5
401.3.4.4	Control Accessibility	Provide readily accessible controls	5.4.6
401.3.4.5	Hotel/Motel Guest Rooms	Provide master switch at entry	5.4.7
401.3.4.6	Exterior-Light Switching	Use timer, photoelectric, or 7-day seasonal control	5.4.8
401.3.5.1	Tandem Wiring	Tandem wire 1- and 3-lamp fixtures	5.4.9
401.3.5.2	Power Factor	None	5.4.10

(a) Energy Policy Act of 1992 (EPAct, Public Law 102-486).

1.3 Relationship Between the 90.1-1989 Code and COM*check*

The following tables provide an overview of how the requirements in the 90.1-1989 Code relate to requirements in COM*check*. Tables 1.1 and 1.2 address building envelope, lighting, and service water heating requirements, while Table 1.3 addresses HVAC requirements. The tables also serve as an index to the more detailed explanations found in this TSD.

The organization of Table 1.1 and some conventions used in it are explained below.

1. Column 1 contains section references to the 90.1-1989 Code.
2. Column 2 lists the topics addressed in the 90.1-1989 Code section.
3. Column 3 contains a summary of how the 90.1-1989 Code requirements are addressed in the COM*check* materials. Where entire lines appear shaded, the requirements have been omitted from the COM*check* materials, usually because the requirements are not applicable given the scope of COM*check* or because other factors ensure that the requirements will be met.
4. Column 4 identifies the section numbers in this TSD where the explanations of the technical basis for the change or interpretations of the code requirement begin. Where three dashes (---) appear, the requirement is not addressed further in this documentation because the rationale is self-evident or because the reason is fully explained in column 3.

Table 1.3 is similar to Table 1.1 but adds two new columns containing check boxes, which indicate whether or not the topic is addressed in the *Simple Systems* and/or the *Complex Systems* section of the IECC and COM*check* Version 2.0 Mechanical Guide.

Table 1.3. Relationship Between 90.1-1989 Code HVAC Requirements and COM*check*

90.1-1989 Code Requirement		COM*check/IECC* Requirement	
90.1-1989 Code Section Number	Section Topic	How Requirement is Addressed	Section Reference in TSD
		HVAC Requirements	
403.1	Mechanical Equipment Efficiency	DOE covered equipment must be new. All other equipment must meet efficiencies in tables.	4.1.2
403.2.1	Load Calculations	Per ASHRAE Fundamentals or equivalent.	4.1.4
403.2.2	Equipment and System Sizing	No larger than loads calculated according to 703.2.1 or 703.3.1	4.1.5
403.2.2 Exception 1	Exception for Combination Equipment	Similar to 90.1-1989 Code	---
403.2.2 Exception 2	Standby Equipment	Similar to 90.1-1989 Code	---
403.2.2 Exception 3	Multiple Staged Units	Similar to 90.1-1989 Code	---
403.2.3	Separate Air Distribution	None	4.1.6
403.2.4	Ventilation Fan Power	Capability to operate at minimum ventilation rate required by IMC Chapter 4. Fan control requirements over 25 hp in place of fan power limitations.	4.1.7
403.2.5	Pumping System Design	Combined with 403.2.6.8 – reset requirements. Systems must have reset, staged pumps, variable flow pumps, or throttling control system.	4.1.8
403.2.6.1	System Controls	Provide one temperature control per simple system. Provide one temperature control per complex system zone.	4.1.9
403.2.6.2	Zone Controls	Solid-state programmable per simple system. Automatic temperature and time control per complex system zone.	4.1.10
403.2.6.3	Zone Thermostat Capability	Automatic temperature and time control per complex system zone.	4.1.11
403.2.6.4	Heat Pump Thermostat	Heat pump thermostat required with heat pumps	4.1.12
403.2.6.5	Humidistats	Any system with humidification must have at least one humidity control device.	4.1.13
403.2.6.6	Simultaneous Heating/Cooling	Not allowed in simple systems. Complex systems must use VAV multi-zone systems, or must sequence heating/cooling to every zone	4.1.14
403.2.6.6 Exception 1	Variable Air Volume Systems	Not used – VAV is now required for all multi-zone systems	4.1.7
403.2.6.6 Exception 2	Special Pressurization Relationships	Included	---
403.2.6.6 Exception 3	Reheat from Renewable/Recovered Sources	Included	---
403.2.6.6 Exception 4	Special Humidity Requirements	Included	---
403.2.6.6	Zones $\leq$ 300 cfm	Included	---
none	Minimum Ventilation Required	New exception for zones where air flow is dictated by minimum ventilation requirements.	4.1.7
none	Systems that Sequence Heating and Cooling	Multi-zone systems that sequence supply of heating and cooling to a zone don't need to be VAV	4.1.14
none	VAV Terminal Device Requirements	Specific sequencing requirements for VAV and mixing boxes	4.1.7

Table 1.3. (contd)

90.1-1989 Code Requirement		COM*check*/*IECC* Requirement	
90.1-1989 Code Section Number	Section Topic	How Requirement is Addressed	Section Reference in TSD
403.2.6.7	Temp. Reset – Air Systems	Included	---
403.2.6.8	Temp. Reset – Hydronic Syst.	See 90.1-1989 Code Section 403.2.5	---
403.2.7.1	Automatic Setback/Shutdown	Use setback/setup thermostats for simple systems. Use setback/setup thermostats or automatic control system for complex system zones.	4.1.15
		HVAC Requirements	
403.2.7.2	Shutoff Dampers	Use shutoff dampers systems with >3000 cfm	4.1.16
403.2.7.3	Zone Isolation	None for simple systems—not applicable to single-zone systems. Complex systems must have zone level automatic controls.	4.1.17
403.2.8	Economizer Controls	Integrated air economizers required >90 kBtu/h or 3000 cfm except in Zones 1, 2 and 3b	4.1.19
403.2.8	Water Economizer	Allowed in place of air economizer on all complex systems. Required on three-duct systems and single-fan dual-duct systems.	4.2.18
none	Exception for High Efficiency Package Direct Expansion Cooling	Minimum efficiency varies by capacity and climate zone	4.1.3
403.2.8 Exception 1	Exception for Small, Fan-Cooling Systems	Included in main code language instead of exception	4.1.18
403.2.8 Exception 2	Exception for Systems Requiring Extensive Filtration	Included, references Section 403.3 of International Mechanical Code	4.1.18
403.2.8 Exception 3	Exception for Systems Where Economizer Would Increase Energy Use	Included, only allowed for open case refrigeration	4.1.18
403.2.8 Exception 4	Exception for Envelope- Dominated Spaces	Not included – Requires previous knowledge of the use of the space, which is only required to be submitted for ECB compliance	---
403.2.8 Exception 5	Exception for Residential Spaces and Hotel Rooms	Not included – 90,000 Btu/h is usually adequate for these spaces	---
403.2.8 Exception 6	Exception for Cooling from Site-Recovered Energy	Not included – application is rare	---
403.2.8 Exception 7	Exception for Operable Openings	Not included	---
403.2.9.1	Pipe Insulation	Table simplified to six entries with minimum k of 0.27	4.1.20
403.2.9.2	Duct/Plenum Insulation	Insulate ducts and plenums	4.1.21
403.2.9.3	Duct/Plenum Construction	Meet IMC	4.1.22
403.2.10	Administration	Standard 90.1-1989R manual requirements, hydronic and air balancing provisions	4.1.23
		Service Water-Heating (SWH) Requirements	
404.1	SWH Equipment Efficiency	Available new equipment meets requirements	4.2.1
404.1.1	Electric/Oil Standby Loss	Meet standby loss criteria	4.2.2
404.1.2	Unfired Storage Tanks	Meet standby loss criteria	4.2.3
404.1.3	Storage Volume	Meet standby loss criteria	4.2.4
404.2	Piping Insulation	Piping insulation and heat traps required	4.2.5
404.3	Controls	Controls integrated within available products	4.2.6
404.4	Water Conservation	Hot water per NAECA[(a)] plus public lavatory requirements	4.2.7
404.5	Swimming Pools	Switching and pool cover requirements	4.2.8
404.6	Combined Heating Systems	Combined SWH/space htg. equip. out of scope	4.2.9

(a) National Appliance Energy Conservation Act of 1987 (NAECA, Public Law 100-12)

1.4 Facilitating the Implementation of Commercial Building Energy Codes

This section provides an overview of the context that motivated the creation of the COM*check* compliance materials (and subsequent adoption of Chapter 7 of the 1998 IECC). Chapter 1 of the IECC (formerly the Model Energy Code [MEC]) was amended with the 1998 edition to authorize use of computer software—such as the COM*check* software (and other similar compliance materials if approved by the building official)—as meeting the intent of the IECC.

The goal of commercial building energy codes is to ensure the design and construction of more energy-efficient buildings. Within current commercial energy codes, this goal is implemented through minimum requirements for building envelope, mechanical, plumbing, electrical, and lighting systems and equipment. If these minimum requirements cannot be readily understood and acted upon by code users, the code requirements cannot be successfully implemented.

Most current commercial building energy codes are based on Standard 90.1-1989, the 90.1-1989 Code, or Standard 90.1-1999. To comply, architects, engineers, and other designers must first read and interpret the applicable code and then decide how to apply the requirements to their clients' needs and relevant plans and specifications. Those who construct buildings must also be able to understand the code requirements to ensure energy savings from the new building. Legislative and regulatory affairs personnel must be able to satisfy the concerns of interested and affected parties to adopt an energy code. Code enforcement personnel, lenders, utility company personnel and building owners interested in code compliance must be able to understand the code requirements. While each of these parties has a different function in creating a new building, they all need to easily understand what is required by the code.

Building, mechanical, plumbing, electrical, accessibility, and fire code requirements also vie for limited resources. Compared to health and life safety, energy is not considered a critical code issue and is generally given a lower priority. Complexity and low priority generally result in marginally effective implementation. Implementation has not been a particular problem for those voluntarily striving to achieve energy efficiency, and a minority of practitioners exist who are highly motivated and well equipped to go far beyond the efficiency levels required by the code. However, most practitioners follow minimum codes for health and life safety and are hard pressed to find time to address energy issues, especially when the code is perceived as unduly complicated or their clients are not interested in the cost of operating the building. Simple guidelines and tools that address the common plea—"just tell me what you want me to do so I can get approval of the design"—help facilitate the use of energy codes, and in so doing, enhance implementation even when energy efficiency remains a low priority. COM*check* is intended to provide these simple guidelines and tools.

The COM*check* materials help various users implement the energy code requirements and achieve the goal of more energy-efficient buildings in a number of different ways.

Architects are keenly interested in the size, shape, function, and aesthetics of a building design. 90.1 provides numerous requirements for building envelope components based on climate, internal loads, shading, and other factors. Architects can use the COM*check* software, which is both more flexible and easier to use than alternative methods, to more easily integrate energy code considerations into the multifaceted design process. The software also standardizes and streamlines the process by which energy feature specification and supporting compliance documentation is generated for those who will review the plans, order materials, construct the building, and inspect construction.

Designers or Builders may perform various design-related activities for small commercial buildings where a licensed design professional is not required. Designers and builders can use COM*check* to quickly determine energy code requirements, acceptable strategies to meet these requirements, and materials to order. During construction, when field substitutions are frequently necessary because of material availability or cost considerations, COM*check* allows a quick assessment of the acceptability of different materials or components such as an alternate insulation material or glazing type.

Engineers must design HVAC, plumbing, electrical, and lighting systems to comply with a wide range of different requirements in addition to energy code requirements. COM*check* allows engineers to quickly determine pertinent code requirements and to readily select complying equipment and system components.

Manufacturers use minimum code requirements as the basis for some of their products and for comparing their products to others to promote better-performing products. Standardization of codes, code interpretations, and compliance materials is helpful to manufacturers in reducing the fragmentation of markets and simplifying product selection. COM*check* can help manufacturers identify minimum requirements to help develop minimally compliant products and strategies for highlighting the benefits of those products.

Distributors can use minimum code requirements as a basis for determining the materials, systems, and equipment they should stock. Distributors also provide code guidance to builders and contractors as part of their marketing initiatives and product selection support. By making it easier to prescriptively determine which materials and products will meet or exceed the code requirements, COM*check* helps distributors get new business and ensure they carry the products necessary for energy code compliance.

Building Owners and Lenders are interested in their investment but may not readily comprehend the importance of energy efficiency or be capable of assessing the energy attributes of proposed designs. By making energy code compliance easier to understand, COM*check* can increase the awareness of financial institutions regarding their stake in cost-effective energy efficiency and facilitate the participation of lenders in decisions affecting the design and construction of energy-efficient buildings.

Code Adopters (e.g., regulatory agencies and legislative staff) face conflicting mandates to encourage higher levels of building energy efficiency and to respond to the needs of their constituents and interested and affected parties. For example, one of the most commonly cited reasons for not adopting the Standard 90.1 has been complexity. By stating the requirements in a simpler manner and providing a clear path for effective implementation, COM*check* may make it easier for state and local jurisdictions to adopt commercial building energy codes based on 90.1-1989 code.

Code Enforcement Officials typically have too little time to adequately address energy issues either during plan review or construction inspections. The perceived complexity of the codes and standards and the time required to check calculations and conduct effective design review are key reasons why some codes have not been overwhelmingly implemented. Without guidance from the plan review process, field inspection activities cannot address energy issues. Even when inspectors are highly motivated, the complexity of the codes and lack of compliance materials oriented toward inspection make it difficult to conduct any type of compliance assessment in the field. The COM*check* materials have been developed with code enforcement officials as a primary audience. The compliance certificates and requirements checklists focus on areas where effective code enforcement can make a real difference in achieving energy-efficient buildings.

2.0 Building Use Types

2.1 Combined Building Use Types

In COM*check*, internal loads and lighting power allowances are based on the user's designation of the building use. COM*check* Version 1.0 required separate designations of building use to establish internal gains for envelope compliance and to determine the lighting power allowance for lighting compliance. In COM*check* Version 2.0, building use types are entered once, rather than separately for envelope and lighting. Users may enter building use types as either whole building types or area categories.

To enable users to enter building use types in one step, it was necessary to associate all occupancy-related descriptors (e.g., receptacle loads and occupancy densities) with the same building use types as are used for lighting and to add minor extensions to cover uses that are exempt from lighting power density (LPD) requirements, such as multifamily residential living units. Three of the whole building types, Assembly, Hotel/Motel, and Multifamily, do not correspond to whole building lighting categories. These whole building types cannot be used for lighting compliance, either because the whole building type contains too much variability (Assembly) or because the predominant spaces are exempt from lighting power budgets (Hotel/Motel and Multifamily). If lighting compliance is required for these whole building types, the Area Category method must be used.

2.2 Source of Building Use Types

Like the 90.1-1989 Code, Standard 90.1-1989, and Standard 90.1-1999, COM*check* and the IECC use a two-tiered approach for controlling lighting power based on whole building types or area categories. The COM*check* building use types were chosen as representative of common building types for which the COM*check* compliance method would likely be used. The lighting building use types were adapted from the California Code of Regulations (CCR 1995). These categories originally took effect in July 1992 and had extensive testing and review by designers and code officials throughout the state of California. The results of the testing and review show that these categories accurately reflect a substantial cross section of building uses and are appropriate for use in determining allowed lighting power levels.

The 2000 IECC uses the same whole building types and area categories as the 90.1-1989 Code, except two new whole buildings types and three new area categories were added. These were later also added to the 90.1-1989 Code version of COM*check* to make it comprehensive and consistent with the 2000 IECC:

- Whole Building Types
  - Museum
  - Religious worship
- Area Categories
  - Gymnasium playing surface
  - Museum
  - Restaurant

2.3 Internal Loads

Tables 2.1 and 2.2 contain the internal-load assumptions that are used by the envelope engine in the calculation of heating and cooling loads for walls and windows in the software. Table 2.1 contains the data for whole building types, and Table 2.2 contains the data used for area category. Lighting budgets are based on the lighting power density for the designated building use type and are independent of values for the proposed design.

The equipment values in Table 2.1 were derived from Table 8-4 in Standard 90.1-1989, wherever Table 8-4 provided a good correspondence with the building use types. For building use types that did not align well with those in Table 8-4, values were drawn from the *ECB Compliance Supplement* to Standard 90.1-1989R, Table 7.1 (ASHRAE 1996). Occupant-sensible loads were based on occupant density assumptions from Table 13-2 in Standard 90.1-1989 and Table 7.1 in the *ECB Compliance Supplement*. The occupant-sensible load assumption was 230 Btu/person-h. A 0.6 W/ft^2 value for occupant loads is embedded in the calculation, as is documented in Standard 90.1-1989, Section 8.5.5.2. The *Total* columns in Tables 2.1 and 2.2 show the total internal-load value, and not the adjusted value used in the calculation after subtraction of the 0.6 W/ft^2 average-occupancy value.

The impact of fixing internal loads at an average value for all commercial building types was evaluated. That option was rejected for the COM*check* software because it would have significantly undermined stringency for high-internal-load buildings and increased stringency for low-internal-load buildings. In the COM*check* prescriptive packages, it was necessary to fix internal loads at a single level to limit the number of requirement sets. The values in bold in the bottom line of Table 2.1 are for use in generating values for the COM*check* prescriptive packages (except for the low window-to-wall ratio category used extensively with warehouse). The values represent an average shaded toward the high side to maintain stringency.

2.4 Lighting Power Budgets

Lighting power budgets (also referred to as lighting power allowances) are derived from the lighting power density (LPD) values corresponding to each whole building type and area category in COM*check*. The *Data Source* columns in Tables 2.1 and 2.2 document how the LPDs in COM*check* were derived from Table 401.3.2 in the 90.1-1989 Code. Whole building type LPDs were derived under the assumption of buildings with gross lighted areas of 10,000 to 25,000 ft^2, reflecting the types of buildings for which the COM*check* materials were initially targeted. ASHRAE's Standing Standard Project Committee (SSPC) Standard 90.1 has abandoned the approach of basing power allowances on building size, and there does not appear to be a problem with applying these LPDs to buildings of any size.

One notable departure in scope from the lighting power budget requirements in the 90.1-1989 Code involves hotel guest rooms. Under the area category compliance method in the 90.1-1989 Code, hotel guest rooms are included as a specific area category. In COM*check* and the IECC, the category has been omitted for lighting compliance. The rationale for this is that the vast majority of lighting in hotel guest rooms is powered through receptacles and is not built in. Therefore, most lighting does not show up on building plans and specifications and is not subject to inspection. Because the LPD for hotel guest rooms clearly anticipates receptacle-based lighting equipment that is outside the scope of the building code, including guest room lighting in the calculation of lighting power budgets has the effect of inflating the lighting power budget. To address this problem, we chose to exempt hotel guest room lighting. Similar reasoning led the SSPC 90.1 to exempt lighting in multifamily dwelling units in the 90.1-1989 Code.

Table 2.1. Whole Building Type Internal Loads

Whole Building Type	Lighting (W/ft^2)	Equip. (W/ft^2)	Occup. (W/ft^2)	Total[(a)] (W/ft^2)	Data Source for Lighting LPD
Assembly	2.07[(c)]	0.25	1.35	3.67	
Exercise Center	0.90	0.25	0.22	1.37	This value was generated using space usage percentages for two different exercise centers and the corresponding activity area power allowances found in Table 401.3.2 in the 90.1-1989 Code.
Grocery Store	2.80	0.25	0.22	3.27	Unit Interior Lighting Power Allowance table, Specific Building Area/Activity section, Retail establishments – Type 5 (Table 401.3.2c in the 90.1-1989 Code)
Hotel/Motel	1.15[(c)]	0.25	0.27	1.67	
Library	1.30	0.75	0.25	2.30	This value was generated using space usage percentages for two different libraries and the corresponding activity area power allowances found in Table 401.3.2 in the 90.1-1989 Code.
Medical and Clinical Care	1.80	1.00	0.34	3.14	Unit Interior Lighting Power Allowance table, Specific Building Area/Activity, Hospital/Nursing Home (Table 401.3.2c in the 90.1-1989 Code) Equal weighting to the following categories: Corridor 1.3 Dental Suite/Examination/Treatment 1.6 Emergency 2.3 Laboratory 1.9 Lounge/Waiting Room 0.9 Medical Supplies 2.4 Nurse Station 2.1 Occupational Therapy/Physical Therapy 1.6 Pharmacy 1.7 Radiology 2.1 Surgical and OB Suites: General Area 2.1 Surgical and OB Suites: Recovery 2.3 Average = 1.858
Multifamily	1.15[(c)]	0.25	0.27	1.67	
Museum	1.7	0.25	1.35	3.30	Added for consistency with the 2000 IECC; (internal gains assumed to be same as Assembly and Theaters).
Office	1.70	0.75	0.25	2.70	Interior Lighting Power Allowance table, Office Type 10 to 25 thousand square foot value (Table 401.3.2a in the 90.1-1989 Code)
Restaurant	1.70	0.10	0.67	2.47	Interior Lighting Power Allowance table, Food Service: Leisure Dining/Bar 10 to 25 thousand square foot value (Table 401.3.2a in the 90.1-1989 Code)
Retails Sales, Wholesale Showrooms	2.80	0.25	0.22	3.27	Interior Lighting Power Allowance table, Retail Type 10 to 25 thousand square foot value (Table 401.3.2a in the 90.1-1989 Code)
Religious Worship	2.2	0.10	1.35	3.65	Added for consistency with the 2000 IECC.
School	1.90	0.50	0.90	3.30	Interior Lighting Power Allowance table, Schools Type 10 to 25 thousand square foot range, Jr. High/High School - middle value (Table 401.3.2a in the 90.1-1989 Code)
Industrial and Commercial Storage	0.60	0.10	0.00	0.70	Interior Lighting Power Allowance table, Warehouse/Storage 10 to 25 thousand square foot value (Table 401.3.2a in the 90.1-1989 Code)
Theater – Motion Picture	1.10	0.25	1.35	2.70	This value was generated using space usage %ages for four different motion picture theaters and the corresponding activity area power allowances found in Table 401.3.2 in the 90.1-1989 Code.
Theater – Performance	1.40	0.25	1.35	3.00	This value was generated using space usage %ages for four different performing arts theaters and the corresponding activity area power allowances found in Table 401.3.2 in the 90.1-1989 Code.

Table 2.1. (contd.)

Whole Building Type	Lighting (W/ft^2)	Equip. (W/ft^2)	Occup. (W/ft^2)	Total[(a)] (W/ft^2)	Data Source for Lighting LPD
Others	0.60/ 1.60[(b)]	0.40	0.60	2.60[b]	The value of 0.6 was taken from the '97 California Title 24, Table 1-M for space type Others. The Unlisted Space category value of 0.2 (Table 401.3.2b) in the 90.1-1989 Code was judged to be so limiting that it would preclude use of the condensed list of space usage types in COM*check* by many users. The 0.6 value was judged to be more reasonable than 0.2, and its use was felt to be warranted in the interest of making the materials easy to use.
Average (for print version)	1.60	0.40	0.60	2.60	

(a) The total is the sum of lighting, equipment, and occupants. The ENVSTD input is reduced by 0.6 W/ft^2, to adjust for the assumed 0.6 W/ft^2 average occupant load (Crawley et al. 1989).
(b) The Others whole building type uses 0.6 W/ft^2 for lighting compliance, but 1.6 W/ft^2 for envelope compliance.
(c) Assembly, Hotel/Motel, and Multifamily whole building types are provided for envelope compliance only.

Table 2.2. Area Category Internal Loads

Area Category	Lighting (W/ft^2)	Equip. (W/ft^2)	Occup. (W/ft^2)	Total[(a)] (W/ft^2)	Data Source for Lighting LPD
Auditorium	1.60	0.25	1.35	3.20	Unit Interior Lighting Power Allowance table, Common Area/Activity section, Auditorium (Table 401.3.2b in the 90.1-1989 Code)
Bank/Financial Institution	2.00	0.75	0.25	3.00	Unit Interior Lighting Power Allowance table, Specific Building Area/Activity section, Bank, equally-weighted combination of Customer Area (1.1) and Banking Activity Area (2.8) (Table 401.3.2c in the 90.1-1989 Code)
Classroom/Lecture Hall	2.00	0.50	0.90	3.40	Unit Interior Lighting Power Allowance table, Common Area/Activity section, Classroom/Lecture Hall (Table 401.3.2b in the 90.1-1989 Code)
Convention, Conference or Meeting Center	1.80	0.25	1.35	3.40	Unit Interior Lighting Power Allowance table, Common Area/Activity section, Common Activity Areas, Conference/Meeting (Table 401.3.2b in the 90.1-1989 Code)
Corridor, Restroom, Support Area	0.80	0.10	0.11	1.01	Unit Interior Lighting Power Allowance table, Common Area/Activity section, Corridor and Toilet and Washroom (Table 401.3.2b in the 90.1-1989 Code)
Dining	2.50	0.10	0.67	3.27	Unit Interior Lighting Power Allowance table, Common Area/Activity section, Leisure Dining (Table 401.3.2b in the 90.1-1989 Code)
Exercise Center	1.00	0.25	0.22	1.47	Version 1.1 New Category. Unit Interior Lighting Power Allowance table, Indoor Athletic Area/Activity, Gymnasium, General Exercising and Recreation Only (Table 401.3.2d in the 90.1-1989 Code)
Exhibition Hall	2.60	0.25	1.35	4.20	Unit Interior Lighting Power Allowance table, Specific Building Area/Activity section, Hotel/Conference Center, Exhibition Hall (Table 401.3.2c in the 90.1-1989 Code)
Grocery Store	2.80	0.25	0.22	3.27	Unit Interior Lighting Power Allowance table, Specific Building Area/Activity section, Retail establishments - Type 5 (Table 401.3.2c in the 90.1-1989 Code)
Gymnasium Playing Surface	1.5	0.10	1.35	2.95	Added for consistency with IECC 2000
Hotel Function	2.40	0.25	0.27	2.92	Unit Interior Lighting Power Allowance table, Specific Building Area/Activity section, Hotel/Conference Center, Banquet Room/Multipurpose (Table 401.3.2c in the 90.1-1989 Code)
Hotel/Motel Guest Room	1.40[(c)]	0.25	0.27	1.92	

Table 2.2. (contd)

Area Category	Lighting (W/ft^2)	Equip. (W/ft^2)	Occup. (W/ft^2)	Total[a] (W/ft^2)	Data Source for Lighting LPD
Industrial Work, General	1.60	1.00	0.22	2.82	Unit Interior Lighting Power Allowance table, Common Area/Activity section, Shop, Painting (Table 401.3.2b in the 90.1-1989 Code)
Industrial Work, Precision	2.50	1.00	0.22	3.72	Unit Interior Lighting Power Allowance table, Common Area/Activity section, Shop, Machinery (Table 401.3.2b in the 90.1-1989 Code)
Kitchen	1.40	1.00	0.34	2.74	Unit Interior Lighting Power Allowance table, Common Area/Activity section, Food Service - Kitchen (Table 401.3.2b in the 90.1-1989 Code)
Library	1.50	0.75	0.25	2.50	Version 1.1 New Category. Unit Interior Lighting Power Allowance table, Common Area/Activity, Library, Stack Area (Table 401.3.2b in the 90.1-1989 Code)
Lobby – Hotel	1.90	0.25	0.27	2.42	Unit Interior Lighting Power Allowance table, Specific Building Area/Activity section, Hotel/Conference Center, Lobby (Table 401.3.2c in the 90.1-1989 Code)
Lobby – Other	1.00	0.25	0.27	1.52	Unit Interior Lighting Power Allowance table, Common Area/Activity section, Lobby, Reception and Waiting (Table 401.3.2b in the 90.1-1989 Code)
Mall, Arcade, or Atrium	1.40	0.10	0.34	1.84	Unit Interior Lighting Power Allowance table, Specific Building Area/ Activity section, Mall Concourse (Table 401.3.2c in the 90.1-1989 Code)
Medical and Clinical Care	1.80	1.00	0.34	3.14	Unit Interior Lighting Power Allowance table, Specific Building Area/Activity, Hospital/Nursing Home (Table 401.3.2c in the 90.1-1989 Code) Equal weighting to the following categories: Corridor 1.3 Dental Suite/Examination/Treatment 1.6 Emergency 2.3 Laboratory 1.9 Lounge/Waiting Room 0.9 Medical Supplies 2.4 Nurse Station 2.1 Occupational Therapy/Physical Therapy 1.6 Pharmacy 1.7 Radiology 2.1 Surgical and OB Suites: General Area 2.1 Surgical and OB Suites: Recovery 2.3 Average = 1.858
Museum	1.7	0.25	1.35	3.30	Added for consistency with IECC 2000
Multifamily Living Units	1.10[c]	0.75	0.27	2.12	
Office	1.80	0.75	0.25	2.80	Unit Interior Lighting Power Allowance table, Common Area/Activity section, Office Category 1, Reading, Typing, and Filing (Table 401.3.2b in the 90.1-1989 Code)
Religious Worship	2.50	0.10	1.35	3.95	Unit Interior Lighting Power Allowance table, Specific Building Area/Activity section, Church, Synagogue, Chapel, Worship/Congregational (Table 401.3.2c in the 90.1-1989 Code)
Retail Sales, Wholesale Showroom	3.10	0.25	0.22	3.57	Unit Interior Lighting Power Allowance table, Specific Building Area/Activity section, Retail establishments - Type 4 (Table 401.3.2c in the 90.1-1989 Code)
Restaurant	1.7	0.50	0.27	2.47	Added for consistency with IECC 2000
Storage, Industrial and Commercial	1.00	0.10	0.00	1.10	Unit Interior Lighting Power Allowance table, Common Area/Activity section, Storage and Warehouse, Active Storage, Fine (Table 401.3.2b in the 90.1-1989 Code)
Theater - Motion Picture	1.00	0.25	1.35	2.60	Unit Interior Lighting Power Allowance table, Specific Building Area/Activity section, Theater, Motion Picture (Table 401.3.2c in the 90.1-1989 Code)

Table 2.2. (contd)

Area Category	Lighting (W/ft^2)	Equip. (W/ft^2)	Occup. (W/ft^2)	Total[a] (W/ft^2)	Data Source for Lighting LPD
Theater – Performance	1.50	0.25	1.35	3.10	Unit Interior Lighting Power Allowance table, Specific Building Area/Activity section, Theater, Performance Arts (Table 401.3.2c in the 90.1-1989 Code)
Others	0.60/ 1.60[b]	0.40	0.60	1.60/ 2.60[b]	Unit Interior Lighting Power Allowance table, Common Area/Activity section, Garage, Auto, and Pedestrian Circulation Area (Table 401.3.2b in the 90.1-1989 Code). The value of 0.6 was taken from the ’97 California Title 24, Table 1-M for space type Others. The Unlisted Space category value of 0.2 (Table 401.3.2b) in the 90.1-1989 Code was judged to be so limiting that it would preclude use of the condensed list of space usage types in COM*check* by many users. The 0.6 value was judged to be more reasonable than 0.2, and it use was felt to be warranted in the interest of making the materials easy to use.

(a) The total is the sum of lighting, equipment, and occupants. The ENVSTD input is reduced by 0.6 W/ft^2, to adjust for the assumed 0.6 W/ft^2 average occupant load (Crawley et al. 1989).

(b) The Others area category uses 0.6 W/ft^2 for lighting compliance, but 1.6 W/ft^2 for envelope compliance.

(c) Hotel/Motel Guest Room and Multifamily Living Units area categories are exempt from lighting power density requirements, but are included in this list for internal load density used in envelope compliance calculations.

3.0 Envelope Documentation

3.1 Envelope Trade-off Calculations

The envelope trade-off calculations for opaque above-grade walls and windows in COM*check* are based on the system performance method in Standard 90.1-1989 (Attachment 8B). Like the ENVSTD program used to show compliance with the envelope requirements of Standard 90.1-1989 (Crawley et al. 1989), the COM*check* envelope trade-off calculations are based on envelope loads only: no provisions exist for trade-offs with other building systems such as HVAC or lighting. The envelope trade-offs in COM*check* simply add load components to the wall and window loads calculated as in ENVSTD. Like ENVSTD, the COM*check* program works by defining both a *proposed* design and a *budget* design and comparing the calculated loads. The proposed version is based on user input, while the budget version is based on minimum prescriptive requirements and the modeling rules detailed in Attachment 8B of Standard 90.1-1989.

The rationale for incorporating the additional component trade-offs in COM*check* is that Standard 90.1-1989 Section 13, *Building Energy Cost Budget (ECB) Method*, sanctions the use of alternative compliance methods provided they ensure equivalent energy efficiency. Enhancing design flexibility is generally understood to be desirable because it frequently allows the intent of the code to be achieved at a lower construction cost and generally reduces unnecessary constraints on building design. In fact, the initial technical work from which Standard 90.1-1989 was developed contained a roof trade-off, but the trade-off was not implemented for reasons of complexity (Jones 1983).

To establish an adequate technical basis for the additional trade-offs to be included in COM*check*, a range of available calculation methods were evaluated. A controlling criterion that served to rapidly narrow the range of options was that of rapid execution. There was a clear consensus that automatic re-execution of the trade-off calculations every time the user makes a change to the proposed design and near instantaneous (i.e., under one second) execution of the calculation was essential if the program was to receive widespread acceptance. This criterion restricted the calculation method to a simplified technique, such as a degree-day or temperature bin method, and precluded using any kind of hourly simulation. After reviewing the advantages and disadvantages of available methods, we chose to use the work of ASHRAE SSPC 90.1 as documented in Standard 90.1-1989R, the first public review draft of the proposed revisions to Standard 90.1-1989, which was made publicly available in the spring of 1996. The specific part of Standard 90.1-1989R containing documentation of the envelope calculation procedures is Appendix C, *Building Envelope Trade-Off Option*.

There were numerous reasons for selecting Standard 90.1-1989R as the primary source document for the additional trade-offs. The calculation method contains all trade-off components we were interested in including, met our execution time criterion, was generally regarded as technically solid, was deemed likely to have credibility with the intended users of COM*check*, had been implemented in available software thereby facilitating validation of our own software, was developed by some of the same individuals who had developed the original ENVSTD model with which integration was required, was readily available without royalty considerations, was documented in printed materials, and direct access to technical support was available. For these reasons, using the Standard 90.1-1989R trade-off methodology was judged to be clearly appropriate for the COM*check* trade-offs.

However, it is important to note that the rationale for using the Standard 90.1-1989R trade-offs was NOT that materials in proposed revisions to Standard 90.1-1989 are necessarily appropriate for use with materials that implement the current 90.1-1989 Code. Decisions relative to using work from Standard 90.1-1989R were based on technical criteria and practical considerations related to successfully achieving the objectives of creating easy-to-use compliance materials.

3.1.1 Load Calculation Assumptions

The cooling and heating loads for components are calculated based on the COOL and HEAT equations provided in the 90.1-1989R Appendix-C, Equation 6.21. COOL and HEAT are expressed in terms of $/year, and this is converted to Btu/year by using equipment efficiencies and eliminating the cost multiplier. The conversion was performed using the following process:

For cooling load calculations:

1. multiply the cooling coefficient (CCoef) by the SEER (12.24)
2. multiply COOL by 1000 W/kW.

For heating load calculations:

1. multiply the heating coefficient (HCoef) by the AFUE (0.608488)
2. multiply HEAT by 100000 Btu/therm.

The details of cooling and heating coefficients calculations are documented for each envelope component separately in Sections 3.4 to 3.12.

3.1.2 Requirements for Locations with Greater than 15,000 HDD65

Standard 90.1-1989 contains envelope requirements for locations with > 15,000 heating degree days. COM*check* completely ignores all requirements in these locations because there are virtually no populated locations within the United States meeting this criterion. For example, of the 14 Alaska locations listed among the 234 TMY sites in Standard 90.1-1989, none meet this criterion. We expect this simplification to have no practical impact.

3.1.3 Space Conditioning

The envelope requirements tables in Appendix A of the 90.1-1989 Code are based on the assumption that the building is both heated and cooled. Appendix A requirements apply equally to buildings that are both heated and cooled and buildings that are heated only or cooled only. ENVSTD permits the user to specify whether the building is heated only, cooled only, or both heated and cooled, and the compliance calculations are adjusted according to the user’s selection. COM*check* employs the same approach as is used in Appendix A of the 90.1-1989 Code and assumes that all buildings are both heated and cooled. The rationale for this decision is that it appears to be a generally conservative assumption that leads to greater consistency of requirements and fewer opportunities for users to manipulate compliance.

Standard 90.1-1989 permits heating and cooling loads to be traded off against each other. The criteria underlying the standard were developed with a building that was both heated and cooled. Most new buildings in the United States are both heated and cooled. Buildings that are specified as heated only may later have cooling added. Even if mechanical cooling is not present, steps that minimize cooling loads are likely to increase the value of the building and the productivity of occupants. Finally, requiring that a building comply only on the basis of heating or cooling loads can, in some cases, significantly increase the stringency of the envelope requirements. Rather than add a seldom-used factor expected to produce requirements that are inconsistent with printed materials and often counter-intuitive in their impact, COM*check* was simplified by not providing these options.

The heated only and cooled only option should not be confused with the issue of semi-heated space types, such as warehouses. Standard 90.1 employs a simplified loads model that assumes normal occupied space temperatures and has no means for varying requirements based on partially-conditioned spaces. This would appear to subject partially-conditioned spaces to much more stringent envelope requirements than warranted. Warehouses—the largest partially-conditioned category—are compared against criteria based on typical office building window areas. Because warehouses usually have few if any windows, stringency is greatly reduced. Within the context of the 90.1-1989 Code, there does not appear to be an easy solution to the shortcomings in the treatment of semi-conditioned spaces, nor is it clear this creates a serious problem.

3.1.4 Internal-Loads

While ENVSTD requires that the user provide numerical inputs for equipment and lighting power (i.e., watts per square foot) and adjust this value for unusual occupancy levels, COM*check* requires only that the user specify one or more whole building types or area categories from a list. These building use types are to determine equipment and lighting power. See Section 2.0 for more information.

3.2 Mandatory Requirements

The following sections describe mandatory requirements that are listed in COM*check*. References to the specific pertinent 90.1-1989 Code sections are shown in parentheses in the section headings below.

3.2.1 Calculations and Supporting Information (402.1)

Section 402.1 addresses 1) data sources used in envelope calculations, 2) calculation procedures governing thermal transmittance calculations, and 3) requirements for how component areas are calculated.

1. In developing COM*check*, we used what we judged to be the best available data sources and have documented the data sources used. Additional data sources beyond those explicitly referenced in the 90.1-1989 Code have been used.
2. A major objective for the COM*check* materials was to eliminate the need for calculation by users. Thus, the results of the calculation methods required in Section 402.1 of the 90.1-1989 Code are embedded in the COM*check* materials. The calculations used to develop COM*check* component library values and convert user R-value inputs into overall thermal transmittance of assemblies are documented in Section 3.4. COM*check* eliminates the need for end-users to perform these calculations, except when the *Other* assembly categories are used.

3. COM*check* software help messages instruct users on area calculations consistent with Section 402.1.3 of the 90.1-1989 Code.

3.2.2 Air Leakage for Fenestration and Doors (402.2.1)

COM*check* specifies maximum leakage rates for manufacturers and directs the user to products certified by an accredited laboratory such as the National Wood Window and Door Association (NWWDA) or the Architectural Aluminum Manufacturers Association (AAMA). A reformatted table based on data in the 90.1-1989 Code Table 402.2.1 is provided in Table 3.1. The COM*check* table leaves out the reference standards, products for residential and heavy commercial applications, and lower leakage requirements for fixed-aluminum windows.

Table 3.1. Maximum Allowed Air Leakage Rates

	Frame Types		
	Wood	Aluminum	PVC
Windows (cfm per ft of operable sash crack)	0.25	0.37	0.06
Sliding Doors (cfm per sq ft of door area)	N/A	0.37	0.37
Swinging Doors (cfm per sq ft of door area)	0.25	1.25	N/A

3.2.3 Exterior Envelope Joints (402.2.2)

COM*check* contains a detailed list of envelope penetrations that must be sealed in place instead of the more generally stated requirement in the 90.1-1989 Code.

3.2.4 Moisture Migration (402.2.3)

COM*check* translates the general requirement for designing to limit moisture migration to specific requirements for vapor retarders in specific locations. This translation is based on work previously done for MEC*check* (now RES*check*), and its derivation is documented in the *Methodology for Developing the REScheck™ Software through Version 3.6.*

The requirement for vapor retarders includes an exception that removes the vapor retarder requirement in specific climate zones in specific states. The locations qualifying for the exception are as follows in Table 3.2.

Table 3.2. States with Vapor Retarder Exception

States	Zones
Texas	Zones 2-5
Alabama, Georgia, North Carolina	Zones 4-6
Oklahoma, South Carolina	Zones 4-6
Arkansas, Tennessee	Zones 6-7
Florida, Hawaii, Louisiana, Mississippi	All Zones

This requirement is based on the 90.1-1989 Code (402.2.3 Moisture Migration) and Standard 90.1-1989, which contain only general statements about designing to eliminate “moisture migration that leads to deterioration in insulation performance.” Standard 90.1-1989 (8.4.5.3 Moisture Migration Requirements for Exterior Envelopes) includes a reference to ASHRAE Fundamentals. While both current research on moisture migration and these requirements are subject to varying interpretations on the appropriate use of vapor barriers, the COM*check* requirement appears to be an appropriate and technically accurate interpretation of the Standard 90.1-1989 intent and consistent with the residential vapor barrier requirements.

3.3 Assumptions in Developing Envelope Assemblies

One of the goals of COM*check* was to provide users true prescriptive envelope requirements expressed in terms of R-values rather than overall assembly U-factors. Standard 90.1 typically provides opaque envelope requirements as assembly U-factors and then specifies calculation procedures and correction factors to be used with these assembly U-factors in calculating the required amount of insulation. COM*check* uses the calculation procedures and correction factors found in Standard 90.1 and precalculates required insulation R-values for common assembly types.

The key to this process is identifying typical assemblies. While the correction factors and calculation procedures are taken directly from Standard 90.1, typical assemblies are not specified. For COM*check*, a series of assemblies used in the development of Standard 90.1-1989R were used. These assemblies are conservative in that material thicknesses were assumed to be as minimal as possible. For example, for wood-frame walls, the wall assembly is assumed to include 5/8-in. gypsum board on the inside of the cavity and stucco over the outside of the cavity. No additional R-value is assumed for exterior sheathing in the calculations. Interior and exterior air films are also included in the calculations. Similarly, a minimal roof system might be a metal deck with no ceiling and with insulation placed directly on top of the deck.

The basic assemblies described in the following sections were taken from Standard 90.1-1989R. Extensive discussion of these assemblies can be found in *Code Compliance Considerations in the Development of the Building Envelope Requirements for ASHRAE/IESNA Standard 90.1-1989R* (Hogan 1995). For COM*check,* the resulting U-factors were converted to a series of equations describing overall assembly U-factors as a function of installed cavity insulation R-value, installed continuous insulation R-value, and the balance of the assembly (BOA). BOA refers to the R-value of the assembly excluding any cavity or continuous insulation. Cavity insulation is defined as insulation subject to thermal bridging from framing or furring members. Continuous insulation is defined as insulation that is continuous across framing or furring members and not subject to thermal bridging. The BOA includes all non-insulation elements of the assembly that contribute to its overall U-factor such as air films, gypsum board, sheathing, and carpets and pads (for floors). Associated with the cavity insulation is an effectiveness factor that reduces the installed R-value of the cavity insulation to an “effective” R-value for cavity insulation. In some cases, the equations used in COM*check* have a constant value for this effectiveness factor, and in others the effectiveness factor is a function of the cavity insulation R-value. Continuous insulation is assumed to have an effectiveness factor of 1.

3.4 Roofs

3.4.1 Roof Assembly Types

3.4.1.1 COM*check* offers the following six roof types:

All-Wood Joist/Rafter/Truss. The base assembly consists of a roof truss with a 2x4 bottom chord. The ceiling is attached directly to the bottom chord of the truss, and the attic space above is ventilated. Insulation is located directly on top of the ceiling, first filling the cavities between the wood, then continuously covering wood and cavity insulation. No credit is given for roofing materials, because they are above the ventilated space. The heat flow path through the wood members is calculated to be the same depth as the insulation. The assembly includes R-0.17 for the exterior air film, R-0.56 for 0.625-in. gypsum board, and R-0.61 for interior air film with heat flow up. U-factors are calculated for standard framing, where insulation is tapered around the perimeter with resultant decreases in thermal resistance. Table 3.3 shows the balance of assembly R-value calculation details. Area weighting factors for the parallel paths are 85% full-depth insulation, 5% half-depth insulation, and 10% framing.

Table 3.3. Balance of Assembly R-values for All-Wood Joist Roof

Description	R-Value at Insulation	R-Value at Joists
Outside Air Film	0.17	0.17
Wood Joists/Cavity	0	4.38
5/8-in. Gypsum Board	0.56	0.56
Inside Air Film	0.61	0.61
Total Path R-value	1.34	5.72
Total Assembly R-value = 1.0 / (0.85/1.34 + 0.05/1.34 + 0.10/5.72) = 1.45		

Non-Wood Joist/Rafter/Truss. The base assembly consists of a roof supported by metal joists with insulation between the joists. The assembly includes R-0.17 for exterior air film, R-0 for metal deck, and R-0.61 for interior air film heat flow up. The performance of the insulation/framing layer is calculated using the parallel path correction factors found in Table 8C-1 of Standard 90.1-1989.

Structural Slab. The structural slab roof consists of a 6-in. concrete slab or concrete on metal deck. The assembly includes R-0.17 for exterior air film, R-0.33 for built-up roofing, R-0.13 for concrete slab on metal deck, and R-0.61 for interior air film heat flow up.

Metal Roof without Thermal Blocks and Metal Roof with Thermal Blocks. The base assembly consists of a roof where the insulation is draped over metal purlins and compressed where the metal structural members are attached to the metal purlins. R-values for additional continuous insulation may be added to the base assembly. Two cases of screw-down metal building roofs are considered in COM*check*. One case involves the use of a 1 in. x 3 in. foam thermal block (other than compressed insulation) between the purlin and metal roof members (NAIMA 1998). The other case is identical but without the thermal block material at the purlins. The base assembly R-value for uninsulated roofs is 0.78, representing the interior and exterior air film coefficients. Balance of assembly U-factors and framing factors is used as coefficients of a linear regression equation developed to represent the assembly U-factors of standard insulation R-values for metal building roof assemblies, as listed in Table 3.4.

Table 3.4. Metal Building Roof (MBR) Assembly U-Factors for Standard Insulation Thicknesses

Insulation R-Value	Assembly U-Factor MBR with Thermal Block	Assembly U-Factor MBR without Thermal Block
R-10	0.104	0.138
R-11	0.098	0.134
R-13	0.088	0.122
R-19	0.07	0.101

Other. COM*check* allows the user to define a roof assembly by specifying its overall effective U-factor. This option permits the user to accurately describe the performance of any roof assembly not adequately covered by the predefined roof types.

3.4.2 Roof Area

Proposed Area. With COM*check* Version 2.0, skylight areas are subtracted from roof gross areas as input by the user to determine opaque roof areas, which is then used in the loads calculations.

Budget Area. The roof area ($Area_{RF}$) used in calculating budget loads is the sum of the opaque roof area and skylight area in excess of 3% of total roof area. The first 3% of skylight area is ignored in calculating both loads for the proposed design and budget design loads (see *Skylights* for additional information).

3.4.3 Roof U-Factor

Proposed U-Factor. The U-factor for opaque roof assemblies is determined using the following equation:

$$U_{RF} = 1/(R_{RF\text{-}BOA} + R_{RF\text{-}CVI} \times AF_{RF} + R_{RF\text{-}CNI}) \tag{3.1}$$

where U_{RF} = opaque roof assembly U-factor input to the trade-off engine
$R_{RF\text{-}BOA}$ = R-value for the balance of the assembly from Table 3.5 for roof type
$R_{RF\text{-}CVI}$ = R-value for the cavity insulation as input by the user
AF_{RF} = parallel path adjustment factor from Table 3.5 for roof type
$R_{RF\text{-}CNI}$ = R-value for continuous insulation input by the user.

Table 3.5. Roof U-Factor Calculation Coefficients

Roof Type	$R_{RF\text{-}BOA}$	AF_{RF}
All-Wood Joist/Rafter/Truss	1.45	0.9
Non-Wood Joist/Rafter/Truss	0.78	1 - 0.00738 * $R_{RF\text{-}CVI}$
Structural Slab	1.24	N/A
Metal Roof without Thermal Blocks	If $R_{RF\text{-}CVI} = 0$, 0.78	If $R_{RF\text{-}CVI} = 0$, AF_{RF} = N/A
	If $R_{RF\text{-}CVI} > 0$, 4.25	If $R_{RF\text{-}CVI} > 0$, 0.298251
Metal Roof with Thermal Blocks	If $R_{RF\text{-}CVI} = 0$, 0.78	If $R_{RF\text{-}CVI} = 0$, AF_{RF} = N/A
	If $R_{RF\text{-}CVI} > 0$, 4.55	If $R_{RF\text{-}CVI} > 0$, 0.514723
Other	User input is overall assembly U-factor.	

Budget U-Factor. The U-factor for roof assemblies (U_{RF}) is based on Equation 8-7 in Standard 90.1-1989.

3.4.4 Roof Loads

The cooling and heating loads for roofs (CL_{RF} and HL_{RF}) are calculated using Equations 3.2 and 3.3.

$$CL_{RF} = Area_{RF} \times CCoef_{RF} \times U_{RF} \times CDD50 \quad (3.2)$$

$$HL_{RF} = Area_{RF} \times HCoef_{RF} \times U_{RF} \times HDD65 \quad (3.3)$$

where CL_{RF} = cooling load for roof
HL_{RF} = heating load for roof
$Area_{RF}$ = roof area in square feet
$CCoef_{RF}$ = 7.393 (from Standard 90.1-1989R, Appendix C, Table C.6-11: 6.04E-04 × 12.24 × 1000 = 7.393)
$HCoef_{RF}$ = 13.874 (from Standard 90.1-1989R, Appendix C, Table C.6-11: 2.28E-04 × 0.608488 × 100000 = 13.874)
U_{RF} = U-factor of roof assembly
CDD50 = cooling degree-days base 50°F for the site.
HDD65 = heating degree-days base 65°F for the site.

3.5 Skylights

Separate requirements for skylights have not been implemented in COM*check* because the skylight requirements in Standard 90.1-1989 are complex and would require several additional user inputs to implement. Standard 90.1-1989 and the 90.1-1989 Code permit qualifying skylights to be ignored when calculating roof conductance. Under favorable circumstances, skylight areas up to 12% of the gross roof area may be ignored in the conductance calculation. These requirements involve dependencies on electric lighting power density, design foot-candle levels, the presence of automatic daylighting controls, and an option for shading devices. Not only are these dependencies complex, but field experience has shown that daylighting controls are often not correctly installed or maintained.

COM*check* implements the skylight requirements for much greater simplicity. COM*check* limits the area of skylights to a range in which skylights are highly productive in daylighting the spaces below and relies on “casual daylighting” (i.e., the tendency of occupants to turn off unneeded lights) to provide lighting savings to offset the higher conductance and presumed increases in space-conditioning loads. The first 3% of skylight area is exempted from inclusion in the proposed and budget building loads calculations, regardless of whether automatic controls are included or not, provided only that they meet minimum U-factor requirements consistent with Standard 90.1. The U-factor requirements are consistent with Addendum F in Standard 90.1-1989.

The rationale for this exemption is that at low percentages of roof area, skylights typically more than offset their added thermal load with lower electric lighting usage and a lower cooling load from lights. This approach represents a conservative implementation of the requirements in Section 8.4.8 of Standard 90.1-1989, which exempts much higher percentages of skylight area provided automatic controls are present. Three percent represents the roof area fraction below which we feel confident detrimental energy use impacts will not result even in the absence of an explicit requirement for automatic controls.

No SHGC requirements are associated with the skylights. In the 0% to 3% area range, setting a maximum SHGC would likely be counterproductive because of reduced daylight contribution from glazing with a reduced SHGC. Skylight areas above 3% are permitted provided the additional loads are fully offset by space-conditioning load reductions achieved elsewhere in the envelope design.

3.5.1 Skylight Area

Proposed Area. The portion of skylight area that exceeds 3% of total roof area (i.e., opaque roof plus skylights) is used in the proposed design loads calculation. The first 3% is ignored. Where more than one skylight type has been entered, the 3% exemption is allocated proportionally based on skylight area.

Budget Area. Skylights are not addressed separately in the calculation of budget loads. Skylight area above the 3% exemption is included in the overall roof area.

3.5.2 Skylight U-Factor

Proposed U-Factor. Skylight U-factors are used as entered by the user. Glass heat gain properties are entered by the user as SHGC and used in that form for calculations.

Budget U-Factor. Skylights above the 3% exemption are included in the overall roof area and are subject to the roof U-factor requirement.

3.5.3 Skylight Loads

The cooling and heating loads for skylights (CL_{SK} and HL_{SK}) are calculated using Equations 3.4 and 3.5. Equation 3.4 was derived from Equation C.6-17 in Standard 90.1-1989R. However, an apparent error was discovered in that equation and a comment was formally sent to ASHRAE SSPC 90.1 as part of the public review. The error was that $Area_{SK}$ was erroneously divided by the conditioned building floor area. Review of the source document for this equation revealed that the equation had not been correctly normalized when it was brought into the draft standard. Note also that unlike the equations for the other components, the skylight equations require dividing by the unit fuel price, while in the other components based on Standard 90.1-1989R the price term canceled out of the equation.

$$CL_{SK} = Area_{SK} \times CCoef_{SK} \times CDD50 \times CCoef_{SK\text{-}SOLAR} \times SHGC_{SK} \tag{3.4}$$

$$HL_{SK} = Area_{SK} \times HAF_{SK} \times HDD65 \times (HCoef_{SK\text{-}COND} \times U_{SK} + HCoef_{SK\text{-}SOLAR} \times SHGC_{SK}) \tag{3.5}$$

where
CL_{SK} = cooling load for skylight
HL_{SK} = heating load for skylight
$Area_{SK}$ = area of skylight assembly
$CCoef_{SK}$ = 0.0109 = cooling coefficient for skylights for nonresidential buildings from Standard 90.1-1989R, Table C.6-9. This coefficient is used for all buildings for simplicity.
$CCoef_{SK\text{-}SOLAR}$ = 14229 = 0.093 × 12.24 × 1000 / 0.08 (from Standard 90.1-1989R, Equation C.6-17)
CDD50 = cooling degree-days base 50°F for the site.

$SHGC_{SK}$ = SHGC for skylight assembly based on National Fenestration Rating Council ratings (NFRC 1995).
HAF_{SK} = 60849 = heating adjustment factor for skylights = 0.56 × 0.608488 × 100000 / 0.56 (from Standard 90.1-1989R, Equation C.6-17)
$HCoef_{SK\text{-}COND}$ = 0.000212 = heating coefficients for skylights from conductance (from Standard 90.1R, Table C.6-9)
U_{SK} = U-factor for skylight assembly
$HCoef_{SK\text{-}SOLAR}$ = -0.0001953 = heating coefficients for skylights from solar = -0.000168 × 1.163 (from Standard 90.1-1989R, Equation C.6-17 and Table C.6-9).
HDD65 = heating degree-days base 65°F for the site.

3.6 Above-Grade Walls

3.6.1 Above-Grade Wall Assembly Types

COM*check* considers six typical above-grade wall types:

Wood-Frame. The base assembly consists of a conventional framed wood wall with insulation installed between 2-in. nominal wood framing. Cavity insulation is full depth and headers are double 2-in. nominal wood framing. The assembly includes R-0.17 for exterior air film, R-0.08 for stucco, R-0.56 for 0.625-in. gypsum board, and R-0.68 for interior air film--vertical surfaces. For most supported codes, COM*check* treats both 16-in. o.c. and 24-in. o.c. wood frame as the same assembly because performance was not found to be sufficiently different. The calculations are based on wood framing at 16 in. o.c. with cavities filled with 14.5-in.-wide insulation for both 3.5-in.-deep and 5.5-in.-deep wall cavities. Headers leave no cavity for insulation. Area weighting factors for parallel paths are 75% insulated cavity; 21% studs, plates, and sills; and 4% headers. The wall assembly U-factor calculations are based on a balance of wall assembly R-value as shown in Table 3.6. The heat capacity of the wall (as defined in Standard 90.1-1989 for use with the ENVSTD program [Crawley et al. 1989]) is 1.0.

Table 3.6. Balance of Assembly R-Values for Wood-Frame Walls

Description	R-Value at Insulation	R-Value at Studs/Header
Outside Air Film	0.17	0.17
Stucco	0.08	0.08
Wood Studs/Cavity	0.91(a)	4.38
5/8-in. Gypsum Board	0.56	0.56
Inside Air Film	0.68	0.68
Total Path R-value	2.40	5.87

Total Assembly R-value = 1.0 / (0.75/2.40 + 0.21/5.87 + 0.04/5.87) = 2.82.
(a) Represents the R-value of air space in the stud cavity.

Metal-Frame (16-in. and 24-in. o.c.). The base assembly consists of a wall with insulation between metal framing but with no metal exterior surface framing spanning members. The metal framing is 16-18 gauge. The assembly includes R-0.17 for exterior air film, R-0.08 for stucco, R-0.56 for 0.625-in. gypsum board, and R-0.68 for interior air film--vertical surfaces. The performance of the insulation/framing layer is calculated using the values in Table 8C-2 of Standard 90.1-1989. COM*check* deals with both standard framing (16-in. o.c.) and advanced framing (24-in. o.c.). The heat capacity of the wall is assumed to be 1.0. Table 3.7 shows the balance of assembly R-value calculation for metal frame walls.

Table 3.7. Balance of Assembly R-values for Steel Frame Walls

Description	R-Value for Steel Frame 16-in. o.c.	R-Value for Steel Frame 24-in. o.c.
Outside Air Film	0.17	0.17
Stucco	0.08	0.08
Stud Cavity	0.79[a]	0.91
5/8-in. Gypsum board	0.56	0.56
Inside Air Film	0.68	0.68
Total Assembly R-value	2.28	2.40

(a) Represents the R-value of air space in the stud cavity adjusted with a framing factor of 0.87.

Structural Masonry. This assembly includes poured-in-place concrete walls, precast concrete panels, and concrete masonry units. Continuous insulation can be installed on the interior or exterior, concrete masonry units can have empty cells or cells insulated with loose-fill insulation or foam inserts, and wood or metal furring may be used in conjunction with cavity insulation on the interior of the wall. The base assembly includes R-0.17 for exterior air film and R-0.68 for interior air film--vertical surfaces. For insulated walls, the U-factor also includes R-0.45 for 0.5-in. gypsum board. U-factors and heat capacities are calculated for six structural masonry wall types. The R-value for each wall type and its assumed density and thickness is given in Table 3.8.

Table 3.8. Balance of Assembly R-values for Above-Grade Masonry Walls

	Solid Concrete or Masonry		CMU w/Empty Cells		CMU w/Integral Insulation	
Layer Name	<8”	>8”	<8”	>8”	<8”	>8”
Outside Air Film	0.17	0.17	0.17	0.17	0.17	0.17
Concrete/Masonry	0.68[a]	1.02[b]	1.31[c]	1.57[d]	1.56[e]	2.36[f]
1/2-in. Gypsum Board	0.45	0.45	0.45	0.45	0.45	0.45
Inside Air Film	0.68	0.68	0.68	0.68	0.68	0.68
Total Assembly R-value	1.98	2.32	2.61	2.87	2.86	3.66

(a) Assuming 6” solid concrete with density 115 lb/ft^3.
(b) Assuming 9” solid concrete with density 115 lb/ft^3.
(c) Assuming 6” concrete block (unreinforced, cells empty) with density 115 lb/ft^3.
(d) Assuming 10” concrete block (unreinforced, cells empty) with density 115 lb/ft^3.
(e) Assuming 6” concrete block (partly grouted, cells insulated) with density 115 lb/ft^3.
(f) Assuming 10” concrete block (partly grouted, cells insulated) with density 115 lb/ft^3.

Metal Wall Without Thermal Blocks. The base assembly consists of wall insulation that is compressed between metal wall panels and the metal structure. The heat capacity of the wall is assumed to be 1.0. For un-insulated metal walls, the overall R-value for the assembly is 0.85 assuming only indoor and outdoor air film coefficient R-values of 0.17 and 0.68. The balance of assembly R-value and framing factor for insulated metal building walls is used as coefficients in a linear regression equation developed to represent assembly U-factors for various standard insulation R-values, as provided in Table 3.9 for metal building wall systems with 7 ft. girt spacing.

Table 3.9. Metal Building Wall (MBW) Assembly U-factors for Standard Insulation Thicknesses

Insulation R-value	Assembly U-factor MBW without thermal block
R-10	0.138
R-11	0.134
R-13	0.122
R-19	0.101

Other. COM*check* allows the user to define a wall assembly by specifying its overall effective U-factor. This option permits the user to accurately describe the performance of any wall assembly not adequately covered by the predefined wall types.

3.6.2 Thermal Mass

COM*check* accounts for thermal mass in walls using the same algorithms and parameters used in ENVSTD--heat capacity and insulation position. While in ENVSTD values for these inputs are entered directly by the user, in COM*check* default heat capacity and insulation position parameters are provided based on the user's selection of wall type. The exception to this is the *Other* wall category, for which users must specify the heat capacity.

All COM*check* compliance calculations assume that any insulation in an above-grade exterior wall (or above-grade portion of a below-grade wall assembly) is integral with the thermal mass of the wall, as opposed to assuming the insulation is either on the exterior or on the interior of the wall. This assumption was made because the insulation position has little impact, producing a maximum of about a 1% change in cumulative space-condition loads in a high-mass wall. In addition, for many wall assemblies it is difficult to determine which of the three options—interior, integral, or exterior—is the most appropriate.

This assumption also appears to be appropriate for the most common wall assemblies; e.g., metal stud walls. Coincidentally, the integral insulation position appears to result in the most favorable impact from high heat-capacity walls. Assuming integral insulation is the best case for advocates of masonry construction and effectively eliminates any grounds for criticism of simplifications in COM*check* in this area.

3.6.3 Orientation-Specific Wall Inputs

Unspecified Orientation. Wall and window areas can be input into the COM*check* software without designation of their orientation. Section 8B.2(a) in Standard 90.1-1989 calls for budget loads to be calculated based on a 2:1 aspect ratio with an elongated north-south building axis. COM*check* uses this aspect ratio for both the proposed and budget building when orientations are unspecified. A certain percentage of the area of each wall or window component is assigned to one of the four cardinal orientations. The benefits of this simplification are that required user inputs of wall and window areas are reduced by a factor of four, and users are no longer penalized for an unfavorable site (i.e., one that requires north-south axis elongation) or rewarded for a favorable site. The adverse consequences are that the modest incentive for favorable placement of fenestration and for favorable building massing and orientation is reduced.

Specified Orientation. With COM*check* Version 2.0 orientation-specific input became optional. Users can select from among the four cardinal orientations, and the inputs are mapped to the orientation-specific input in the original ENVSTD calculation. Cardinal orientations (as opposed to the eight orientations offered in ENVSTD) were deemed adequate, because the underlying ENVSTD model only supports four orientations. The intermediate orientations (e.g., NE) are achieved by splitting the area between adjacent cardinal orientations (e.g., 50% N, 50% E), resulting in a near identical result to simply requiring users to enter wall area to its *nearest* cardinal orientation.

When orientation is specified, the budget building is modeled after the proposed building design rather than the 2:1 aspect ratio described above. Recent development work on building energy codes reflects a rejection of basing criteria on prototypes in favor of basing them on custom budgets; i.e., neutralizing the effect of building massing. The envelope trade-off procedure in Standard 90.1-1989R, the energy cost budget method in Standard 90.1-1989R, California Title 24, and the performance path in the Commercial Energy Code in Canada all base performance criteria on the user's design and not on a prototype design. In addition, the ENVSTD 2 program bases criteria on the user's input of areas and orientations and does not implement the Standard 90.1-1989 Section 8B.2(a) requirement. No documentation could be found that explained the reason for the inconsistency. Given the history and recent developments, basing budget loads on the proposed design's aspect ratio was the only reasonable choice for COM*check*.

3.6.4 Above-Grade Wall Area

Proposed Area. Above-grade walls, windows, doors, and portions of below-grade wall assemblies (e.g., basement walls) that are above grade are all included in the above-grade wall calculations. Areas for above-grade portions of below-grade walls (A_{ABW}) are determined according to the following formula:

$$\begin{aligned} &\text{If,} && H_{BG} <= D_{BG} \\ & && A_{ABW} = 0 \\ &\text{else,} && A_{ABW} = A_{BW} \times ((H_{BG} - D_{BG}) / H_{BG}) \end{aligned} \quad (3.6)$$

where A_{ABW} = opaque above-grade area of below-grade wall assembly
A_{BW} = opaque area of below-grade wall assembly
H_{BG} = average height of below-grade wall
D_{BG} = average depth below grade of the base of the below-grade wall.

The proposed window-to-wall ratio is a ratio of the sum of the area of all windows and glazed doors to the total gross area of exterior walls. The gross area of exterior walls is the sum of the gross areas of above-grade walls and the areas of above-grade portion of below-grade walls.

Budget Area. The wall area (A_{WL}) used in calculating budget loads is the sum of the opaque wall area, window area, and door area, plus the above-grade portions of below-grade assemblies as determined using Equation 3.6.

The window-to-wall ratio used in calculating the cooling and heating coil loads attributable to windows and opaque above-grade walls (CL_{WW}) and (HL_{WW}) are based on the equations illustrated in Figures 8B-1 or 8B-2 in Standard 90.1-1989, whichever yields the smaller value.

3.6.5 Above-Grade Wall U-Factor

Proposed U-Factor. The U-factors for above-grade wall assemblies and above-grade portions of below-grade assemblies are determined using the following equation:

$$U_{WL} = 1/(R_{WL\text{-}BOA} + R_{WL\text{-}CVI} \times AF_{WL} + R_{WL\text{-}CNI}) \quad (3.7)$$

where U_{WL} = U-factor for the opaque wall assembly
$R_{WL\text{-}BOA}$ = R-value for the balance of the assembly from Table 3.10 based on wall type
$R_{WL\text{-}CVI}$ = R-value for the wall cavity insulation input by the user
AF_{WL} = parallel path adjustment factor from Table 3.10 for wall type
$R_{WL\text{-}CNI}$ = R-value for continuous insulation input by the user.

Budget U-Factor. The U-factor for opaque wall assemblies (U_{WL}) is based on Equations 8B-17 and 8B-18 in Standard 90.1-1989. Wall heat capacity is set to 1 [per Standard 90.1-1989 Section 8B.2(h)], and insulation position is set to “Integral.”

3.6.6 Mandatory U-Factor Limits

Standard 90.1-1989, Section 8.6.10.2(a), *Constraints on Thermal Transmittance Values, Opaque Wall Assemblies*, contains a requirement that the overall U-factor of lightweight opaque exterior walls (i.e., those with HC <7 Btu/[$ft^2 \times °F$]) not exceed the value given by Equation 3.8 (see Standard 90.1-1989, Figure 8-8). COM*check* enforces this mandatory requirement regardless of the envelope compliance index of the proposed design.

If, $HDD65 <= 540$ (3.8)
$U_{OW} = 1.0$
else, $U_{OW} = 0.0528 + 510.9 / HDD65$
where U_{OW} = maximum overall conductance of opaque wall sections with HC <7.

3.6.7 Above-Grade Wall Loads

COMcheck loads for the budget building opaque walls, windows, and doors are calculated using the same equations as are found in Standard 90.1-1989 Attachment 8B and embedded in the ENVSTD Version 2.4 program (Crawley et al. 1989). A program containing these algorithms written at Concordia University was used in COM*check*. The primary reason for using this program rather than ENVSTD Version 2.4 was that the Concordia University program was written in C++. The Concordia University program has been validated against ENVSTD Version 2.4.

HC and insulation position are required inputs to the heating and cooling loads calculations. Input values for HC are given in Table 3.6 based on wall type. Insulation position is assumed to be “integral” with the thermal mass of the wall, as opposed to assuming the insulation is either on the exterior or on the interior of the wall.

Table 3.10. Above-Grade Wall U-Factor Calculation Coefficients

Wall Type	$R_{WL\text{-}BOA}$	AF_{WL}	HC
Metal Frame, 16 in. o.c.	2.28	(Eq. a) If $R_{WL\text{-}CVI}$ <11, AF = 0.78814-0.03274 * $R_{WL\text{-}CVI}$ If 11>=$R_{WL\text{-}CVI}$ <30, AF = 0.54564-0.01069 * $R_{WL\text{-}CVI}$ Else, AF = 6.7482/$R_{WL\text{-}CVI}$	1
Metal Frame, 24 in. o.c.	2.40	(Eq. a) If $R_{WL\text{-}CVI}$ <11, AF = 0.94322-0.03872 * $R_{WL\text{-}CVI}$ If 11>=$R_{WL\text{-}CVI}$ <30, AF = 0.65373-0.01241 * $R_{WL\text{-}CVI}$ Else, AF = 8.4429/$R_{WL\text{-}CVI}$	1
Wood Frame	2.82	(Eq. c) If $R_{WL\text{-}CVI}$ <11, AF = 0.9921-0.03297 * $R_{WL\text{-}CVI}$ Else, AF = 0.62943	1
Metal Wall Without Thermal Blocks	If $R_{WL\text{-}CVI}$ = 0, 0.85 Else, 4.25	(Eq. d) If $R_{WL\text{-}CVI}$ = 0, AF = N/A else, AF = 0.298251	1
Solid Concrete or Masonry, 8 in. or less			
No Furring Strips	1.98	None	11.5
Metal Furring	1.98	(Eq. a) If $R_{WL\text{-}CVI}$<11, AF = 0.78814-0.03274 * $R_{WL\text{-}CVI}$ If 11>=$R_{WL\text{-}CVI}$<30, AF = 0.54564-0.01069 * $R_{WL\text{-}CVI}$ Else, AF = 6.7482/$R_{WL\text{-}CVI}$	11.5
Wood Furring	1.98	(Eq. d) If $R_{WL\text{-}CVI}$<11, AF = 0.9921-0.03297 * $R_{WL\text{-}CVI}$ Else, AF = 0.78526-0.01417 * $R_{WL\text{-}CVI}$	11.5
Solid Concrete or Masonry, > 8 in. thick			
No Furring Strips	2.32	None	17.3
Metal Furring	2.32	Eq. a	17.3
Wood Furring	2.32	Eq. d	17.3
CMU, 8 in. or less w/ Empty Cells			
No Furring Strips	2.61	None	5.6
Metal Furring	2.61	Eq. a	5.6
Wood Furring	2.61	Eq. d	5.6
CMU, > 8 in. w/ Empty Cells			
No Furring Strips	2.87	None	8.7
Metal Furring	2.87	Eq. a	8.7
Wood Furring	2.87	Eq. d	8.7
CMU, 8 in. or less w/ Integral Insulation			
No Furring Strips	2.86	None	8.4
Metal Furring	2.86	Eq. a	8.4
Wood Furring	2.86	Eq. d	8.4
CMU, > 8 in. thick w/ Integral Insulation			
No Furring Strips	3.66	None	13.9
Metal Furring	3.66	Eq. a	13.9
Wood Furring	3.66	Eq. d	13.9
Other	User inputs are U-factor and heat capacity.		

HC = Heat capacity of the wall assembly (with the average level of insulation) measured in Btu/(°F × ft^2 of wall area). Wall heat capacity (HC) is the product of thickness, density, and specific heat for every material that makes up the wall. This is used as input to the heating and cooling loads calculation.

The output from the gross wall calculation is annual cumulative cooling and heating coil loads for 1200 ft^2 of wall area (which is associated with 1500 ft^2 of exterior-zone floor area). The output units are in MBtu/y for 1,200 ft^2 of exterior wall. The individual cooling and heating load terms in Equations 3.30 and 3.31 (e.g., CL_{WW} and HL_{WW}) are in units of British thermal units per year (Btu/y) for the entire building. The following steps are required to convert the engine output to Btu/y:

1. Multiply by 1,000,000 (to covert from MBtu to Btu)
2. Multiply by total wall area divided by 1200 ft^2.

The cooling and heating loads for windows, opaque walls, and doors are calculated using Equations 3.9 and 3.10.

$$CL_{WW} = CL \times 1000000 \times A_{WL} / 1200 \quad (3.9)$$

$$HL_{WW} = HL \times 1000000 \times A_{WL} / 1200 \quad (3.10)$$

where CL_{WW} = cooling load for exterior walls, windows and doors
HL_{WW} = heating load for exterior walls, windows and doors
CL = cooling loads for the proposed or budget building design output by the engine
A_{WL} = total wall area for all orientations, opaque wall, windows, doors, and above-grade portions of below-grade walls.
HL = heating loads for the proposed or budget building design output by the engine.

3.7 Walls Next to Unconditioned Spaces

Walls next to unconditioned space are defined as walls that separate conditioned from unconditioned spaces but that are not exterior walls.

3.7.1 Walls Next to Unconditioned Spaces Area

Proposed Area. The area of these walls is not included in the calculation of window-to-wall ratio. For simplicity, the areas of doors or windows in these walls are included with the opaque wall area.

Budget Area. The area for determining budget loads for walls next to unconditioned spaces is identical to that used for calculating loads for the proposed design.

3.7.2 Walls Next to Unconditioned Spaces U-Factor

Proposed U-Factor. The U-factor for walls next to unconditioned spaces is determined using the following equation:

$$U_{WU} = 1/(R_{WU\text{-}BOA} + R_{WU\text{-}CVI} \times AF_{WU} + R_{WU\text{-}CNI} + 0.29) \quad (3.11)$$

where U_{WU} = U-factor for the wall next to unconditioned space
$R_{WU\text{-}BOA}$ = R-value for the balance of assembly (excluding insulation) for the above-grade wall type
$R_{WU\text{-}CVI}$ = R-value for the cavity insulation as input by the user

AF_{WU} = parallel path adjustment factor for cavity insulation for the above-grade wall type
$R_{WU\text{-}CNI}$ = R-value for the continuous insulation as input by the user.

An R-value of 0.29 is added to R-values of walls next to unconditioned spaces to account for the tempering effect of the adjacent enclosed but unconditioned space. This assumption is consistent with that used in Standard 90.1-1989R for walls next to unconditioned spaces. The adjustment has been made here but not for floors next to unconditioned spaces because Standard 90.1 applies the same requirements to floors next to unconditioned spaces as to floors exposed to exterior conditions.

Budget U-Factor. The U-factor for walls next to unconditioned spaces is determined by the equation in Figure 8-8 of Standard 90.1-1989.

3.7.3 Walls Next to Unconditioned Spaces Loads

The cooling and heating loads for walls next to unconditioned spaces (CL_{WU} and HL_{WU}) are calculated using Equations 3.12 and 3.13.

$$CL_{WU} = Area_{WU} \times CCoef_{WU} \times (1/(1/U_{WU} + 2)) \times CDD50 \qquad (3.12)$$

$$HL_{WU} = Area_{WU} \times HCoef_{WU} \times (1/(1/U_{WU} + 2)) \times HDD65 \qquad (3.13)$$

where CL_{WU} = cooling load for walls next to unconditioned space
HL_{WU} = heating load for walls next to unconditioned space
$Area_{WU}$ = area of walls next to unconditioned spaces in ft^2
$CCoef_{WU}$ = 7.393 = from Standard 90.1-1989R, Appendix C, Table C.6-11: 6.04E-04 × 12.24 × 1000
U_{WU} = U-factor of walls next to unconditioned spaces
CDD50 = cooling degree-days base 50°F for the site.
$HCoef_{WU}$ = 13.873 = from Standard 90.1-1989R, Appendix C, Table C.6-11: 2.28E-04 × 0.608488 × 100000
HDD65 = heating degree-days base 65°F for the site.

3.8 Windows

3.8.1 Window Area

Proposed Area. By default, orientation is not specified by the user. With orientation unspecified, the calculation of both design and budget loads is based on the following distribution of window area: 1/6 of the area facing north, 1/3 facing east, 1/6 facing south, and 1/3 facing west. Matching the orientation for the proposed design to the mildly adverse orientation specified in the budget design for calculating the requirements represents a conservative approach in that it tends to preserve stringency. Beginning with COM*check* Version 2.0, users have the option of designating cardinal orientations for each window and wall, and these inputs are used directly by the engine for both design and allowable loads. The area to which the window-to-wall ratio is applied is the sum of the net opaque wall area, window area, and door area, as specified by the user, plus the above-grade portions of below-grade assemblies.

Budget Area. Values for window-to-wall ratio, glass U-factor, and glass SC are based directly on requirements in Standard 90.1-1989.

The window-to-wall ratio used in calculating budget loads is based on either the equation shown in Figure 8B-1 or the equation shown in Figure 8B-2 in Standard 90.1-1989, whichever yields the smaller value.

3.8.2 Solar Heat Gain Coefficient

Proposed SC. Glass heat gain properties are entered by the user as solar heat gain coefficients (SHGCs) and these values are converted to shading coefficients (SCs) for internal use by the program. The following equation is used in performing this conversion:

$$SC = SHGC / 0.87 \qquad (3.14)$$

The conversion value of 0.87 is for standard summer conditions and normal incidence angles and is from the *1993 ASHRAE Handbook of Fundamentals*, page 27.19, Equation (39) (ASHRAE 1993a).

Budget SC. Shading coefficients (SCs) are based on Equations 8B-19 through 8B-22 of Standard 90.1-1989.

3.8.3 Projection Factor

Proposed Projection Factor. Projection factors are used as entered by the user.

Budget Projection Factor. Projection factors are set to 0.0 for consistency with Section 8B.2(e) and 8B.2(f) of Standard 90.1-1989.

3.8.4 Daylighting Control Credits

Beginning with Version 2.0, COM*check* offers compliance credit in the envelope section for using automatic controls for daylight utilization. Daylight control credits were not included in Version 1 of COM*check* because automatic daylighting controls were judged to be infrequently used and because daylighting performance is somewhat orientation-specific, and Version 1 did not permit orientation-specific inputs. This feature was later requested for the Massachusetts Code and was added as an optional feature with other Standard 90.1 based codes. When the daylighting control credit option is selected, orientation, visible light transmittance, and daylighting control factors are required from the user.

Daylighting control credits have been implemented according to the equations in Attachment 8B of Standard 90.1-1989. The daylighting credit is calculated by adjusting the effective internal gain based on the fraction of the electric lighting controlled by automatic daylighting controls and the effective aperture for visible light transmission. The adjustments are made separately to the cooling and heating load equations. These adjustments apply only to the calculation of design loads and do not apply to the calculation of the allowable loads.

Equations 8B-3 and 8B-3a of Standard 90.1-1989 adjust the effective internal gain input in the cooling load equation based on daylighting control factor and glass visible light transmittance. Equations

8B-7 and 8B-7a adjust the effective internal gain input in the heating load equation based on daylighting control factor and glass visible light transmittance.

Proposed DLCF and VLT. Daylighting control factors (DLCFs) and visible light transmittance (VLT) are used as entered by the user. These are optional inputs, and remain set at 0.0 if not entered.

Budget DLCF and VLT. Daylighting control factors (DLCFs) and visible light transmittance (VLT) are set to 0.0 for consistency with Sections 8B.2(k) and 8B.2(l) of Standard 90.1-1989.

3.8.5 Window U-Factor

Proposed U-Factor. Window U-factors are used in calculations exactly as entered by the user.

Budget U-Factor. U-factors are based on the equations in Section 8B.2j in Standard 90.1-1989.

3.8.6 Mandatory U-Factor Limit

Standard 90.1-1989, Section 8.6.10.2(b), *Constraints on Thermal Transmittance Values, Fenestration Assemblies*, as amended in Addendum F, contains a requirement that the U-factor of fenestration not exceed the value given by Equation 7-9 of the Standard 90.1-1989 except where the window-to-wall ratio for the entire building is 10% or less. This requirement is shown below as Equation 3.15. COM*check* enforces this as a mandatory requirement regardless of the value of the envelope compliance index.

$$\text{If } HDD65 > 3000 \text{ and } WWR > 0.10 \qquad (3.15)$$
$$U_{of} = 0.72$$

where WWR = window-to-wall ratio
U_{of} = maximum overall conductance of fenestration assemblies.

3.8.7 Window Default Values

The software optionally provides suggested (default) values for vertical glass U-factors, SHGCs, and visible light transmittances (VLTs) for commercially available combinations of glazing layers (i.e., single, double, double low-e, triple, and triple low-e), glass type (i.e., clear, tinted, reflective), and frame type (i.e., wood or vinyl, metal, and metal with thermally broken frame). Tables 3.11 and 3.12 contain these suggested values and documentation of sources for both window and skylight glazings.

These typical values have been included in COM*check* for ease-of-use reasons. They enable users to check building compliance prior to having selected actual glazing products from manufacturers' literature. Given this use, the suggested values are most helpful if they are conservative; i.e., represent performance that is about as poor as can be found within a given class of products. For that reason, glazing U-factors and solar heat gain coefficients are intended to represent high values for the given glazing and frame combinations. Visible light transmittance was selected to reflect typical (or slightly adverse) relationships between solar heat gain coefficients and visible light transmittance for each glazing type.

Where possible, suggested glazing data were derived from readily-available published sources. The primary sources were 1997 ASHRAE Fundamentals Handbook (AHF), Chapter 9 *Fenestration*, Table 5, *U-Factors for Various Fenestrations Products* and Table 11, *Visible Transmission, Shading Coefficient and Solar Heat Gain Coefficients at Normal Incidence for Single Pane Glass and Insulating Glass*. However, because these tables contain data representing only a small portion of available products, it was necessary to supplement these data sources with other data that better reflect the range of currently available products. Data representing current products were drawn from Standard 90.1-1989R, 2nd Public Review Draft, December 1997 (90.1R#2) Table A-18 Assembly Solar Heat Gain Coefficients (SHGC) and Assembly Visible Light Transmittance (VLT) for Unlabeled Glazing Wall Systems (Site-Built Windows) and Unlabeled Skylights (I-P). In addition, some data that could not be found in published data sources were drawn from an unpublished database used in the development of Standard 90.1-1989R.

Table 3.11. Glazing SHGC and VLT Values

Glass Type	SHGC Metal Frame Without TB	SHGC Other Frame (including Metal with/TB)	VLT Metal Frame Without TB	VLT Other Frame (including Metal with/TB)	SHGC Source and VLT Source
Single Clear	0.78	0.76	0.80	0.78	AHF Tbl. 11, glass ID 1a
Single Tinted	0.67	0.65	0.61	0.59	AHF Tbl. 11, glass ID 1c
Single Reflective	0.53	0.52	0.37	0.36	SHGC: db, high value VLT: 70% of SHGC
Double Clear	0.68	0.66	0.72	0.70	AHF Tbl. 11, glass ID 5a
Double Tinted	0.57	0.56	0.55	0.54	AHF Tbl. 11, glass ID 5c
Double Reflective	0.46	0.45	0.32	0.31	SHGC: db, high value VLT: 70% of SHGC
Double Low-e Clear	0.64	0.63	0.68	0.66	AHF Tbl. 11, glass ID 17c
Double Low-e Tinted	0.59	0.58	0.50	0.49	Standard 90.1-1989R #2 Tbl. A-18, e=0.4
Double Low-e Reflective	0.46	0.45	0.32	0.31	SHGC: db, high value VLT: 70% of SHGC
Triple Clear	0.61	0.60	0.66	0.64	AHF Tbl. 11, glass ID 29a
Triple Tinted	0.42	0.41	0.22	0.22	Standard 90.1-1989R #2 Tbl. A-18
Triple Reflective	0.36	0.35	0.25	0.25	SHGC: db, high value VLT: 70% of SHGC
Triple Low-e Clear	0.57	0.56	0.61	0.59	AHF Tbl. 11, glass ID 32c
Triple Low-e Tinted	0.42	0.41	0.33	0.32	Standard 90.1-1989R #2 Tbl. A-18, e=0.2
Triple Low-e Reflective	0.36	0.35	0.25	0.25	SHGC: db, high value VLT: 70% of SHGC

(a) The database (db) identified in the source column refers to the unpublished database of glazing products compiled for Standard 90.1-1989R development. *High value* means that the value represents a high value (but not necessarily the highest value) found in the database for the given glass type.

(b) For both solar heat gain coefficient and visible light transmittance, the values shown are the overall values for the frame types listed. Values from AHF were derived from center of glass values listed in Table 1.1 using the assumption that frames cover 11% of rough openings for metal framed windows and skylights and cover 13% of rough openings for other (wood and vinyl framed) windows and skylights. That assumption is derived from AHF (p. 29.24). All windows and skylights are assumed to be fixed (i.e., not operable).

(c) Neither AHF nor Standard 90.1-1989R #2 list SHGC or VLT values for reflective glazings. These values were derived from the same unpublished Standard 90.1-1989R database used in establishing these values for COM*check* Version 1. VLT was set equal to 70% of SHGC, to avoid having missing data. It is unlikely that reflective glazings will be used with automatic controls for daylight utilization, hence no adverse consequences are expected from uncertainties surrounding this assumption.

Table 3.12. Glazing U-Factors

Vertical (Windows)	Window Frame Type			Source
	Metal	Metal w/ TB	Wood/Vinyl	
For Use in COMcheck and COMcheck-Plus Software				
Single	1.13	1.07	0.98	AHF Tbl 5, 1 (1/8” glass)
Double	0.69	0.63	0.56	AHF Tbl 5, 4 (1/4” air space)
Double Low-e	0.61	0.54	0.48	AHF Tbl 5, 16 (1/4” air space)
Triple	0.55	0.48	0.41	AHF Tbl 5, 28 (1/4” air space)
Triple Low-e	0.50	0.44	0.37	AHF Tbl 5, 32 (1/4” air space)
Sloped (Skylights)	Skylight Frame Type			Source
	Metal	Metal w/ TB	Wood/Vinyl	
For Use in COMcheck and COMcheck-Plus Software				
Single	1.98	1.89	1.47	AHF Tbl 5, 1 (1/8” glass)
Double	1.31	1.11	0.84	AHF Tbl 5, 4 (1/4” air space)
Double Low-e	1.20	1.00	0.74	AHF Tbl 5, 16 (1/4” air space)
Triple	1.12	0.89	0.64	AHF Tbl 5, 28 (1/4” air space)
Triple Low-e	1.08	0.85	0.59	AHF Tbl 5, 32 (1/4” air space)

(a) The defaults used in the COM*check* prescriptive packages have been rounded up to the nearest 0.1 values, which correspond with the precision used in representing the prescriptive requirements. These values do not correspond exactly with the suggested values used in the software. Rounding was judged to be helpful in a simplified, paper-based compliance method, but unnecessary and inappropriate for a software-based method.

3.9 Doors

3.9.1 Door Area

Proposed Area. Standard 90.1-1989 has no separate requirements for exterior doors; doors are included in the calculation of overall conductance of opaque walls. COM*check* provides inputs for doors to eliminate the need for users to calculate overall conductance outside of the program. Menu options are available to identify door type and to provide default values for door conductance. In COM*check*, sliding-glass doors are entered by the user as doors, although the software treats them as windows. Doors entered as glass doors are assigned an SHGC of 0.87.

Budget Area. Exterior doors are not addressed separately in the calculation of allowable loads. Door area is included in the overall wall area.

3.9.2 Door U-Factor

Proposed U-Factor. Door U-factors are used as entered by the user.

Budget U-Factor. Doors have the same U-factor requirement as exterior opaque wall assemblies.

3.9.3 Door Typical (Default) U-Factors

Door U-factors in Table 3.13 have been drawn from Standard 90.1-1989R and are intended to reflect typical products (ASHRAE 1996).

Table 3.13. Default Door U-Factor

Door Type	Default U-Factor
Opaque Door	0.7
Glass Door	0.92
Overhead Door	1.45
Air-Lock Entry Door	0.5
Revolving Door	0.5
Other	N/A

3.10 Floors

The *Floor* assembly type is used for any floor of a conditioned space whose underside is exposed to exterior conditions or unconditioned space, including crawl spaces.

3.10.1 Floor Assembly Types

COM*check* considers five types of floors:

All-Wood Joist Truss. The subfloor is attached directly to the top of the wood joist and insulation is located directly below the subfloor with a ventilated airspace below the insulation. The distance of the heat flow path through the joist is calculated to be the same as through the insulation. The assembly includes R-0.92 for interior air film--heat flow down, R-1.23 for carpet and pad, R-0.94 for 0.75-in. wood subfloor, and R-0.46 for semi-exterior air film, providing a total balance of assembly R-value of 3.55.

Nonwood Joist/Truss. The insulation is either placed between the metal joists or is sprayed on the underside of the metal floor deck. In both cases, the metal joist provides a thermal bypass to the insulation. The assembly includes R-0.92 for interior air film--heat flow down, R-1.23 for carpet and pad, R-0.25 for 4-in. concrete, R-0 for metal deck, and R-0.46 for semi-exterior air film. The total balance of assembly R-value of 2.88 includes an adjustment for metal framing construction. The performance of the insulation/framing layer is calculated using the parallel path correction factors found in Table 8C-1 of Standard 90.1-1989.

Concrete (over unconditioned space). This assembly consists of continuous insulation under (or over) a structural concrete floor slab. The assembly includes R-0.92 for interior air film--heat flow down, R-1.23 for carpet and rubber pad, R-0.50 for 8-in. concrete, and R-0.46 for semi-exterior air film, providing a total balance of assembly R-value of 3.11.

Slab-on-grade. Slab-on-grade assemblies are listed with other floor types in COM*check*, but the U-factor and loads calculations are described in this TSD in a subsequent section. The calculations explained in this section do not apply to slab-on-grade assemblies.

Other. COM*check* allows the user to define a floor assembly by specifying its overall effective U-factor. This option permits the user to accurately describe the performance of any floor assembly not adequately covered by the predefined floor types.

3.10.2 Floor Area

Proposed Area. Exposed floor area is used as entered by the user.

Budget Area. Exposed floor area is used as entered by the user.

3.10.3 Floor U-Factor

Proposed U-Factor. Cavity and continuous insulation inputs are used in calculating the U-factor for exposed floors using the following equation:

$$U_{EF} = 1/(R_{EFn\text{-}BOA} + R_{EF\text{-}CVI} \times AF_{EFn} + R_{EF\text{-}CNI}) \tag{3.16}$$

where U_{EF} = U-factor for the exposed floor input to the trade-off engine
$R_{EFn\text{-}BOA}$ = R-value for the balance of the assembly from Table 3.14
$R_{EF\text{-}CVI}$ = R-value of the cavity insulation as input by the user
AF_{EFn} = parallel path adjustment factor from Table 3.14
$R_{EF\text{-}CNI}$ = R-value for continuous insulation as input by the user.

Table 3.14. Exposed Floor U-Factor Calculation Coefficients

Floor Type	$R_{EF\text{-}BOA}$	AF_{EF}
All-Wood Joist/Truss	3.55	0.894
Nonwood Joist/Truss	2.88	1-0.00738 x $R_{EF\text{-}CVI}$
Structural Slab	3.11	None
Other	User input is overall U-factor.	

Budget U-Factor. The U-factor is determined from the following equation, as provided in Figure 8-5 of Standard 90.1-1989:

For: HDD65 <= 550, U_{EF} = 0.40 (3.17)
For: 550 < HDD65 <= 8000, $U_{EF} = 1 / (0.84 + 0.00302 \times HDD65)$
For: 8000 < HDD65 < 15000, U_{EF} = 0.04

where U_{EF} = budget U-factor for exposed floors
HDD65 = heating degree-days base 65° F.
Note: HDD65 >=15000 is not applicable.

3.10.4 Floor Loads

The cooling and heating loads for exposed floors (CL_{EF} and HL_{EF}) are calculated using Equations 3.18 and 3.19.

$$CL_{EF} = Area_{EF} \times CCoef_{EF} \times U_{EF} \times CDD50 \tag{3.18}$$

$$HL_{EF} = Area_{EF} \times HCoef_{EF} \times U_{EF} \times HDD65 \quad (3.19)$$

where CL_{EF} = cooling load for floors
HL_{EF} = heating load for floors
$Area_{EF}$ = exposed floor area in ft^2
$CCoef_{EF}$ = 8.678 = from Standard 90.1-1989R, Appendix C, Table C.6-11: 7.09E-04 × 12.24 × 1000
U_{EF} = U-factor of exposed floor
CDD50 = cooling degree-days base 50°F for the site.
$HCoef_{EF}$ = 14.786 = from Standard 90.1-1989R, Appendix C, Table C.6-11: 2.43E-04 × 0.608488 × 100000
HDD65 = heating degree-days base 65°F for the site.

3.11 Slab-On-Grade Floors

3.11.1 Slab-On-Grade Floor Perimeter

Proposed Perimeter. Concrete slabs on grade are entered as the perimeter length of exposed slab edge. The perimeter is used for determining design and budget loads. Slab-on-grade floors input is used with conditioned space only; slabs associated with unconditioned spaces are ignored.

Budget Perimeter. The budget building perimeter is calculated the same as the proposed building.

3.11.2 Slab-On-Grade Floor F-Factor

Proposed F-Factor. The slab-on-grade floors are 6-in. concrete poured directly on earth. The bottom of the slab is at grade line; soil conductivity is 0.75 $Btu/h \cdot ft^2 \cdot °F$. Heat loss for the slab is expressed in terms of F-factors based on the perimeter of the slab rather than U-factors based on the area of the slab.

The slab-on-grade F-factor is determined based on whether the slab is heated or unheated, the insulation position (i.e., vertical or horizontal), the insulation depth in inches, and the insulation R-value. Table 3.15 contains both numbers and simple arithmetic functions that approximate the F-factor for slabs based on these inputs. The F-factor is the heat transfer coefficient of a slab edge per unit of perimeter length in units of Btu/h·ft·°F. The data on which Table 3.15 is based are from Table 5-89 in Standard 90.1-1989R. Using arithmetic approximations of the data in Standard 90.1-1989R, we have eliminated the need for complex interpolation of the tabular data.

Budget F-Factor. The F-factors used for calculating budget loads are based on Figure 8-6 in Standard 90.1-1989. Loads are based on user inputs for perimeter length, insulation position, and whether the slab is heated or unheated. The values for F-factors are determined using a two-step process. First, the required R-value is determined using Equation 3.20. Second, the F-factor is determined using the required R-value, position, and heating/unheated slab condition as lookup values in Table 3.16. The formulas in Table 3.16 are based on the combinations of insulation depth and R-value in Standard 90.1-1989, Figure 8-6, which lead to the lowest F-factor; i.e., the required values are based on the compliance options in Standard 90.1-1989 that tended to be the most thermally effective based on the data from

Table 3.15. Assembly F-Factors for Slab-on-Grade Floors for Proposed Design

Slab and Insulation Description	F-Factor	
	R-0 to R-5 Insulation R-Value	> R-5 Insulation R-Value
Unheated Slabs		
None	0.73	0.73
12 in. horizontal	0.73-0.002*R_{SBI}[(a)]	0.72
24 in. horizontal	0.73-0.006*R_{SBI}	0.70
36 in. horizontal	0.73-0.008 R_{SBI}	0.69-0.003*R_{SBI}
48 in. horizontal	0.73-0.012*R_{SBI}	0.67-0.004*R_{SBI}
12 in. vertical	0.73-0.024*R_{SBI}	0.61-0.006*R_{SBI}
24 in. vertical	0.73-0.030*R_{SBI}	0.58-0.006*R_{SBI}
36 in. vertical	0.73-0.034*R_{SBI}	0.56-0.007*R_{SBI}
48 in. vertical	0.73-0.038*R_{SBI}	0.54-0.009*R_{SBI}
Fully insulated slab	0.73-0.054*R_{SBI}	0.46-0.016*R_{SBI}
Heated Slabs		
None	1.35	1.35
12 in. horizontal	1.35-0.006*R_{SBI}	1.32
24 in. horizontal	1.35-0.014*R_{SBI}	1.28
36 in. horizontal	1.35-0.022*R_{SBI}	1.24-0.006*R_{SBI}
48 in. horizontal	1.35-0.030*R_{SBI}	1.20-0.009*R_{SBI}
12 in. vertical	1.35-0.058*R_{SBI}	1.06-0.013*R_{SBI}
24 in. vertical	1.35-0.072*R_{SBI}	0.99-0.013*R_{SBI}
36 in. vertical	1.35-0.080*R_{SBI}	0.95-0.016*R_{SBI}
48 in. vertical	1.35-0.088*R_{SBI}	0.91-0.019*R_{SBI}
Fully insulated slab	1.35-0.122*R_{SBI}	0.74-0.030*R_{SBI}

(a) R_{SBI} = R-value of slab insulation.

Table 3.16. Assembly F-Factors for Calculating Budget Loads for Slab-on-Grade Floors

Slab and Insulation Description	Required Insulation R-value	
	R-0 to R-5	> R-5
Unheated Slabs		
Horizontal	0.73-0.012 * R_{SBI}	0.67-0.004 * R_{SBI}
Vertical	0.73-0.034 * R_{SBI}	0.56-0.007 * R_{SBI}
No insulation	0.73-0.034 * R_{SBI}	0.56-0.007 * R_{SBI}
Heated Slabs		
48 in. horizontal	1.35-0.030 * R_{SBI}	1.20-0.009 * R_{SBI}
36 in. vertical	1.35-0.080 * R_{SBI}	0.95-0.016 * R_{SBI}
No insulation	1.35-0.080 * R_{SBI}	0.95-0.016 * R_{SBI}

Standard 90.1-1989R. For horizontal positions, the F-factor is based on a 48-in. depth and for vertical insulation positions, the F-factor is based on a 36-in. depth. For un-insulated slabs in locations that normally require slab-edge insulation (i.e., > 3000 HDD65), the allowable load is based on 36-in. depth of vertical insulation. This method represents a conservative approach (i.e., tending to preserve stringency) to adding this new flexibility because it bases the loads on the most effective and cost-efficient position and depth for the insulation.

For unheated slabs: (3.20)

for horizontal insulation:

- for HDD65 <= 3000, $R_{SBI} = 0.0$
- for 3000 < HDD65 <= 5000, $R_{SBI} = 0.00135 \times HDD65 + 3.25$
- for 5000 < HDD65 <= 8000, $R_{SBI} = 0.0004 \times HDD65 + 8.0$
- for HDD65 > 8000, $R_{SBI} = 11.2$

for vertical insulation:

- for HDD65 <= 3000, $R_{SBI} = 0.0$
- for 3000 < HDD65 <= 5000, $R_{SBI} = 0.0005 \times HDD65 +3.2$
- for 5000 < HDD65 <= 8000, $R_{SBI} = 0.0001 \times HDD65 +5.2$
- for HDD65 > 8000, $R_{SBI} = 6.0$

for no insulation:

same as vertical insulation.

For heated slabs:

for horizontal insulation:

- for HDD65 <= 3000, $R_{SBI} = 0.0$
- for 3,000 < HDD65 <= 5000, $R_{SBI} = 0.00135 \times HDD65 + 5.25$
- for 5,000 < HDD65 <= 8000, $R_{SBI} = 0.0004 \times HDD65 + 10.0$
- for HDD65 > 8000, $R_{SBI} = 13.2$

for vertical insulation:

- for HDD65 <= 3000, $R_{SBI} = 0.0$
- for 3000 < HDD65 <= 5000, $R_{SBI} = 0.0005 \times HDD65 + 5.2$
- for 5000 < HDD65 <= 8000, $R_{SBI} = 0.0001 \times HDD65 + 7.2$
- for HDD65 > 8000, $R_{SBI} = 8.0$

for no insulation:

same as vertical insulation.

Note that this procedure provides credit for insulation that extends under the entire slab and permits the trade-off of insulation depths and R-values down to zero insulation levels. The justification for providing these additional trade-offs is found in Section 13, *Building Energy Cost Budget Method* in Standard 90.1-1989.

3.11.3 Slab-On-Grade Floor Loads

The cooling and heating loads for concrete slabs on grade (CL_{SB} and HL_{SB}) are calculated using Equations 3.21 and 3.22. Concrete slabs will have no effect on cooling loads. The cooling term ($CCoef_{SB}$) is included so that alternate assumptions can be implemented easily in the future.

$$CL_{SB} = Perimeter_{SB} \times CCoef_{SB} \times F_{SB} \times CDD50 \quad (3.21)$$

$$HL_{SB} = Perimeter_{SB} \times HCoef_{SB} \times F_{SB} \times HDD65 \quad (3.22)$$

where	CL_{SB}	=	cooling load for slabs
	HL_{SB}	=	heating load for slabs
	$Perimeter_{SB}$	=	length of exposed slab-on-grade floor perimeter in ft
	$CCoef_{SB}$	=	0.0 = from Standard 90.1-1989R, Appendix C, Table C.6-11.
	F_{SB}	=	F-factor of exposed slab-on-grade floor
	CDD50	=	cooling degree-days base 50°F for the site.
	$HCoef_{SB}$	=	13.873 = from Standard 90.1-1989R, Appendix C, Table C.6-11: 2.28E-04 × 0.608488 × 100000
	HDD65	=	heating degree-days base 65°F for the site.

3.12 Below-Grade Walls

Below-grade walls are defined as walls below finish grade and **not** as below-grade wall assemblies, portions of which may be above finish grade. In COM*check*, user entry determines what part of a below-grade wall assembly is assumed to be below grade, and the software uses that information to model part of the wall as below grade and part as above grade.

3.12.1 Below-Grade Wall Assemblies

COM*check* defines seven types of masonry walls that may be used either above grade or below grade. The seven types are

- solid concrete ≤ 8 in.
- solid concrete > 8 in.
- CMU ≤ 8 in. with empty cells
- CMU >8 in. with empty cells
- CMU ≤ 8 in. with integral insulation
- CMU >8 in. with integral insulation
- Other.

The balance of assembly R-values for basement walls were derived from the above-grade structural masonry wall types shown in Table 3.10 for above-grade walls. For below-grade walls, the balance of assembly R-value is calculated as a sum of the concrete/masonry R-value and the inside air film - outside air films (R-0.17) have been removed. Unfurred below-grade walls are assumed to have rigid insulation on the outside of the walls; hence, the balance of assemblies are lower than those with interior furring by the R-value of the assumed gypsum board finish (R-0.45).

Table 3.17. Balance of Assembly R-values for Below-Grade Walls

Layer Name	Solid Concrete or Masonry		CMU w/Empty Cells		CMU w/Integral Insulation	
	<8”	>8”	<8”	>8”	<8”	>8”
Concrete/Masonry	0.68	1.02	1.31	1.57	1.56	2.36
Inside Air Film	0.68	0.68	0.68	0.68	0.68	0.68
Total Assembly R-Value (unfurred)	1.36	1.70	1.99	2.25	2.24	3.04
1/2-in. Gypsum Board	0.45	0.45	0.45	0.45	0.45	0.45
Total Assembly R-Value (furred)	1.81	2.15	2.44	2.70	2.69	3.49

3.12.2 Below-Grade Wall Area

Proposed Area. Above-grade portions of below-grade wall assemblies are estimated from the average height and average depth below-grade inputs. Above-grade portions of below-grade walls are treated as above-grade walls. The definition of a below-grade wall in this document is different from the definition used with the prescriptive packages, which permits some above-grade wall area to be included in what is considered below-grade wall. For purposes of this document, the term "below-grade wall" applies only to the portion of the wall that is below grade.

Below-grade areas of below-grade walls (A_{BBW}) are determined according to the following formula:

$$\begin{aligned} &\text{If,} \quad H_{BG} \leq D_{BG} \\ &\qquad A_{BBW} = A_{BW} \\ &\text{else,} \quad A_{BBW} = A_{BW} \times (D_{BG} / H_{BG}) \end{aligned} \tag{3.23}$$

where A_{BBW} = below-grade area of below-grade wall assembly
A_{BW} = opaque area of below-grade wall assembly
H_{BG} = average height of below-grade wall
D_{BG} = average depth of below-grade wall.

Budget Area. The wall area for determining budget loads for below-grade walls is identical to that used for calculating loads for the proposed building.

3.12.3 Below-Grade Wall R-Values and Heat Capacity

Proposed R-Values and Heat Capacity. Above-grade portions of below-grade wall assemblies are treated the same as above-grade walls. Heat capacity for the above-grade portion of all below-grade walls is set at 1.0. The heat capacity is used in the above-grade wall heating and cooling loads calculation. The R-value for below-grade wall assembly (R_{BWA}) is determined using the following equation:

$$R_{BWA} = R_{BW\text{-}BOA} + R_{BW\text{-}CVI} \times AF_{BW} + R_{BW\text{-}CNI} \tag{3.24}$$

where R_{BWA} = R-value of below-grade wall assembly
$R_{BW\text{-}BOA}$ = R-value of balance of assembly (excluding insulation) for below-grade wall type
$R_{BW\text{-}CVI}$ = R-value of cavity insulation as input by the user
AF_{BW} = adjustment factor for parallel path conduction (from Table 3.18) based on below-grade wall type
$R_{BW\text{-}CNI}$ = R-value for continuous insulation as input by the user.

Budget Building R-value and Heat Capacity. The R-value for below-grade wall assemblies (R_{BWI}) is as specified in the following equation, which is based on Figure 8-7 in Standard 90.1-1989:

$$\begin{aligned} &\text{for HDD65} \leq 3000,\ R_{BWA} = R_{BW\text{-}BOA} \\ &\text{for } 3000 < \text{HDD65} < 15000,\ R_{BWA} = 4.5 + 0.00075 \times \text{HDD65} \\ &\text{for HDD65} \geq 15000,\ R_{BWA} = 18 \end{aligned} \tag{3.25}$$

Table 3.18. Below-Grade Wall U-Factor Calculation Coefficients

Wall Type	$R_{BW\text{-}BOA}$	AF_{BW}
Solid Concrete or Masonry, 8 in. or less		
No Furring Strips	1.36	None
Metal Furring	1.81	(Eq. a) If $R_{WL\text{-}CVI} < 11$, $AF = 0.78814-0.03274 * R_{WL\text{-}CVI}$ If $11>= R_{WL\text{-}CVI} < 30$, $AF = 0.54564-0.01069 * R_{WL\text{-}CVI}$ Else, $AF = 6.7482/R_{WL\text{-}CVI}$
Wood Furring	1.81	(Eq. d) If $R_{WL\text{-}CVI}<11$, $AF = 0.9921-0.03297 * R_{WL\text{-}CVI}$ Else, $AF = 0.78526-0.01417 * R_{WL\text{-}CVI}$
Solid Concrete or Masonry, > 8 in. thick		
No Furring Strips	1.70	None
Metal Furring	2.15	Eq. a
Wood Furring	2.15	Eq. d
CMU, 8 in. or less w/ Empty Cells		
No Furring Strips	1.99	None
Metal Furring	2.44	Eq. a
Wood Furring	2.44	Eq. d
CMU, > 8 in. w/ Empty Cells		
No Furring Strips	2.25	None
Metal Furring	2.70	Eq. a
Wood Furring	2.70	Eq. d
CMU, 8 in. or less w/ Integral Insulation		
No Furring Strips	2.24	None
Metal Furring	2.69	Eq. a
Wood Furring	2.69	Eq. d
CMU, > 8 in. w/ Integral Insulation		
No Furring Strips	3.04	None
Metal Furring	3.49	Eq. a
Wood Furring	3.49	Eq. d
Other	User input is assembly U-factor.	

The expressions that we developed for below-grade wall assemblies and Figure 8-7 in Standard 90.1-1989 specify R-values for wall assemblies, which we have interpreted to include wall structural components; i.e., insulation, finishes, and interior air films. For locations where no insulation is required, we set the R-value of the assembly to the balance of assembly value for the particular assembly type, rather than to zero, as in Figure 8-7.

Above-grade portions of below-grade wall assemblies are treated the same as above-grade walls.

3.12.4 Below-Grade Wall U-Factor

Proposed U-Factor. The proposed below-grade wall U-factor (U_{BW}) is calculated using Equation 3.26. R_{soil} is selected from Table 3.19 based on the average depth of the bottom of the wall below the surface of the ground.

$$U_{BW} = 1 / (R_{BWA} + R_{soil}) \quad (3.26)$$

where R_{BWA} = R-value of the below-grade wall assembly
R_{soil} = effective R-value of the soil from Table 3.17.

Table 3.19. Effective R-Value of Soil for Below-Grade Walls

Depth (ft)	R_{soil}
1	0.86
2	1.6
3	2.2
4	2.9
5	3.4
6	4.0
7	4.5
8	5.1
9	5.6
10 or more	6.1

The original equation from Standard 90.1-1989R specified the use of the insulation R-value plus a fixed value of 0.85 for the non-insulation portions of below-grade walls for interior and exterior air film coefficients. We have chosen to use values for the entire below-grade wall assembly (R_{BWA}) because they better reflect the actual performance variations in these assemblies.

Budget U-Factor. Values for the U-factor for standard walls are taken from Section 5 of Standard 90.1-1989R.

3.12.5 Below-Grade Wall Loads

The cooling and heating loads for below-grade walls (CL_{BW} and HL_{BW}) are calculated using Equations 3.27 and 3.28.

$$CL_{BW} = Area_{BW} \times CCoef_{BW} \times U_{BW} \times CDD50 \quad (3.27)$$

$$HL_{BW} = Area_{BW} \times HCoef_{BW} \times U_{BW} \times HDD65 \quad (3.28)$$

where CL_{BW} = the cooling load for the below-grade wall
HL_{BW} = the heating load for the below-grade wall
$Area_{BW}$ = area of below-grade wall in ft^2
$CCoef_{BW}$ = 3.158 = from Standard 90.1-1989R, Appendix C, Table C.6-11: 2.58E-04 × 12.24 × 1000
U_{BW} = U-factor for below-grade walls
CDD50 = cooling degree-days base 50°F for the site.
$Area_{BW}$ = area of below-grade wall in ft^2
$HCoef_{BW}$ = 13.934 = from Standard 90.1-1989R, Appendix C, Table C.6-11: 2.29E-04 × 0.608488 × 100000
HDD65 = heating degree-days base 65°F for the site.

3.13 Calculation of Envelope Compliance Index

Cumulative annual space-conditioning coil loads (heating plus cooling) is the basis for both the prescriptive and system performance envelope compliance paths in the Standard 90.1 including ENVSTD, the ACP tables in Standard 90.1-1989, and the Appendix A tables in the 90.1-1989 Code. The term "coil" here refers to the heat exchanger coils in the HVAC system, which must meet both thermal loads in the space as well as loads created by system fans. The COM*check* software uses an index based on coil loads to determine compliance status and to convey information about performance relative to the code. This same index has been used in defining the prescriptive packages. The envelope compliance index (ECI) is defined in the following equation:

$$ECI = [(CL_{REQ} + HL_{REQ}) - (CL_{DES} + HL_{DES})] / (CL_{REQ} + HL_{REQ}) \qquad (3.29)$$

where CL_{REQ} = required (i.e., maximum allowed) cumulative annual cooling coil load normalized a square foot of conditioned floor area basis [Btu/(y·ft^2)]

CL_{DES} = cumulative annual cooling coil load for the proposed design normalized on a square foot of conditioned floor area basis [Btu/(y·ft^2)]

HL_{REQ} = required (i.e., maximum allowed) cumulative annual heating coil load normalized on a square foot of conditioned floor area basis [Btu/(y·ft^2)]

HL_{DES} = cumulative annual heating coil load for the proposed design normalized on a square foot of conditioned floor area basis [Btu/(y·ft^2)].

COM*check* determines envelope compliance based on ECI and displays calculated ECI results in the performance field to the nearest % and to the nearest tenth of one % on the status line for ECI values between -1% and +1%; e.g., -0.7%. Any design having an ECI displayed as 0.0% or higher is considered to comply, even though the actual design space-conditioning loads may be up to 0.05% greater than the required ECI--an insignificant margin. This provision ensures consistency between displayed numeric results and compliance messages.

The equations used in calculating cooling and heating load values for the proposed design and for calculating the requirements (i.e., the maximum loads permitted under the code) are expanded in the equations below and are specified fully in Section 3.2.3. The cooling and heating coil load terms are identical and are presented as a single set of equations.

$$CL = (CL_{WW} + CL_{RF} + CL_{SK} + CL_{EF} + CL_{WU} + CL_{BW} + CL_{SB}) / BFA \qquad (3.30)$$

where CL_{WW} = cooling coil load attributable to windows and opaque exterior above-grade walls and doors (Btu/y)

CL_{RF} = cooling coil load attributable to roofs (Btu/y)

CL_{SK} = cooling coil load attributable to skylights (Btu/y)

CL_{EF} = cooling coil load attributable to exposed floors (Btu/y)

CL_{WU} = cooling coil load attributable to walls next to unconditioned spaces (Btu/y)

CL_{BW} = cooling coil load attributable to below-grade walls (Btu/y)

CL_{SB} = cooling coil load attributable to concrete slabs on grade (Btu/y)

BFA = building conditioned floor area.

$$HL = (HL_{WW} + HL_{RF} + HL_{SK} + HL_{EF} + HL_{WU} + HL_{BW} + HL_{SB}) / BFA \quad (3.31)$$

where HL_{WW} = heating coil load attributable to windows and opaque exterior above-grade walls and doors (Btu/y)

HL_{RF} = heating coil load attributable to roofs (Btu/y)

HL_{SK} = heating coil load attributable to skylights (Btu/y)

HL_{EF} = heating coil load attributable to exposed floors (Btu/y)

HL_{WU} = heating coil load attributable to walls next to unconditioned spaces (Btu/y)

HL_{BW} = heating coil load attributable to below-grade walls (Btu/y)

HL_{SB} = heating coil load attributable to concrete slabs on grade (Btu/y)

BFA = building conditioned floor area.

4.0 Mechanical Documentation

COM*check* reduces the complexity of the mechanical requirements in the supported codes. Because most requirements in the mechanical section of the energy code are mandatory, the *Mechanical* section of the software works somewhat differently than the *Envelope* and *Lighting* sections. Rather than generating a numeric compliance index, the *Mechanical* section generates a customized list of mandatory requirements applicable to the mechanical components identified by the user.

The *Mechanical* section of the COM*check* software was designed to provide a simplified and enforceable set of requirements for building heating, cooling, and hot-water systems. Buildings that comply with the COM*check* software requirements or the corresponding code-language sections in the IECC are deemed to comply with the building mechanical requirements in Sections 403 and 404 of the 90.1-1989 Code. The primary purpose of this section is to document the technical basis for the changes designed to simplify, clarify, and improve enforcement results in equivalent stringency with the 90.1-1989 Code. Where applicable, the 90.1-1989 Code sections are noted in the subsection headings.

4.1 Scope and Permitted Equipment Types

4.1.1 Heating and Cooling Equipment

The following list of most common heating and cooling equipment types are covered by COM*check*:

- Unitary-packaged absorption cooling equipment – electrically operated or fuel-fired
- Unitary-packaged, split-system or packaged terminal air-conditioners and heat pumps
- Central air handling units with any heating or cooling source
- Cooling sources: chilled water, refrigerant (direct expansion)
- Heating sources: electric resistance or fuel-fired furnace, hot water, steam
- Zonal fan distribution systems with hydronic or steam heating, hydronic cooling or both
- Hydronic heat pumps served by a circulating or ground-coupled water loop and central plant, if needed.

All common plant equipment types are supported, including:

- Electric and fuel-fired steam and hot water boilers
- Electric water chillers
- Refrigeration condensing units
- Absorption water chillers.

Both single-zone and multi-zone systems are covered by COM*check* for the following system types:

- Constant volume single-zone distribution systems
- Variable volume "changeover" multiple-zone distribution systems
- Radiant heating systems
- Single duct variable air volume with any of the following zone terminal devices:
  - Standard VAV boxes with or without reheat

  - Fan-powered VAV boxes with or without reheat
- Dual duct variable air volume with any of the following zone terminal devices
  - Mixing boxes
  - Standard VAV boxes with or without reheat
  - Fan-powered VAV boxes with or without reheat
- Three duct constant volume with zone terminal mixing boxes.

The requirement for newly-purchased heating and cooling equipment was included to assure that equipment used will meet the efficiency requirements in EPAct or NAECA (Public Law 100-12) without the efficiencies needing to be checked. A review of available equipment manufacturers' literature as well as the Air Conditioning and Refrigeration Institute's (ARI) online database (ARI 1996) and the California Energy Commission's (CEC 1995) cooling equipment database did not show any large commercial package air-conditioners or heat pumps then being manufactured with energy efficiency eatio (EER) efficiencies below those required under the 90.1-1989 Code.

4.1.2 Mechanical Equipment Efficiency (403.1)

With the exception of boilers, the mechanical equipment efficiency for all single-zone, unitary equipment is addressed through EPAct (Public Law 102-486). Because reconditioned boilers are sometimes used in new construction, boilers must meet requirements of EPAct (Public Law 102-486) and the 90.1-1989 Code.

Research performed in 1996 (Baylon and Heller) showed that duct furnaces and unit heaters that do not meet the 90.1-1989 Code minimum efficiency levels are still readily available. Occasionally, used central plant and large, packaged equipment is specified in an otherwise completely new system. Therefore, all equipment not covered by EPAct or NAECA are required to meet the minimum efficiency requirements from the 90.1-1989 Code. Minimum efficiencies for these types of equipment are included in tables in the IECC. Equipment made up of components from different manufacturers, such as built-up DX cooling systems, is required to meet requirements found in the tables. For "custom" systems, calculations are required to demonstrate compliance with minimum equipment efficiencies.

4.1.3 Economizer Trade-off

COM*check* provides an economizer trade-off that is not specified in the 90.1-1989 Code. The use of economizers is required under the 90.1-1989 Code in specific climates with systems > 90,000 Btu/h cooling capacity. Although the cost of including an economizer for a given size of system can be assumed to be fairly consistent across the country, the efficiency benefits and hence cost effectiveness of economizers vary significantly with climate. The economizer trade-off allows building designers to trade-off use of an economizer in exchange for use of higher-efficiency air-conditioning equipment.

Table 4.1 shows the increased cooling efficiency required for an air-conditioner or heat pump to fully offset the absence of an air-side economizer in each climate zone in which economizers are required under COM*check*. These efficiencies generally result in levels of energy efficiency that are somewhat greater than with using minimum-efficiency-level cooling equipment (as defined by EPAct [Public Law 102-486] or NAECA [Public Law 100-12]) and air-side economizers.

Table 4.1. EER Requirements for Economizer Trade-off

Equipment Size Category	EER under EPAct	Zones 6a, 9a, 10a, 11a, 12a, 12b, 12a, 13b, 14a, 14b, 15 - 19	Zones 4a, 10b, 11b, 7a, 9b, 8, 3a	Zones 4b, 5a, 5b, 6b, 7b
			28% Increase in EER	17% Increase in EER
65,000 Btu/h to 135,000 Btu/h	8.9	N/A	11.4	10.4
135,000 Btu/h to 760,000 Btu/h	8.5	N/A	10.9	9.9
760,000 Btu/h or more	8.2	N/A	10.5	9.6

The economizer trade-off was developed from the economizer trade-off tables shown in Section 4.1.36.3 of Standard 90.1-1989R. In that work, a single-story building was modeled in DOE2.1E to determine the energy cost of foregoing the use of an economizer in 16 different U.S. locations. The difference in cooling energy between the economizer and no economizer simulations was calculated for each of the 16 cities using a base case energy efficiency ratio EER of 10.3. This cooling energy difference was multiplied by the ratio of the energy input ratio (EIR), calculated using the EER from the proposed Standard 90.1-1989R requirement, to the base case EIR actually used in the simulation. This method allowed for an estimate of the total difference in building cooling energy that would be required if different efficiency equipment had been used in the simulation. This estimate was necessary because of the changing base efficiency required by Standard 90.1-1989 for different size cooling equipment. The difference in energy cost was calculated by multiplying the energy savings by the assumed electrical energy price.

The change in EIR necessary to make up the economizer/no economizer cost difference was calculated by dividing the difference in energy cost used above by the no economizer cooling load and the electrical energy price. The result is the decrease in EIR (delta EIR) needed to make up the energy cost difference.

The above steps were done for the four packaged cooling equipment categories for each of the 16 climates. The resultant delta EIRs were regressed against a climate parameter (CDD65) using a robust regression technique. The regression was then used to calculate the delta EIR for various CDD65 values.

By subtracting the delta EIR from the original EIR (calculated from the Standard 90.1 EER values), and then converting the resultant EIR to an EER, the EER needed to make up for eliminating the economizer was computed for various CDD65 values. These values were then placed into Standard 90.1-1989R trade-off table for economizers vs. cooling efficiency.

The economizer requirement in COM*check* is based on the percentage improvements in EER in the heat pump section of the economizer trade-off table in Section 6.1.3 of Standard 90.1-1989R. In examining the 90,000 to 135,000 Btu/h and the 135,000 to 240,000 Btu/h categories, the Standard 90.1-1989R economizer trade-off shows a 28% average improvement in system EER for locations having CDD65 values between 901 and 1800, when all heat pump and air-conditioner categories are considered, and a 17% average improvement in system EER for locations having CDD65 values between 1801 and 2700. An examination of 4774 climate locations dispersed among the 33 COM*check* climate zones showed that the majority of locations in Zones 3a, 4a, 7a, 8, 9b, 10b, and 11b had CDD65 values between 901 and 1800. Similarly, the climate data show that Zones 4b, 5a, 5b, 6b, and 7b all have the majority of climate locations in each zone falling between CDD65 values of 1801 and 2700. For the majority of locations with CDD65 values higher than 2700, economizers are not required under COM*check* and no trade-off was considered. For climate Zones 6a, 9a, 10a, 11a, 12a, 12b, 13a, 13b, 14a, 14b, 15, 16, 17, 18, and 19, the majority of locations in each climate zone have CDD65 values below 900 and are not candidates for an economizer trade-off because the energy savings from the economizer preclude a reasonable EER trade-off under Standard 90.1-1989R.

The COM*check* requirements for economizer trade-off show 28% and 17% improvements in EER relative to the minimum EERs as listed under EPAct (Public Law 102-486) for each size range of unitary packaged air-conditioning equipment. For simplicity, separate trade-off requirements are not listed for heat pumps (the tonnage of unitary air conditioning units shipped in these size ranges is several times that of heat pumps). The COM*check* table begins at 90,000 Btu/h because that is the smallest size for which an economizer is required. In addition, because the percentage efficiency improvement is essentially identical to that proposed under Standard 90.1-1989R, but is applied to the lower equipment efficiency levels in Standard 90.1-1989, the magnitude of energy savings from the trade-off is actually larger than that shown.

Because the supporting research for the trade-off was performed for unitary packaged equipment only, the economizer trade-off is not allowed for built-up systems.

4.1.4 Load Calculations (403.2.1)

Load calculations are an essential part of good mechanical design. They are used in the equipment selection process to assure that comfort conditions are maintained using the most economical piece of equipment. As such, there are many variations on the assumptions used in these calculations based on design intent, the experience of the designer, climate, future additions, etc. It is not possible to regulate the quantity of assumptions nor the judgment of the designer when it comes to load calculations. Maintaining a legal standard of care helps to ensure that minimum engineering principles are observed for all system designs. Though most building inspectors will not review load calculations for accuracy, maintaining the requirement for load calculations underscores the designer’s primary responsibility for load calculations.

4.1.5 Equipment/System Sizing (403.2.2)

Equipment selection and system sizing is also an essential part of good mechanical design. Selecting and sizing equipment requires a designer to consider a variety of parameters including air flow, duct design, sensible and latent loads, operating sequences (warm-up/cool-down), and equipment location to name a few. A designer must also take budget and equipment availability into account.

The requirements in Standard 90.1 take these parameters into account. But to accommodate the full range of flexibility necessary to properly select equipment, the rules become subject to such a broad range of possibilities that the requirement has no practical effect on energy consumption. For example, a designer could take a worse case set of assumptions into account for their load calculations, add warm-up/cool-down sizing factors to that load, and then select the “smallest” piece of equipment available to meet the load. This could be based on a specific manufacturer’s product line that is lowest cost, but only manufacturers' units that substantially exceed justified loads. This has the effect of negating any energy benefits of the requirement.

As with load calculations, sizing requirements may not be explicitly enforceable by the local building department; however, they do establish legal responsibility for the engineer to properly size and specify system equipment. As long as a plans examiner ensures that systems and equipment are completely specified on the plans, then a field inspector can still inspect to see if a system is built according to approved plans and specifications.

4.1.6 Separate Air Distribution (403.2.3)

Neither COM*check* nor the IECC requires special processes to be identified and served by separate air distribution systems. The required hardware and controls needed to serve special processes or maintain critical environments make these systems much more expensive than systems needed solely for comfort conditioning. In short, there are economic incentives to keep specialty systems as small as possible. In addition to economic reasons, enforcing or complying with this requirement requires knowledge about the use of the space prior to the building being constructed. For a large amount of square footage, particularly speculative office, commercial and light industrial construction, this information is not known until space is leased to tenants. In these cases, specialty and supplemental systems are usually added as tenant improvements and can be dealt with in terms of code compliance at the time they are constructed.

4.1.7 Ventilation and Fan Power (403.2.4)

COM*check* requires that all enclosed spaces where people are expected to remain for extended periods of time be continuously vented with outdoor air. Ventilation can be provided mechanically or through natural ventilation (passive ventilation strategies such as windows). For minimum ventilation requirements, COM*check* refers the user to the local code or, in the absence of local requirements, Chapter 4 of the International Mechanical Code (IMC) (ICC 1996).

Mechanically ventilated spaces are typically controlled by a thermostat. The 90.1-1989 Code requires a thermostat in each space. It also requires that the design comply with a ventilation requirement to be determined by the adopting authority. Most ventilation requirements are based on ASHRAE Standard 62-1989. This standard provides for the design of ventilation systems to achieve adequate air quality in buildings. It was intended by the SSPC 62 that once a system is designed in accordance with Standard 62, it would be operated as such. The IMC, Chapter 4, codified Standard 62 and extended the scope of its authority to include system operation, thereby codifying the intent of SSPC 62.

When operating a unitary system that provides heating, cooling, and ventilation, the supply-air fan is controlled by the thermostat. Temperature control is achieved by activating the heating or cooling subcomponent and the supply-air fan, thereby adding or removing heat from a space.

Most thermostats have a fan control setting that allows placing the fan in either a continuously ON mode or in an AUTO mode. When placed in the AUTO mode, the supply fan and subcomponent are automatically shut off when temperature conditions are satisfied. If a space is relying on the supply of ventilation air via a mechanical system, the supply of that air is then dependent on the rate of heat gain/loss of the space. In energy-efficient buildings designed to meet Standard 90.1 requirements, this dependency means that the rate of heat gain/loss is minimized through insulation, shading, etc. This also means that temperature conditions are more easily satisfied, and the system is likely to remain off a higher percentage of the time. Even a properly sized system will experience this situation during part-load conditions. While the system is off, ventilation air is not being supplied to the space, which violates the IMC Chapter 4 provisions.

COM*check* requires that the fan system be operated continuously to meet the provisions of the IMC, Chapter 4, and the intent of ASHRAE Standard 62. “Continuously” in this context means continuously during occupied periods, and requires the use of a thermostat capable of being set to continuously run the supply fan (i.e., set to the fan ON mode).

As with the 90.1-1989 Code, systems capable of providing for higher ventilation rates than minimum levels must be able to reduce outdoor-air flow to minimum levels through the use of manual or automatic means such as control dampers or fan volume controls.

COM*check* allows the use of natural ventilation of building spaces through building openings (e.g., windows, doors, louvers) to ensure compliance. However, it refers the user to either the local code or to Section 402 of the IMC to find minimum opening area requirements to ensure adequate natural ventilation rates. The IMC, Chapter 4, allows natural ventilation as an acceptable alternative to continuous mechanical ventilation. The IMC contains specific provisions that must be met to provide the required levels of ventilation through non-mechanical means. The IMC also assumes that a design containing these provisions will provide sufficient opportunity for the occupant to ventilate the space if they feel a need for outdoor air. Because the occupant has the ability to directly control ventilation levels, the area of ventilation required by the IMC is not required to be permanently open.

COM*check* does not place limits on fan power in terms of W/cfm. We felt that the Standard 90.1-1989 requirements (based on W/cfm) are not effectively enforced in practice because they depend on design calculations. In system designs using the packaged HVAC equipment allowed under COM*check*, fan energy use is typically less than the maximum allowed under Standard 90.1-1989. In the allowed system types, higher fan energy use generally only occurs where extra filtration is needed, a situation for which Standard 90.1-1989 provides an exception. However, COM*check* does place limits on air handler design in variable flow systems with the following requirements:

- Discharge dampers are prohibited on individual fans with motors ≥ 25 hp.
- Variable volume fans must be driven by a mechanical or electrical variable speed drive, the fan must be a vane-axial type with variable pitch blades, or the fan motor must have controls or devices that result in fan motor demand of no more than 50% of their design wattage at 50% of design air flow when static pressure set point equals 1/3 of the total design static pressure.
- Fan systems with no more than 50% design wattage at 50% design air flow must be supported by specifications and information sufficient for an inspector to verify conformance at the time of inspection.

No requirements for VAV fan partial-load energy use exist in COM*check*. VAV systems are not allowed in COM*check* with the exception of packaged VAV changeover systems. When properly designed, these systems operate at design conditions much like a constant volume system because the volume control dampers are in a fully open condition. These systems are assumed to reduce fan energy use at off-design conditions over their constant volume counterparts and so are allowed under COM*check*.

Air Transport Energy: Section 403.2.4 limits fan power in terms of watts per cfm. There are many ways to reduce fan power including efficient fan control technologies and designing for lower static pressure in the system. Enforcement of this type of requirement involves reviewing design calculations and inspecting in the field to ensure the system is built as designed. Small changes in the design, such as a change in the size of a duct, can move a system from complying to non-complying. Enforcement difficulty is the primary reason for not including air transport energy requirements.

Fan Control Technologies: COM*check* requires more efficient fan air flow controls starting at 25 hp instead of 75 hp as required in the 90.1-1989 Code Section 403.2.4. This difference is necessary to achieve energy equivalence with the 90.1-1989 Code. The lower motor horsepower threshold is required to offset the removal of limits on fan power.

The main impact of these two requirements is to explicitly prohibit discharge dampers on fans of 25 hp and greater. It explicitly allows certain technologies and allows nearly all other technologies as long as they meet certain performance criteria. Enforcement of this provision is limited to the fan control technologies and need not involve the distribution system. Cost premiums for the prescriptive technologies in the proposed language have dropped significantly since Standard 90.1-1989 was adopted in 1989, and many other cost-effective fan control technologies have also become available.

4.1.8 Pumping System Design (403.2.5)

COM*check* requires hydronic systems of 600,000 Btu/h or greater design capacity (heating or cooling) to have part-load controls that:

1. automatically reset the supply water temperatures based on zone return water temperature, building return water temperature, or outside air temperature as an indicator of building heating or cooling demand. The temperature shall be capable of being reset by at least 25 % of the design supply-to-return water temperature difference; or
2. reduce pump flow by at least 50 % of design flow rate by: adjustable speed drive(s) on pump(s), multiple staged pumps where at least 1/2 of the total pump horsepower is capable of being automatically turned off, or control valves designed to modulate or step down and close as a function of load.

These requirements are the result of combining the 90.1-1989 Code Section 403.2.5, *Pumping System Design*, and 403.2.6.8, *Temperature Reset for Hydronic Systems*. Exception 4 to 403.2.5 states that systems that comply with 403.2.6.8 do not need to comply with 403.2.5. Exception 1 to 403.2.6.8 states that systems complying with 403.2.5 do not need to comply with 403.2.6.8. These two requirements can therefore be combined into one requirement, which gives the choice of either to the designer.
600,000 Btu/h was chosen as the lower limit (instead of 10 hp) because a system of this capacity will rarely need more than 10 hp of pumping capacity. This approach maintains design flexibility while maintaining equivalent stringency with the 90.1-1989 Code.

4.1.9 System Controls (403.2.6.1)

In COM*check*, the system control requirement was simplified to a single thermostatic control per HVAC system. Section 403.2.6.1 requires each system to have at least one temperature control device. Section 403.2.6.2 requires each zone to have its own temperature and humidity control. Therefore, any multi-zone system with zone controls will comply with Section 403.2.6.1 automatically.

This thermostat must be in the building zone served by the HVAC system. The thermostat must also have a capability for automatic setback/shutdown, as in the 90.1-1989 Code, and an accessible override so occupants can operate the system during off-hours without having to disable or reprogram the thermostat. Standard programmable thermostats meet these requirements.

The 90.1-1989 Code does not require a thermostat setback capability on thermostats for systems serving areas that are expected to operate continuously. In addition, setback or shutoff control is not required on thermostats that control the temperature in residences, hotel/motel guestrooms, or areas where the heating and/or cooling system might normally be expected to operate continuously.

VAV changeover systems use multiple thermostats (one per controlled zone). However, a single-system control signal is developed from all zone thermostats. Hence, they are somewhat an exception to the one thermostat per system rule.

4.1.10 Zone Controls (403.2.6.2)

COM*check* maintains the 90.1-1989 Code requirements for zone control as already described in the System Controls section, including the exception that allows control in blocks of zones served by "perimeter systems."

4.1.11 Zone Thermostat Capability (403.2.6.3)

COM*check* maintains the 90.1-1989 Code requirements for zone control as already described in the System Controls Section 4.1.9. COM*check* allows many types of automatic control including programmable thermostats, manual thermostat/timeclock combinations, and fully automated energy management systems.

4.1.12 Heat Pump Thermostat (403.2.6.4)

COM*check* requires that heat pumps with supplementary electric resistance heaters shall use a thermostat designed for heat pump operation. Thermostats specifically designated for heat pumps are designed to control the use of backup electric resistance heat to minimize energy costs.

4.1.13 Humidistats (403.2.6.5)

COM*check* does not set specific design requirements for individual humidistats. Instead, individual humidistats are required for individual humidification systems. This requires zone-level humidity controls that can be modified or removed in the future without affecting other zones.

4.1.14 Simultaneous Heating/Cooling (403.2.6.6)

COM*check-EZ* limits simultaneous heating and cooling by requiring multi-zone systems to be variable-air-volume with zone-level terminal equipment and controls to minimize reheating, recooling or simultaneously mixing air or water that has been mechanically heated or cooled. In contrast, the 90.1-1989 Code prohibits simultaneous heating and cooling except under specific conditions or applications, variable-air-volume systems being one of them. Today, variable-air-volume systems are the most prevalent type of systems used to serve multiple thermostatic zones. Explicitly requiring variable-air-volume systems and exempting multi-zone systems that do not simultaneously heat and cool (such as three-duct or "Texas" multi-zone systems), makes the requirements in the code more compatible with contemporary systems.

In addition to requiring variable-air-volume, COM*check* requires all zone terminal devices (VAV mixing boxes) to have controls that minimize simultaneous heating and cooling. Hydronic fan coils must have separate hot water and cold water supply and return lines to prevent mixing of hot and cold water, except for changeover systems, which are permitted to mix small amounts of water left in the coil at changeover from one mode to another.

4.1.15 Automatic Setback/Shutdown (403.2.7.1)

COM*check* allows many types of automatic control, including programmable thermostats, manual thermostat/timeclock combinations, and fully automated energy management systems. Controls must meet all of the 90.1-1989 Code requirements including:

- automatic setback capability
- 7 day time clock
- 2 hour occupant override
- ability to maintain program settings for 10 hours if power to the control is unexpectedly shut off, such as during a power failure.

COM*check* requires each zone to have automatic controls. Automatic controls at the zone level will comply with 403.2.7.1, *Zone Isolation Controls*, inherently. This allows a wide variety of control and building automation technologies to be used for complex systems.

4.1.16 Shutoff Dampers (403.2.7.2)

As in Standard 90.1-1989, systems with outdoor-air supply and exhaust flow rates > 3,000 cfm of outdoor air must have dampers that automatically close when equipment is not operating. This requirement will mainly affect buildings with a dedicated ventilation system. The requirement does not apply to dampers restricted by health and life safety codes.

4.1.17 Zone Isolation (403.2.7.3)

The 90.1-1989 Code requires, at a minimum, groups of zones not exceeding 25,000 square feet, to have controls that can isolate and/or devices that can isolate and control these zones independently from other zones or zone groups. COM*check* requirements for automatic thermostatic controls also inherently serve to meet the 90.1-1989 Code requirements for zone isolation. In some cases, where a group of perimeter zones exceeds 25,000 square feet, or a group of continuously operating zones exceeds 25,000 square feet, automatic zone controls are less stringent than the 90.1-1989 Code. The expected effect of this simplification in terms of energy use is insignificant and results in a simple enforceable requirement for automatic zone controls, which will inherently meet the zone isolation requirements in most cases.

4.1.18 Economizer Controls (403.2.8)

Prescriptive requirements for economizers were developed from the economizer requirements in Standard 90.1-1989, which requires that all fan systems have either an air or water economizer system, with exceptions made for small fan systems (with a cooling capacity of < 90,000 Btu/h or with a supply capacity of < 3000 cfm). Exceptions are also made for climates with both < 2000 heating degree-days (base 65°F) and summer 2.5% design wet-bulb temperatures in excess of 72°F. Other exceptions exist for envelope-dominated spaces, systems with extensive filtering requirements, systems where the introduction of outside air may affect the performance of other equipment, systems serving residential spaces (including hotel/motel space), systems where site-recovered or site-solar energy resources are used for cooling, or systems serving zones with high amounts of operable openings (i.e., windows and doors).

The economizer requirements in COM*check* provide significant simplification from the 90.1-1989 Code. The system size limitation was retained, so only systems with capacities > 90,000 Btu/h require economizers. No exception was made for systems < 3,000 cfm because this requirement matches the 90,000 Btu/h requirement (assuming a typical 400 cfm per ton of cooling) for typical packaged cooling equipment. An analysis of weather data for 4,774 cities scattered throughout the 33 COM*check* climate zones suggested that economizers would be required for all climate zones except Zones 1a, 1b, 2a, 2b, 3b, and 3c. Almost all of the locations examined for these six climate zones have heating degree-days (base 65°F) of < 2000 hours and have summer 2.5% temperatures in excess of 72°F and thus would be exempt from economizer requirements under the 90.1-1989 Code.

The following exceptions included in the 90.1-1989 Code are implemented in COM*check*:

1. Systems with air or evaporatively cooled condensers that include extensive filtering equipment: This exception has been included and references IMC Chapter 4 for the criteria to determine outdoor air quality.
2. Systems with air or evaporatively cooled condensers where use of outdoor air will affect the operation of other systems. This exception has been incorporated for supermarket refrigeration systems only, thus making it easy to verify in the field.
3. Water-side economizers may be substituted for air-side economizers. This is a logical addition because hydronic system/equipment types are permitted.
4. Water-side economizers are required with three-duct and single-fan dual-duct systems. This requirement is necessary because these types of systems cannot isolate the supply of outside air from the warm-air duct because all supply air passes through a single fan. An air economizer operating in the fully open position would supply 100% outside air to both the cooling and heating ducts. This would not be in compliance with Section 403.2.8 of the 90.l-1989 Code, which prohibits economizer operation from increasing building heating energy use during normal operation. A water economizer coil can be placed directly in the cool air duct, overcoming this problem.

The other 90.1-1989 Code exceptions were removed from the economizer requirements under COM*check* because they were deemed overly complex or required detailed design information that would require extensive documentation or engineering judgment during compliance checking.

Climate Zone 4b appeared to encompass two distinct climate types: dry climates (e.g., Dagget, California and Tucson, Arizona) and relatively humid climates (Austin, Texas; San Antonio, Texas; Baton Rouge, Louisiana; Tallahassee, Florida; Savannah, Georgia; and Mobile, Alabama). Some consideration was given to breaking Zone 4b into two separate zones based on the economizer requirements; however, given the county-based climates zones, the dry areas in Zone 4b consisted of only one county in Arizona, one in California, and three in Texas. In previous work (i.e., with MEC*check* [DOE 1995b, 1995c, 1995d]), we avoided adding a new zone to a state if applied to only one county. The final decision to not create an additional zone had conservative results with respect to preserving stringency because it resulted in the application of the economizer requirement to all of Zone 4b. Designers not wishing to use economizers in the humid parts of Zone 4b can omit them by qualifying for the equipment-efficiency trade-off.

4.1.19 Integrated Economizer Requirement

The COM*check* integrated economizer requirement is considerably stricter than the integrated economizer requirements in the 90.1-1989 Code. In the 90.1-1989 Code, integrated economizers are required for all systems > 180,000 Btu/h installed capacity in climates that require an economizer and have more than 750 hours between 8 a.m. and 4 p.m. with dry-bulb temperatures between 55°F and 69°F. An analysis of the 234 climate locations in Standard 90.1-1989 shows that the only climate zones where this requirement applies for the majority of the 234 sites in that zone are Zones 3a, 4a, 6a, 10a, and 11a. These sites represent primarily the California Coast, Willamette Valley and Oregon Coast, and Western Washington below Bellingham, all of which are very mild climate locations and can make good use of integrated economizers.

This requirement was simplified in COM*check* to require the use of an integrated economizer control strategy. Factory-supplied or factory-installed economizers supplied by major equipment manufacturers include integrated controls, which also prevent ice formation when very cold air is brought over the cooling coils. Non-integrated controls prevent ice formation by not allowing the use of the economizer if the outdoor-air temperature is below a set value (typically around 50°F). Because controls using integrated strategies that also prevent ice formation are commonly used in packaged air-conditioning systems, they were included as a standard requirement for all situations in which an economizer is required.

While economizer sensor type requirements (e.g., differential, temperature, and enthalpy) were proposed in Standard 90.1-1989R, no such requirements were included in COM*check* because such requirements were not included in the 90.1-1989 Code.

4.1.20 Pipe Insulation (403.2.9.1)

The pipe insulation requirements cover three categories of piping:

1. Steam
   1-1/2 in. insulation for pipes <=1-1/2-in. nominal diameter
   3 in. insulation for pipes >1-1/2-in. nominal diameter.
2. Hot water
   1 in. insulation for pipes <=1-1/2-in. nominal diameter
   1-1/2 in. insulation for pipes >1-1/2-in. nominal diameter.
3. Chilled water, refrigerant, brine.
   1-in. for pipes <=1-1/2-in. nominal diameter
   2-in. for pipes >1-1/2-in. nominal diameter.

Requirements are based on these three categories and whether the pipe is above or below 1-1/2 inches in diameter. The pipe insulation requirements in COM*check* vary from those in the 90.1-1989 Code, however the difference, is never more than 1/2 inch of required insulation, with some values higher and some values lower. These changes are expected to improve the ease and consistency of compliance, implementation, and field verification while the energy impacts of the changes are expected to be negligible.

4.1.21 Duct/Plenum Insulation (403.2.9.2)

Duct insulation levels in COM*check* are based on the minimum duct insulation requirements shown in the 90.1-1989 Code. In the 90.1-1989 Code, the insulation requirements for ducts outside of the building envelope are described explicitly in terms of R-value with cooling duct requirements based on cooling degree-days to a 65°F base and heating duct requirements based on heating degree-days to a 65°F base. The requirements for cooling or heating ducts inside the building envelope are based on the design temperature difference between the air inside the duct and the air surrounding the duct under design conditions. This provision requires a determination of design conditions and estimated temperatures inside different buildings spaces. In addition, duct insulation requirements for ducts used for both heating and cooling use the more stringent insulation requirement for either heating or cooling. Because most packaged equipment is designed for both heating and cooling applications and would be so used in the majority of simple buildings, the first simplification made to the *Simple Systems* section was to always use the more stringent (heating or cooling) criterion.

To simplify the duct insulation requirements, assumptions from Table 7-H of the *Federal User's Manual - Performance Standards for New Commercial and Multi-Family High-Rise Residential Buildings* were used (DOE 1994). This table shows default design dry-bulb temperatures, which result in different insulation levels for supply and return ducts inside different building spaces (specifically ventilated attics, unvented attics, other unconditioned spaces, indirectly conditioned spaces, and buried ductwork). Average design drybulb temperature for both heating and cooling seasons as well as the average CDD65 and HDD65 values were determined for each of the COM*check* climate zones using the 234 climate locations outlined in Standard 90.1-1989. Using these data, we were able to determine insulation requirements for interior ducts for each climate zone. Similarly, using the average degree-day data for each zone, exterior-duct insulation requirements were determined. The maximum heating or cooling duct insulation requirement for each zone was used. For all climate zones, this procedure yielded R-5 for the vented attic, unvented attic, and the other unconditioned space category and R-3.3 for indirectly conditioned spaces. For exterior ducts, the zones were grouped into larger HDD65 categories. Based on the resulting duct insulation requirements and common insulation R-values, insulation requirements were selected, resulting in an R-8 requirement for exterior ducts for Zones 1 through 4 (0 to 2000 HDD65), R-6.5 being required for Zones 5 through 14 (2000 to 7000 HDD65), and R-8 being required for Zones 15 through 19 (>7000 HDD65). For simplicity in COM*check*, all unconditioned spaces inside the building are treated the same way, requiring R-5 duct insulation. However, ducts located internal to HVAC equipment, exhaust air ducts, and ducts located anywhere the design temperature difference between air within the duct and air surrounding the duct is < 15°F do not require duct insulation.

4.1.22 Duct/Plenum Construction (403.2.9.3)

COM*check* requires that transverse and longitudinal seams of all ducts be mechanically fastened and sealed using welds, gaskets, mastics (adhesives), mastic-plus-embedded-fabric systems or tapes. Additionally, duct connections to flanges or air distribution system equipment must be sealed and mechanically fastened. In comparison, the 90.1-1989 Code sets sealing requirements based on static pressure in the duct, a very difficult field observation, and according to a referenced standard published by the Sheet Metal and Air Conditioning Contractors National Association. The IECC requirements are generally considered to be the requirements that would apply to nearly all simple systems under strict application of the 90.1-1989 Code requirements. Tapes and mastics used to seal ductwork must be listed and labeled in accordance with UL 181A or UL 181B. In comparison, the 90.1-1989 Code prohibits the use of pressure sensitive tape on ducts operating at 1 inch of static pressure or greater. Field observation of a UL label is much easier than first determining if the tape is pressure sensitive and then determining the static pressure of the duct.

4.1.23 Administration (403.2.10)

Completion requirements under Standard 90.1-1989 have been adapted for easier verification in the field, and are summarized below.

1. Manuals – COM*check* incorporates language similar to that used in the second public review draft of Standard 90.1-1989R. This requires specific topics to be covered by the manuals that can be identified by quick review of the documentation. The new language is also more explicit than the 90.1-1989 Code language, so designers can easily understand what documentation is required.
2. Air Systems Balancing – COM*check* requires verification of dampers at each duct branch or zone terminal device. For complex air distribution systems, dampers are necessary for long-term energy-efficient operation. Additionally, discharge dampers are prohibited on the full complement of zone controls (thermostats, reheat/recool, mixing, balancing dampers) to ensure that the most energy-efficient operation sequence can be achieved should the space-conditioning needs of a zone change.
3. Hydronic Balancing – COM*check* requires verification of balancing valves and pressure test connections at each individual hydronic coil.

4.2 Service Water Heating (SWH) Systems and Equipment

COM*check* includes only water-heating equipment specifically covered by Federal efficiency regulation (primarily EPAct, Public Law 102-486). These types of equipment include:

- electric water heaters of all types
- fuel-fired storage water heaters

- fuel-fired packaged boilers used as water heaters
- fuel-fired instantaneous heaters (as defined under EPAct)
- fuel-fired pool and spa heaters.

Gas or oil water heaters with a storage volume of > 140 gal are not covered by Federal efficiency regulations; their use is allowed under the *Complex Systems* section but not under the *Simple Systems* section.

Water-heating equipment efficiency levels equivalent to those defined in Standard 90.1 are mandated as a manufacturing standard under EPAct. Thus, all above types of water-heating equipment will meet the 90.1-1989 Code efficiency levels. For the same reason, standby loss testing procedures (Sections 401.1, 401.2, and 401.3 in the 90.1-1989 Code [ASHRAE 1993b]) are not included.

4.2.1 SWH Equipment Efficiency (404.1)

Service water heating efficiency is addressed through EPAct (Public Law 102-486) legislation, which establishes minimum manufacturing standards for equipment efficiencies.

4.2.2 Electric/Oil Standby Loss (404.1.1)

Electric and oil service water heating standby losses are addressed through EPAct (Public Law 102-486) legislation.

4.2.3 Unfired Storage Tanks (404.1.2)

Unfired storage tanks are addressed through EPAct (Public Law 102-486) legislation.

4.2.4 Storage Volume (404.1.3)

Storage volume is addressed through EPAct (Public Law 102-486) legislation.

4.2.5 Piping Insulation (404.2)

Like Standard 90.1-1989, COM*check* has specific requirements for heat traps on noncirculating water-heating systems and vent or flue dampers on all water heaters. As in Standard 90.1-1989, the requirement for vent or flue dampers is waived for water heaters that do not have an electrical supply.

4.2.6 Controls (404.3)

Requirements for hot-water temperature settings were removed from COM*check* as they were deemed to be unenforceable. The Standard 90.1-1989 requirement for automatic time-switch controls on circulating hot-water systems was maintained in COM*check*. COM*check* also has a requirement for time-switch controls when heat tracer tape is used with circulating system. This requirement is meant to prevent the use of circulating water as a freeze protection method when unnecessary, since heat tracing is provided for.

4.2.7 Water Conservation (404.4)

No water conservation requirements are included in COM*check*. EPAct (Public Law 102-486) legislation addresses water-using appliances, so all new lavatories and shower heads are presumed to meet this manufacturing standard.

4.2.8 Swimming Pools (404.5)

A requirement for readily-accessible shutoff controls, as well as time-clock switches, for swimming pool heaters and pumps was maintained in COM*check*. Exceptions to the time-clock requirement for solar or site-recovered heating are the same as in Standard 90.1-1989R. In Standard 90.1-1989, an exception was made for pools with over 70% of the annual energy for heat supplied from a site-recovered or site-solar system. This exception required a compliance official to certify the annual fraction of heating energy from different sources. By removing this exception, the COM*check* requirement is more restrictive and more enforceable.

Under COM*check-EZ* Version 1, pool covers were required for all heated swimming pools, but this requirement was removed from COM*check-EZ* Version 2.0. Pool covers are not addressed in the 1998 or 2000 IECC because they were deemed to not fall within the normal scope for a building code and because they have reportedly not been used in some commercial buildings out of concern for safety and liability.

4.2.9 Combined Heating Systems (404.6)

The 90.1-1989 Code requirements related to combined SWH and space-heating equipment is not addressed in COM*check* or the IECC. Section 404.6 of the 90.1-1989 Code serves to prohibit use of combined systems except where boilers are small or water and space-conditioning loads are similar in magnitude. These requirements were not included in COM*check* because it was not clear that the impact of such a requirement in discouraging inefficient combined-system applications would outweigh its potential adverse impact in discouraging highly-efficient combined-systems applications possible with current equipment and controls.

5.0 Lighting

References to specific pertinent 90.1-1989 Code sections are shown in parentheses in the following section headings.

5.1 Interior Lighting Calculation (401.3.2)

COM*check* lighting requirements are based on the prescriptive requirements outlined in Section 401.3.2 of the 90.1-1989 Code. The software simply automates the calculation of the lighting power budget for the building and the connected load of the lighting systems specified in the proposed design. The implementation of this calculation in COM*check* is very similar to the corresponding procedure found in the 90.1-1989 Code, with some simplifications and with changes to the building use types and their corresponding lighting power density (LPD). Lighting power densities (LPDs) used to determine the lighting power budget are based on building use types entered by the user (refer to Section 2.4 of this document, *Lighting Power Budgets)*.

5.1.1 Lighting Control Credits (401.3.3)

Lighting control credits were included in the 90.1-1989 Code as a trade-off for increased installed (proposed) lighting power. However, the lighting control credits were complicated to apply, and special lighting controls have been infrequently used in simple commercial buildings, for which COM*check* was initially targeted.

The control credit approach was also abandoned with Standard 90.1-1989R for reasons of simplicity. Some felt the credits in the 90.1-1989 Code had been ineffective in motivating use of advanced controls because users were able to show compliance without use of the credits. Although control credits were implemented in COM*check* for the Minnesota code, in the interest of simplicity and remaining conservative with respect to stringency, they are not made available for other COM*check* codes.

5.1.2 Area Factors (401.3.2)

One area of simplification to the procedure in COM*check*, which also served to enhance stringency, was the elimination of area factors. Area factors greatly complicate compliance if the area category method is used because ceiling height and room areas must be determined before the allowable wattage of each space can be determined. Area factors have also been eliminated from Standard 90.1-1989R for simplification and in recognition that acceptable power budgets can be established without that information. This change means that the COM*check* lighting power budgets are not directly comparable to code budgets calculated using area factors - the COM*check* values will be more stringent.

5.2 Lighting Input Wattage Defaults

Compliance with the lighting power budget in Standard 90.1 requires the calculation of installed (proposed) wattage of all covered lighting systems. This calculation depends on input wattage values for various lighting technologies and lamp-ballast combinations. The software provides typical wattage values for these lamp-ballast combinations, which can be useful when a specific fixture has not yet been selected or the exact input wattage of a selected fixture is not known. For these suggested input wattage values to be helpful to the user in streamlining the compliance process, the input wattage values need to be representative of the current market and conservative with respect to efficiency. The user needs to be able to use the suggested values knowing that an actual product can easily be found and specified that will be at least as efficient as the suggested value.

A wide variety of similar lighting products is on the market today, and typical values for these products were needed. Three potential sources of this type of information were considered for use:

- industry/manufacturers' data
- Lighting Technology Screening Matrix (LTSM) software internal lighting database (Stucky et al. 1994)
- expanded default/wattage table originally based on 1993 *Advanced Lighting Guidelines* (ExCEC) (CEC 1993).

Industry/manufacturers' data necessarily formed the basis for default wattage values reflecting available products and technologies. However, much work has been done to create summaries of available products and associated characteristics, and much of it is considered representative of products currently on the market. Beginning with raw manufacturers' data was not considered a cost-effective or necessary approach. Rather, existing summaries of applicable data were considered the most appropriate for this purpose.

A search of available summaries found that the LTSM internal database and ExCEC tables were at the time the most current and comprehensive for the level of detail required in COM*check*. Other smaller and usually manufacturer-specific databases existed but were not considered comprehensive enough for this purpose.

The LTSM internal database was developed using a variety of product characteristic sources including manufacturers' data and summaries done by others. This database has a good variety of wattage values for fluorescent, incandescent, exit, and high-intensity discharge (HID) lighting with three fluorescent ballast categories. However, many less-common long fluorescent lamp types and newer compact fluorescent lamps are not yet represented in this database.

The ExCEC data are a collection of default wattage values that cover the majority of compact fluorescent, long fluorescent, and HID product sizes and types. The ExCEC data were initially based on the American National Standards Institute (ANSI) values from the *Advanced Lighting Guidelines* (CEC 1993). This set of wattage values is one of the most extensive and well documented, has had extensive public review, and has been disseminated and used throughout the United States. Since their inception, the ExCEC data have been updated and used as the model for a nationally accepted default lighting wattage source. Because this collection is likely to be considered and used by other organizations as the source for default wattage values, it was also expected to be the best maintained over time. For these reasons as well as the large variety of product types it covers, the ExCEC collection was chosen as the basis for the COM*check* suggested wattage values.

To ensure that these values are representative and conservative, the ExCEC data were compared where possible with the in-depth listings of manufacturer-specific electronic ballast-lamp combinations put together by the Lighting Design Lab (LDL) in Seattle--a well known source of reliable lighting information. These lists are extensive and thorough and represent currently available products that meet many energy conservation requirements (typically a power factor >90% and total harmonic distortion [THD] <33%). Because of this, the LDL list tends to exclude most of the really low-efficiency ballasts that are phased out by EPAct (Public Law 102-486), making it a valid benchmark for lighting systems installed in new construction. For the most common lamp types, the average of the electronic ballast-lamp wattage values in the LDL list, were found to be within ±2% of the corresponding ExCEC numbers.

The only major category of lighting missing from the ExCEC data was incandescent. These values, which are commonly known and standardized, were included as a simple listing of wattage ratings. This listing, as well as the option of user input of an exact wattage, will cover the entire range of incandescent and halogen products because the wattage rating is considered an accurate measure of wattage input to the fixture.

5.3 Exemptions (401.3.2)

COM*check* allows exemptions for qualifying fixtures. When a lighting fixture is identified as exempt, the power for the fixture is excluded from the total proposed wattage for the building. The following exemptions are implemented in COM*check*:

- Art/Museum Display
- Emergency Lighting (Automatic Control)
- High-Risk Security Area
- Lighting for Physically/Visually Impaired
- Plant Growth Lighting
- Residential Dwelling Units
- Retail Store-Front Display Windows (Enclosed)
- Sign Lighting
- Special Medical/Dental/Research Lighting
- Theatrical/Broadcasting/Entertainment.

Eight of the above exemptions are listed in Section 401.3.2 of the 90.1-1989 Code. COM*check* includes two additional exemptions: (i) Retail Store-Front Display Windows (Enclosed), and (ii) Sign Lighting. These spaces were exempted in Section 6.2.2 of the 90.1-1989 Standard and are included in the list of exceptions to building exterior lighting in Section 401.3.1 of the 90.1-1989 Code. These spaces are deemed to meet the definition of exemptions for interior lighting and hence were included in COM*check* interior lighting exemptions.

5.4 Mandatory Requirements

The following sections describe mandatory requirements as listed in COM*check*. Some of these have also been included in the Lighting Compliance Certificate - these are identified below.

5.4.1 Check Metering Provisions (401.1.1)

Current building practice already provides for electrical service configurations that meet many of these provisions. Hence check metering requirements are not included in COM*check*.

5.4.2 Electrical Schematic (401.1.2)

Providing electrical schematics to building owners is currently a requirement in building codes, so was not included as a mandatory requirement in COM*check*.

5.4.3 Motor Efficiency (401.2.1)

Minimum Federal efficiency requirements for electric motor efficiency that meet or exceed those in the 90.1-1989 Code took effect in October 1997 as a result of EPAct. At the time COM*check* was originally developed, electric motors being shipped and sold were already approaching compliance with those minimum efficiency requirements. Motor efficiency requirements have been omitted from COM*check* because they are redundant with the preemptive Federal requirements in EPAct.

5.4.4 Building Exteriors (401.3.1)

Exterior lighting is subject to local safety regulations and zoning rules and serves specific marketing functions. The 90.1-1989 Code provides for these requirements by restricting misuse of exterior lighting. COM*check* similarly restricts misuse by requiring that the designer use efficient sources to meet local safety, zoning, and marketing functions, setting a minimum lamp efficacy of 45 lumens per watt. In almost all cases, this requirement will result in a building that would comply with the 90.1-1989 Code using the exterior lighting power budget calculation.

According to efficacy graphs in the 1993 NLPIP report on compact fluorescents (NLPIP 1993) and the 1993 CEC lighting guideline on lighting design practice (CEC 1993), a limit of 45 lumens per watt precludes use of all incandescent lighting but would permit most compact fluorescents. A value of 60, which was originally proposed, would eliminate use of all but some very high wattage compact fluorescents and some small wattage metal halide and high pressure sodium fixtures. While the original 60 lumens per watt may have been appropriate for large exterior spaces such as parking lots, it precluded applications of smaller lamps (for example, under building overhangs), hence 45 lumens per watt was used.

5.4.5 Manual Controls (401.3.4.2)

The *Interior-Lighting Controls* section of the mandatory requirements along with the *Bi-Level Switching* section of the COM*check* Lighting Compliance Certificate provides the same requirement as the interior lighting controls in the 90.1-1989 Code. The bi-level requirement replaces the 90.1-1989 Code requirement for multiple controls based on task locations. It is considered common for most spaces with tasks required to have no more than two primary controls, which is provided by the bi-level requirement.

5.4.6 Control Accessibility (401.3.4.4)

Control accessibility is covered under the Control, Switching, and Wiring Requirements section of the COM*check* Lighting Compliance Certificate.

5.4.7 Hotel/Motel Guest Rooms (401.3.4.5)

The *Master Switches in Hotel and Motel Guest Rooms* requirements in the Lighting Compliance Certificate and the mandatory requirements list are the same as found in the 90.1-1989 Code.

5.4.8 Exterior Light Switching (401.3.4.6)

The *Exteri*or *Lighting Controls* requirements in the Lighting Compliance Certificate and mandatory requirements list are the same as found in the 90.1-1989 Code. Some specific references to the capability and backup provisions for timers have been eliminated because these characteristics are common features of current products.

5.4.9 Ballast Tandem Wiring (401.3.5.1)

The *Tandem Wiring* requirements in the Lighting Compliance Certificate and mandatory requirements list are the same as found in the 90.1-1989 Code. The COM*check* sections have simplified wording but cover the same installation configurations as are known to exist in buildings. These requirements exempt fixtures with high-frequency electronic ballasts because of their increased efficiency when operating one or three lamps compared to standard ballasts.

5.4.10 Ballast Power Factor (401.3.5.2)

Because of market pressures, most current products already meet the 90% or greater power factor requirement and hence, this is not included in the COM*check* requirements.

6.0 References

Air-Conditioning and Refrigeration Institute (ARI). May 1996. *Unitary and Applied Certification Directories* [Online report]. Available URL: http://ari-directory.com/

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE). 1985. *1985 ASHRAE Handbook: Fundamentals.* Atlanta, Georgia.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE). 1989a. *ASHRAE/IES Standard 90.1-1989,* "Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings." Atlanta, Georgia.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE). 1989b. *ASHRAE Standard 62-1989,* "Ventilation for Acceptable Indoor Air Quality." Atlanta, Georgia.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE). 1993a. *1993 ASHRAE Handbook: Fundamentals.* Atlanta, Georgia.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE). 1993b. *Energy Code for Commercial and High Rise Residential Buildings—Codification of ASHRAE/IES Standard 90.1-1989,* "Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings." Atlanta, Georgia.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE). 1996. *BSR/ASHRAE/IESNA Standard 90.1-1989R,* "Energy Code for Buildings Except Low-Rise Residential Building." First Public Review Draft, March 1996, Atlanta, Georgia.

Baylon, D. and J. Heller. 1988. *Super Good Cents Heat Loss Reference.* Vol. I-IV, prepared by Ecotope for the Bonneville Power Administration, Portland, Oregon.

California Code of Regulations (CCR). 1995. "Prescriptive Requirements for Lighting - Calculation of Allowed Lighting Power Density - Area Category Method." Subchapter 5, Section 146 (b) 2, Sacramento, California.

California Energy Commission (CEC). 1993. *Advanced Lighting Guidelines: 1993.* Sacramento, California.

California Energy Commission (CEC). 1995. *Energy Efficiency Standards for Residential and Nonresidential Buildings: July 1995.* Sacramento, California.

Council of American Building Officials (CABO). 1993. *Model Energy Code; 1993 Edition.* Falls Church, Virginia.

Crawley, D.B., P.K. Riesen, and R.S. Briggs. 1989. *Users Guide for ENVSTD program Version 2.0 and LTGSTD Program Version 2.0.* PNL-6839 (includes software), Pacific Northwest Laboratory, Richland, Washington.

Energy Information Administration (EIA). 1994. *Commercial Buildings Characteristics 1992: Energy Consumption Survey.* DOE/EIA-0246 (92), U.S. Department of Energy, Washington, D.C.

Energy Policy Act of 1992 (EPAct). Public Law 102-486, 106 Stat 2776, 16 USC 1531 et seq., as amended.

Hogan, J.F. 1995. "Code Compliance Considerations in the Development of the Building Envelope Requirements for ASHRAE/IESNA Standard 90.1-1989R." In *"Thermal VI" Thermal Performance of the Exterior Envelopes of Buildings VI,* p. 269. December 4-8, 1995, Clearwater Beach, Florida. U.S. Department of Energy (DOE), Office of Building Technologies; Oak Ridge National Laboratory (ORNL); The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE); and Building Environment and Thermal Envelope Council (BETEC).

International Code Council, Inc. (ICC). 1996. *International Mechanical Code.* ICC, Falls Church, Virginia.

International Code Council, Inc. (ICC). March 1998. *International Energy Conservation Code 1998.* ICC, Falls Church, Virginia.

Jones JW. October 1983. "Special Project 41: Development of Recommendations to Upgrade ASHRAE Standard 90A-1980, 'Energy Conservation in New Building Design.'" *ASHRAE Journal* 25(10):30-36.

Lighting Design Lab (LDL). *Elegant Lighting for Elegant Dining.* 1991. Bonneville Power Administration, Seattle, Washington.

National Appliance Energy Conservation Act of 1987 (NAECA). Public Law 100-12, 42 USC 6291 et seq., as amended.

National Fenestration Rating Council (NFRC). 1995. *Certified Products Directory.* Fifth Edition, Silver Spring, Maryland.

NLPIP. 1993. Report on compact fluorescents.

North American Insulation Manufacturers Association (NAIMA). 1998. *ASHRAE 90.1 Compliance for Metal Buildings*, MB304, Alexandria, VA.

Owenby, J.R., D.S. Ezell, and R.R. Heim, Jr. 1992. *Annual Degree Days to Selected Bases Derived from the 1961 to 1990 Normals.* Climatography of the United States No. 81 - Supplement No. 2, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.

Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACNA). 1985. *HVAC Duct Construction Standards: Metal and Flexible*. Vienna, Virginia.

Stucky, D.S., S.A. Shankle, R.W. Schultz, E.E. Richman, and J.A. Dirks. 1994. "Pacific Northwest Laboratory's Lighting Technology Screening Matrix: Let There Be Energy-Efficient Light." *Energy Engineering* 91(6):23-41.

U.S. Bureau of Census. 1988. *County and City Data Book—1988—Places*. U.S. Department of Commerce, Washington, D.C.

U.S. Department of Energy (DOE). 1994. *Federal User's Manual - Performance Standards for New Commercial and Multi-Family High-Rise Residential Buildings.* Office of Codes and Standards, Washington, D.C.

U.S. Department of Energy (DOE). 1995a. *90.1-1989 Code Compliance Manual*. Prepared by Eley Associates under contract to the Building Standards and Guidelines Program, Pacific Northwest National Laboratory, Richland, Washington.

U.S. Department of Energy (DOE). 1995b. *1993 MECcheck™ Manual - 1993 Model Energy Code Compliance Guide, Version 2.0.* Building Standards and Guidelines Program, Pacific Northwest National Laboratory, Richland, Washington.

U.S. Department of Energy (DOE). 1995c. *1993 MECcheck™ Prescriptive Packages - 1993 Model Energy Code, Version 2.0.* Building Standards and Guidelines Program, Pacific Northwest National Laboratory, Richland, Washington.

U.S. Department of Energy (DOE). 1995d. *1993 MECcheck™ Software User's Guide - 1993 Model Energy Code, Version 2.0.* Building Standards and Guidelines Program, Pacific Northwest National Laboratory, Richland, Washington.

U.S. Department of Energy (DOE). 1997. *COMcheck-EZ™ Compliance Guides - Commercial and High-Rise Residential Energy Code Compliance; Version 1.0.* DOE/EE/OBT-28432, Building Standards and Guidelines Program, Pacific Northwest National Laboratory, Richland, Washington.

U.S. Department of Energy (DOE). 2004. *Methodology for Developing the REScheck™ Software through Version 3.6*. Building Energy Codes Program, Pacific Northwest National Laboratory, Richland, Washington.

Appendix A

1998 IECC

Appendix A

1998 IECC

This appendix describes features that have been changed in COM*check* to support the 1998 International Energy Conservation Code (IECC). The 1998 IECC software implementation is almost identical to the 90.1-1989 Code version - the differences are discussed in this section.

A.1 Building Use Types

The 1998 IECC version uses the building use types and corresponding lighting power densities found in the printed 1998 IECC, with the exception of a correction of an erratum related to the *Other* category (misprinted as Theater-others).

A.2 Envelope

A.2.1 Vapor Retarder Requirements

The vapor barrier exception was translated into the 1998 (and 2000) IECC as "Buildings located in Climate Zone 1 through 7…" This significantly enlarged the areas subject to the exception compared to the 90.1-1989 Code requirements. There are 10 states that are impacted by the change, many of them substantially. Affected states are listed in Table A.1. Refer to the IECC for a list of counties and their corresponding climate zones.

Table A.1. Vapor Retarder Exemptions

States Exempted	Affected Portion of State
Alabama	10 counties in Climate Zone 7
Arizona	half the state
California	half the state
Georgia	one sixth of the state
Nevada	Clark County
New Mexico	seven counties
North Carolina	one third of the state
Oklahoma	40% of the state
South Carolina	one third of the state
Texas	one quarter of the state.

It is unclear whether the difference is a result of an intentional reinterpretation of the 90.1-1989 Code language or a change that was made inadvertently during efforts to simplify the IECC language. Regardless of the reason for the difference, the 1998 and 2000 IECC versions of COM*check* were changed to make them fully consistent with the IECC language, but the 90.1-1989 Code version was not changed, because we believe it contains the preferred interpretation.

A.3 Mechanical

A.3.1 Economizer Requirements

The 90.1-1989 Code version of COM*check* requires an *integrated-control* economizer and defines the term ‘integrated-control’. The 1998 IECC contains the economizer requirement but does not require that it have integrated control.

All codes based on the 90.1-1989 Code exempt Climate Zones 1a, 1b, 2a, 2b, 3b, and 3c from the economizer requirement. However, the 1998 IECC exempts Climate Zones 1a, 1b, 2a, 2b, and 3b but does not exempt 3c. Climate Zone 3c encompasses parts of Arizona (3 of 15 counties including Phoenix) and parts of south Texas (11 counties).

Both of these differences appear to be the result of inaccurate translation rather than deliberate technical revision. Regardless of the reason for the difference, the 1998 IECC version of COM*check* was changed to make it fully consistent with the 1998 IECC.

A mandatory requirement was added to require an air economizer for individual cooling systems over 90,000 Btu/h or 3,000 cfm in the selected climate.

An appropriate test for this requirement is that under the 1998 and 2000 IECC versions of COM*check*, a building with a large DX cooling system in Phoenix should require an economizer, while under the 90.1-1989 Code version of COM*check*, the same building should not be required to have an economizer.

A.3.2 Multiple-Zone Systems

The scope for the mechanical section of the 1998 IECC version of COM*check* is potentially confusing because Chapter 7 of the 1998 IECC, *Design by Acceptable Practice for Commercial Buildings*, has a much narrower scope and covers only single-zone HVAC equipment, in comparison to the 90.1-1989 Code. Wherever possible, we have matched the COM*check* implementation to specific provisions in the *Design by Acceptable Practice* chapter of the IECC. However, in the case of mechanical requirements, we felt that removing the requirements for complex systems from the 1998 IECC version of COM*check* would unnecessarily limit its usefulness. Therefore, the 90.1-1989 Code requirements for complex systems were used to supplement the scope of the 1998 IECC Mechanical requirements in COM*check*.

The expanded scope is fully appropriate for use with the 1998 IECC under provisions of Sections 103 and 601. Section 103 of the 1998 IECC, *Alternative Materials—Methods of Construction, Design or Insulating Systems*, authorizes “the use of computer software, worksheets, compliance manuals and other similar materials when they have been approved by the building official as meeting the intent of the code.” Section 601.1 of the 1998 IECC references the ASHRAE/IES *Energy Code for Commercial and High-Rise Residential Buildings*. The justification for using COM*check* for showing compliance with the IECC rests on the above two sections. The interpretations embedded in the software have the implied endorsement of the IECC Committee by virtue of their adoption into the 2000 IECC based on the justification of equivalence with the 90.1-1989 Code.

A.4 Lighting

The following exemptions based on Section 705.4 of the 1998 IECC are available in the 1998 version of COM*check*:

- Art/Museum Display
- Special Medical/Dental/Research Lighting.

Appendix B

2000 IECC

Appendix B

2000 IECC

This appendix describes features that have been changed in COM*check* to support the 2000 International Energy Conservation Code (IECC). The 2000 IECC version is very similar to the 90.1-1989 Code version. Areas not addressed in this appendix are the same as in the 90.1-1989 Code version of COM*check*. Major differences occur in only one area – lighting system requirements.

B.1 Building Use Types

The 2000 IECC uses the same whole building types and area categories as the 90.1-1989 Code and the 1998 IECC, except five new building use types were added to the 2000 IECC and the 90.1-1989 Code, but not the 1998 IECC. The new building use types were not added to the 1998 IECC version of COM*check* to keep it fully consistent with the 1998 IECC as published (see Section 2.2 of this document, for a list of these new building use types). Roughly 60% of the existing building use types have different lighting power densities, reflecting the 2000 IECC changes. The densities have decreased for some building use types and increased for others. Overall they appear to represent a modest increase in stringency. The 2000 IECC version of COM*check* uses the building use types and their corresponding lighting power densities exactly as listed in Table 805.4.2 of the 2000 IECC. Tables B.1 and B.2 list the lighting power density requirements for whole building types and area categories, respectively.

The 2000 IECC changes were based on what were proposed revisions to Standard 90.1-1989 at the time the IECC code changes were accepted. The changes were proposed by Jeff Johnson with the New Buildings Institute (NBI), and NBI prepared the technical justification for those changes.

Table B.1. Whole Building Type Lighting Power Density (LPD) Requirements

Whole Building Type	LPD (W/ft^2)
Exercise Center	1.4
Grocery Store	1.9
Library	1.5
Medical and Clinical Care	1.6
Museum	1.6
Office	1.3
Religious Worship	2.2
Restaurant	1.7
Retail Sales, Wholesale Showroom	1.9
School	1.5
Storage, Industrial and Commercial	0.6
Theater-Motion Picture	1.1
Theater-Performance	1.4
Other	0.6

Table B.2. Area Category Lighting Power Density (LPD) Requirements

Area Category	LPD (W/ft^2)
Auditorium	1.6
Bank/Financial Institution	2.0
Classroom/Lecture Hall	1.6
Convention, Conference or Meeting Center	1.5
Corridor, Restroom, Support Area	0.8
Dining	1.4
Exercise Center	1.1
Exhibition Hall	3.3
Grocery Store	2.1
Gymnasium Playing Surface	1.9
Hotel Function	2.4
Industrial Work, < 20 ft Ceiling Height	2.1
Industrial Work, >= 20 ft Ceiling Height	3.0
Kitchen	2.2
Library	1.8
Lobby-Hotel	1.9
Lobby-Other	1.0
Mall, Arcade, or Atrium	1.4
Medical and Clinical Care	1.6
Museum	1.6
Office	1.5
Religious Worship	3.2
Restaurant	1.7
Retail Sales, Wholesale Showroom	2.1
Storage, Industrial and Commercial	1.0
Theaters-Motion Picture	1.0
Theaters-Performance	1.5
Other	1.0

The internal load values used in calculating envelope compliance are based in part on lighting power budgets. The internal loads in the 2000 IECC version of COM*check* were adjusted to reflect the revised lighting power densities described above. The methods and assumptions used in determining the internal load values were identical to those used in developing the values for the 90.1-1989 Code, except that the values in Table 805.4.2 of the 2000 IECC were substituted for the 90.1-1989 Code values.

B.2 Envelope

B.2.1 Vapor Retarders

The vapor retarder requirement in the 2000 IECC is the same as discussed in A.2.1 for the 1998 IECC.

B.3 Lighting

B.3.1 Exemptions and Allowances

Each code version has exemptions for specific space uses, lighting applications, and/or equipment. Codes using exemptions and allowances based on Standard 90.1-1999 (i.e., 2000 IECC and the Massachusetts Code) also have power allowances. COM*check* allows exemptions or power allowances for qualifying fixtures.

B.3.2 Exemptions

The following exemptions based on Section 805.4.1 of the 2000 IECC are available in the 2000 IECC version of COM*check*:

- Special Medical/Dental/Research
- Professional Sports Arena Playing Field
- Gallery/Museum/Monument Exhibits
- Lighting in Residential Dwelling Units
- Emergency Lighting (Automatic Control).

B.3.3 Allowances

Additional lighting power allowances can be claimed under certain conditions resulting in the lighting power budget being increased, but only within limits and only to the extent the additional power is used for the qualifying application. Allowances in the 2000 IECC version of COM*check* are available with both the whole building type and area category methods. This differs from Standard 90.1-1999 and the Massachusetts commercial code, in which allowances are only available under the area category method.

When a fixture is identified as qualifying for an allowance, the user must provide the floor area qualifying for the allowance, the whole building type or area category corresponding with that floor or display area, and the type of allowance. The lighting power budget is increased by the product of the affected area and the wattage per square foot claimed up to the permitted maximum allowance, but not more than the total wattage of the selected fixtures.

COM*check* does not require space-by-space input of lighting fixtures. Without a space-by-space mapping of lighting fixtures to spaces, it is not possible to ensure that a space fully utilizes its lighting power budget before claiming the exemption or allowance. As a result, any unused budget for a space becomes usable elsewhere in the building, if the exemption or allowance is claimed. This was deemed to be a minor compromise relative to the large advantage of not requiring users to enter every fixture in the building on a space-by-space basis. In addition, both Massachusetts code and Standard 90.1-1989R language do not explicitly require the rigorous interpretation of these provisions.

Allowances can be obtained for any fixture by specifying the allowance type and its floor area. The budget lighting power is adjusted as below:

$$LPD_{required} = \sum Area_{space_i} \times LPD_{space_i} + \sum Area_{allowance_i} \times LPD_{allowance_i} \quad \text{(B.1)}$$

where space^{i} = area category types specified for the building
LPD = lighting power density
allowance^{i} = allowance claimed for allowance types specified for fixtures.

The allowances in Table B.3 are available in the 2000 IECC version of COM*check* and are based on the footnotes to Table 805.4.2 *Interior Lighting Power* in the 2000 IECC. The whole building types and area categories qualifying for these allowances are also listed.

Table B.3. Whole Building Types and Area Categories Qualifying for Allowances

Allowance Type	Allowance Amount (W/ft^2)	Whole Building Type/Area Category
Decorative	1.0	Bank/Financial Institution
		Convention, Conference or Meeting Center
		Dining
		Exercise Center
		Hotel Function
		Library
		Lobby - Hotel
		Lobby - Other
		Religious Worship
		Restaurant
		Theaters - Performance
Visual Display Terminals	0.35	Classroom/Lecture Hall
		Medical and Clinical Care
		Museum
		Office
Merchandise Display	1.6	Grocery Store
		Retail Sales, Wholesale Showroom
Fine Merchandise Display	3.9	Retail Sales, Wholesale Showroom
Emergency Medical/Pharmacy	1.0	Medical and Clinical Care

B.4 Mechanical

B.4.1 Economizer Requirements

In the 2000 IECC, buildings in Climate Zone 3c are not exempted from the economizer requirements. The integrated economizer requirement was included in the 2000 IECC, so COM*check-EZ* Version 2.0 and the 2000 IECC were already consistent; however, the Climate Zone 3c economizer requirement was included for the 2000 IECC version of COM*check*. All other requirements are identical to the 90.1-1989 Code.

Appendix C

2001 IECC

Appendix C

2001 IECC

This appendix describes the changes in COM*check* to support the 2001 International Energy Conservation Code (IECC). The Envelope and Lighting System requirements in the 2001 IECC are identical to the 2000 IECC, and no changes were made to the Envelope and Lighting compliance calculations. However, with the reference to Standard 90.1-1999 in Chapter 7, the trade-off requirements are no longer applicable across Chapter 7 and Chapter 8, which is based on Standard 90.1-1989. Hence, a warning message was added to alert users entering projects with a window-wall ratio > 50% to use either the Standard 90.1-1999 version of COM*check* or Section 806: Total Building Performance method in the 2001 IECC.

C.1 Mechanical

The Mechanical section has several changes in the 2001 IECC version of COM*check* affecting the equipment efficiency and economizer requirements.

1. Economizers are required for all cooling systems whose capacity is >65 KBtu/h. Climate Zones 1, 2, 3b, 5a and 6b are exempted from the economizer requirement (Section 803.2.6).
2. Economizers are exempted for systems with a cooling capacity < 135 KBtu/h in Climate Zones 3c, 5b, 7, 13b and 14 (Section 803.3.3.5).
3. All cooling plant efficiency requirements are revised as shown in Table C.1.
4. Heating equipment efficiency requirements are revised as shown in Table C.2.

Table C.1. Cooling Plant Efficiency Requirements

Cooling Plant Type	Condenser Type	Capacity	Efficiency Required	2001 IECC Reference
Water Chiller	Air Cooled/ Evaporatively Cooled	All	2.8 COP 2.8 IPLV	Table 803.3.2(2)
Water Chiller	Water Cooled	< 150 Tons	4.45 COP 4.50 IPLV	Table 803.3.2(2)
Water Chiller	Water Cooled	>= 150 Tons < 300 Tons	4.90 COP 4.95 IPLV	Table 803.3.2(2)
Water Chiller	Water Cooled	>= 300 Tons	5.5 COP 5.6 IPLV	Table 803.3.2(2)
Water Chiller	No Condenser	All	3.1 COP 3.1 IPLV	Table 803.3.2(2)
Condenser Unit	Water/Evaporatively Cooled	>= 135 KBtuh	13.1 EER 13.1 IPLV	Table 803.3.2(1)
Condenser Unit	Air Cooled	>= 135 KBtuh	10.1 EER 11.2 IPLV	Table 803.3.2(1)

Table C.2. Heating Equipment Efficiency Requirements

Heating Equipment Type	Efficiency	2001 IECC Reference
Unit heater (Oil)	80% Ec	Table 803.2.2(4)
Unit heater (Gas)	80% Ec	Table 803.2.2(4)
Unit heater (Propane)	80% Ec	Table 803.2.2(4)
Duct furnace (Gas)	80% Ec	Table 803.2.2(4)
Duct furnace (Gas)	80% Ec	Table 803.2.2(4)
Duct furnace (Propane)	80% Ec	Table 803.2.2(4)

5. Heat pump efficiency requirements are revised in Table C.3.

Table C.3. Heat Pump Efficiency Requirements

Condenser Type	Capacity	Heat Pump Type	Efficiency Required	2001 IECC Reference
Air cooled	< 65 KBtuh	Split system	10.0 SEER 6.8 HSPF	Table 803.2.2(2)
Air cooled	< 65 KBtuh	Roof top unit	9.7 SEER 6.6 HSPF	Table 803.2.2(2)
Air cooled	>= 65 KBtuh < 135 KBtuh	Split system roof top unit	10.1 EER 3.2 COP	Table 803.2.2(2)
Air cooled	>= 135 KBtuh < 240 KBtuh	Split system roof top unit	9.3 EER 3.1 COP	Table 803.2.2(2)
Air cooled	>= 240 KBtuh	Split system roof top unit	9.0 EER 9.2 IPLV 3.1 COP	Table 803.2.2(2)
Water cooled	< 135 KBtuh	All types	12.0 EER 4.2 COP	Table 803.2.2(2)
Groundwater	< 135 KBtuh	All types	16.2 EER 3.6 COP	

6. Cooling equipment efficiency requirements for split systems and roof top units in Table C.4.

Table C.4. Cooling Equipment Efficiency Requirements

Condenser Type	Capacity	Efficiency	2001 IECC Reference
Air cooled	< 65 KBtuh	10.0 SEER	Table 803.2.2(1)
Air cooled	>= 65 KBtuh < 135 KBtuh	10.3 EER	Table 803.2.2(1)
Air cooled	>= 135 KBtuh < 240 KBtuh	9.7 EER	Table 803.2.2(1)
Air cooled	>= 240 KBtuh < 760 KBtuh	9.5 EER 9.7 IPLV	Table 803.2.2(1)
Air cooled	>= 760 KBtuh	9.2 EER 9.4 IPLV	Table 803.2.2(1)
Evaporatively cooled/ water cooled	< 65 KBtuh	12.1 EER	Table 803.2.2(1)
Evaporatively cooled/ water cooled	>= 65 KBtuh < 135 KBtuh	11.5 EER	Table 803.2.2(1)
Evaporatively cooled/ water cooled	>= 135 KBtuh < 240 KBtuh	11.0 EER	Table 803.2.2(1)
Evaporatively cooled/ water cooled	>= 240 KBtuh	11.0 EER 10.3 IPLV	Table 803.2.2(1)

Appendix D

90.1-1999

Appendix D

90.1-1999

This appendix describes changes that have been made to COM*check* to support Standard 90.1-1999. The major changes in the Envelope section are the trade-off calculation using cost factors, envelope prescriptive requirements, and assembly proposed U-factor calculations. The Lighting section has a new set of building use types and provides options for allowances and exemptions. The Mechanical section includes a new set of mandatory requirements and efficiency requirements for HVAC and SWH systems.

D.1 Building Use Types

The building use types were revised to be consistent with Standard 90.1-1999. This list is similar to the Massachusetts version of COM*check*, with changes to occupancy names and lighting power density (LPD) requirements as detailed below.

D.1.1 Whole Building Types

Table D.1. Whole Building Type Lighting Power Density Requirements

Whole Building Type	LPD (W/ft^2)	Whole Building Type	LPD (W/ft^2)
Automotive Facility	1.5	Museum	1.6
Convention Center	1.4	Office	1.3
Court House	1.4	Parking Garage	0.3
Dining: Bar Lounge/Leisure	1.5	Penitentiary	1.2
Dining: Cafeteria/Fast Food	1.8	Performing Arts Theater	1.5
Dining: Family	1.9	Police/Fire Station	1.3
Dormitory	1.5	Post Office	1.6
Exercise Center	1.4	Religious Building	2.2
Gymnasium	1.7	Retail	1.9
Hospital/Health Care	1.6	School/University	1.5
Hotel	1.7	Sports Arena	1.5
Library	1.5	Town Hall	1.4
Manufacturing Facility	2.2	Transportation	1.2
Motel	2.0	Warehouse	1.2
Motion Picture Theater	1.6	Workshop	1.7
Multifamily	1.0		

D.1.2 Area Categories

Table D.2 shows the area categories list from Table 9.3.1.2 of Standard 90.1-1999.

Table D.2. Area Category Lighting Power Density (LPD) Requirements

Area Category Name	LPD (W/ft^2)	Area Category Name	LPD (W/ft^2)
Athletics		*Hospitality and Food Service*	
Audience/Seating Area	0.5	Bar Lounge/Leisure Dining Area	1.2
Court Sports Area	4.3	Cafeteria/Fast Food Dining Area	1.4
Dressing/Locker/Fitting Room	0.8	Dormitory Living Quarters	1.9
Exercise Area	1.1	Family Restaurant Dining Area	2.2
Indoor Playing Field Area	1.9	Hotel Dining Area	1.0
Playing Area	1.9	Hotel Lobby	1.7
Ring Sports Area	3.8	Hotel/Motel Guest Rooms	2.5
Common Space Types		Motel Dining Area	1.2
Active Storage	1.1	Multifamily Living Units	*0*
Atrium - First Three Floors	1.3	*Industrial and Auto Service*	
Atrium - Each Additional Floor	0.2	Automotive Facility Garage Service/Repair	1.4
Classroom/Lecture/Training	1.6	Detailed Manufacturing	6.2
Conference/Meeting/Multipurpose	1.5	Manufacturing Control Room	0.5
Corridor/Transition	0.7	Manufacturing Corridor/Transition	0.5
Dining Area	1.4	Manufacturing Equipment Room	0.8
Electrical/Mechanical	1.3	Manufacturing General - High Bay	3.0
Food Preparation	2.2	Manufacturing General - Low Bay	2.1
Inactive Storage	0.3	Workshop	2.5
Laboratory	1.8	*Library and Museum*	
Lobby	1.8	Library Card File and Cataloging	1.4
Lounge/Recreation	1.4	Library Reading Area	1.8
Office – Enclosed	1.5	Library Stacks	1.9
Office - Open Plan	1.3	Museum Active Storage	1.4
Restrooms	1.0	Museum General Exhibition	1.6
Stairs-Active	0.9	Museum Inactive Storage	1.4
Government and Public Safety		Museum Restoration	*2.5*
Confinement Cell	1.1		
Court House/Police Station/Town Hall	1.6	*Public Assembly*	
Audience/Seating Area		Convention Center Audience/Seating Area	0.5
Courtroom	2.1	Convention Center Exhibit Space	3.3
Fire Station Engine Room	0.9	Motion Picture Audience/Seating Area	1.3
Fire Station Sleeping Quarters	1.1	Motion Picture Theater Lobby	0.8
Judges Chamber	1.1	Performing Arts Audience/Seating Area	1.8
Penitentiary Audience/Seating Area	1.9	Performing Arts Theater Lobby	1.2
Penitentiary Classroom/Lecture/Training	1.4	*Religious*	
Post Office Sorting Area	1.7	Audience/Seating Area	3.2
Hospital and Healthcare		Fellowship Hall	2.3
Active Storage – Hospital	2.9	Worship - Pulpit/Choir	5.2
Corridors /Transition - Hospital	1.6	*Retail and Banking*	
Emergency	2.8	Banking Activity Area	2.4
Exam/Treatment	1.6	General Retail Sales Area	2.1
Laundry/Washing	0.7	Mall Concourse	1.8
Medical Supplies	3.0	*Transportation*	
Nurse Station	1.8	Air/Train/Bus Baggage Area	1.3
Nursery	1.0	Airport Concourse	0.7
Operating Room	7.6	Seating Area	1.0
Patient Room	1.2	Terminal Ticket Counter	1.8
Pharmacy	2.3	*Warehouse and Parking*	
Physical Therapy	1.9	Fine Material Storage	1.6
Radiology	0.4	Medium/Bulky Material Storage	1.1
Recovery	2.6	Parking Garage - Attendant Only	0.1
		Parking Garage - Pedestrian	0.2

The grouping of area categories in COM*check* is different from that of Standard 90.1-1999, but it is simple to use and consistent with the Massachusetts version.

D.2 Envelope

D.2.1 Trade-off Calculations

The exterior wall/window trade-off calculation methodology in Standard 90.1-1999 is based on envelope performance factor (EPF) using cost factors and is significantly different from that of Standard 90.1-1989, which is based on normalized heating and cooling coil loads. Another important difference in the trade-off calculation methodology between Standard 90.1-1989 and Standard 90.1-1999 is related to the budget window-to-wall ratio (WWR) and exclusion of the door area from the gross wall area. The trade-off calculations in Standard 90.1-1999 use the same WWR for both the budget and proposed design, whereas in Standard 90.1-1989, the WWR for the budget design is calculated as a function of the heating degree days, cooling degree hours, VSEW (annual average incident solar energy in east/west facades) and internal load density.

The envelope compliance index is calculated from the EPF for the proposed and budget designs using the EPF calculation procedure, as outlined in Appendix C of Standard 90.1-1999. EPF is the sum of heating factor, cooling factor and lighting for each zone considering the daylighting potential. The heating and cooling factors are calculated using the heating/cooling coefficients provided in Table C6.10.3 of Standard 90.1-1999. For each envelope component, the heating and cooling loads are calculated and added separately to determine the total heating and cooling loads for the building. The heating and cooling loads for exterior walls and vertical fenestration are calculated using the regression equations, as published in Standard 90.1-1989. The opaque door component is excluded from the regression equation-based load calculation and Standard 90.1-1999 provides heating and cooling coefficients for opaque doors identical to exterior walls. These loads are added with other component loads calculated using the heating/cooling coefficients, as described in Section 3.0 (*Envelope Documentation*), of this document, with the assumption of a SEER 12.24 for cooling and AFUE 0.608488 for heating equipment efficiencies. The cooling and heating coefficients in Table C6.10.3 of Standard 90.1-1999 are converted, as shown below for calculating the loads:

$$\text{Cooling coefficient} = C_{coeff} \times 12.24 \times 1000 \quad \text{(D.1)}$$

$$\text{Heating coefficient} = H_{coeff} \times 0.608488 \times 100000 \quad \text{(D.2)}$$

where C_{coeff} = cooling coefficients from Table C6.10.3 of Standard 90.1-1999.

H_{coeff} = heating coefficients from Table C6.10.3 of Standard 90.1-1999.

The total heating and cooling loads are divided by the equipment efficiencies and the following cost factors are applied to convert the loads and calculate the EPF:

$$\text{Cooling cost factor} = 0.08 \text{ per kW} \quad \text{(D.3)}$$

$$\text{Heating cost factor} = 0.66 \text{ per therm} \quad \text{(D.4)}$$

The cooling/heating load calculation assumes the following for the budget building:

1. All windows are assumed to be fixed.

2. The above-grade wall budget U-factor is area averaged based on the wall type and its corresponding budget U-factor, as specified in Appendix B of Standard 90.1-1999.

3. The WWR upper limit is set at 50% instead of 40% as in C3.3 of Standard 90.1-1999, because the proposed design could meet prescriptive requirements for WWR of 40 to 50% in the prescriptive tables of Appendix B of Standard 90.1-1999.

4. Skylight areas up to 3% of the total roof area are not included in load calculations.

At present, the daylighting potential is not included in the calculation of EPF and the envelope compliance index because of the unreliable and counter-intuitive results, as detailed in Section D.2.4 of this appendix. There are significant issues with the calculation of the lighting power density adjustment for daylighting potential. These issues were brought to the attention of the Envelope Committee for resolution.

D.2.2 Budget U-Factors

The required U-factor for each envelope assembly is obtained from the Envelope Requirements Tables in Appendix B of Standard 90.1-1999. The envelope U-factor requirements are based on the WWR, heating and cooling degree days, space-conditioning type and the assembly type. Based on an ASHRAE interpretation, below-grade wall areas are included in the calculation of WWR. See Section D.5 for details. The heating and cooling degree days are obtained from the weather data for the proposed building location, which falls under one of the 26 bin ranges, as provided in Figure B-1 of Standard 90.1-1999. The space-conditioning type is determined based on the building use type of the proposed design. All building types not listed in Table D.3 under residential are considered to be non-residential. Table D.4 lists occupancies that could be designated as ‘semi-heated’ if the building has no mechanical cooling and meets the heating equipment capacity limit specified by the Standard.

If the list of area categories contains a combination of residential and non-residential, then the area category with the largest floor area is used to determine the compliance requirement. If both residential and non-residential have the same floor area, then non-residential requirements apply.

Table D.3. Residential Occupancies

Whole Building Type	*Dormitory* *Hotel, Motel* *Multifamily* *Penitentiary*
Area Category	*Confinement Cell* *Fire station Sleeping Quarters* *Patient Room* *Guest Rooms* *Multifamily Living Units* *Dormitory Living Quarters*

Table D.4. Semi-Heated Occupancies

Whole Building Type	*Automotive Facility* *Manufacturing Facility* *Parking Garage* *Warehouse* *Workshop*

Area Category	*Common Space Types:*
	    Active and Inactive Storage
	Hospital and Healthcare:
	    Active Storage – Hospital
	Industrial and Auto Service:
	    Automotive Facility Garage Service/Repair
	    Detailed Manufacturing
	    Manufacturing Control Room
	    Manufacturing Corridor/Transition
	    Manufacturing Equipment Room
	    Manufacturing General – High Bay
	    Manufacturing General – Low Bay
	Library and Museum:
	    Museum Active and Inactive Storage
	Warehouse and Parking:
	    Fine Material Storage
	    Medium/Bulky Material Storage
	    Parking Garage – Attendant Only
	    Parking Garage – Pedestrian

The budget building envelope U-factors, C-factors, and F-factors are specified for approximately 19 assembly types in Appendix B of Standard 90.1-1999 and vary based on heating-degree-day (HDD65) and cooling-degree-day (CDD50) bins. For proposed building calculations, COM*check* uses pre-calculated assembly U-factors, C-factors, and F-factors, as given in Appendix A of Standard 90.1-1999. Table D.5 shows the mapping between the proposed assemblies, as presented in COM*check*, along with the Standard 90.1-1999 Appendix A table number used in computing U-factors for those assemblies (column 1) and the budget assemblies from Appendix B (column 2).

Some of the assembly types in Standard 90.1-1999 closely match those used in the 90.1-1989 Code version of COM*check*. Where assembly types are similar, the assemblies entered in the software by the user remain valid when the user switches from one code to another. Some of the Standard 90.1-1999 assembly types, however, could not be correlated to Standard 90.1-1989 assemblies. For these cases, a user changing from one code to the other must reselect the assembly type before a valid compliance calculation can be performed.

Table D.6 shows the mapping of the assembly types in the 90.1-1989 Code version of COM*check* to the Standard 90.1-1999 version -- some with a slight name change. The Standard 90.1-1999 assemblies not listed in this table were not mapped to the 90.1-1989 Code assemblies, and must be re-selected if the user switches between codes.

Table D.5. Mapping Between Proposed and Required Assemblies

Proposed Building		Budget Building
COM*check* Proposed Building Assemblies	90.1-1999 Appendix A Table Numbers	Budget Building Assemblies from 90.1-1999 Appendix B
Roof		Roof
Insulation Entirely Above Deck	A-1	Insulation Entirely Above Deck
Metal Building, Standing Seam	A-2	Metal Building
Metal Building, Screw Down	A-2	Metal Building
Attic Roof with Wood Joists	A-3	Attic and Other
Attic Roof with Steel Joists	A-4	Attic and Other
Other (U-factors provided by user)		Attic and Other
Skylight		Skylight
Skylight (U-factors provided by user.)	A-17 A-18 (used for suggested U-factors, SHGC for unlabeled skylights)	Skylight required U-factors and SHGC vary based on glass or plastic, curb type, orientation, and ratio of skylight to roof area
Other (U-factors provided by user)		Same as above
Exterior Wall		Above-Grade Wall
Wood-Framed, 16" o.c.	A-11	Wood Framed and Other
Wood-Framed, 24" o.c.	A-11	Wood-Framed and Other
Steel-Framed, 16" o.c.	A-10	Steel-Framed
Steel-Framed, 24" o.c.	A-10	Steel-Framed
Metal Building Wall	A-9	Metal Building
Solid Concrete	A-6	Mass
Concrete Block	A-7	Mass
Other (U-factors provided by user)		Wood-Framed and Other
Interior Wall		
Same as Exterior Walls		Same as Exterior Walls, using Semi-Heated Requirements
Window		Vertical Glazing
Windows (U-factors provided by user)	A-19 (used for suggested U-factors, SHGC, and VLT for unlabeled skylights)	Window required U-factors and SHGC vary based on glass or plastic, curb type, orientation, and window to wall ratio
Door		Door
Uninsulated Single-Layer Metal	Section A7	Based on opening type (swinging or non-swinging)
Uninsulated Double-Layer Metal	Section A7	
Insulated Metal	Section A7	
Wood	Section A7	
Glass (>50% glazing)	Section A7	
Other		
Basement		Below-Grade Wall
Solid Concrete	A-12	Below-Grade Wall
Concrete Block	A-12	Below-Grade Wall
Other (U-factors provided by user)		Below-Grade Wall
Floor		Floor/Slab-On-Grade Floor
Concrete Floor (over unconditioned space)	A-13	Mass
Steel Joist	A-14	Steel Joist
COM*check* Proposed Building Assemblies	90.1-1999 Appendix A Table Numbers	Budget Building Assemblies from 90.1-1999 Appendix B
Wood-Framed	A-15	Wood-Framed and Other
Slab-On-Grade – Unheated	A-16	Unheated Slab-On-Grade
Slab-On-Grade – Heated	A-16	Heated Slab-On-Grade
Other		Wood-Framed and Other

Table D.6. Mapping Between 90.1-1989 Code and Standard 90.1-1999 Assembly Names in COM*check*

Category	90.1-1989 Code Assembly Name	90.1-1999 Assembly Name
Roof	All-Wood Joist/Rafter/Truss Non-Wood Joist/Rafter/Truss	Attic Roof with Wood Joists Attic Roof with Steel Joists
Windows	All Frame Types and Glass Types	All frame types and glass types are retained the same as in 90.1-1989 Code, and skylights are assumed to be Skylights without Curb
Above Grade Wall	Wood Frame, Any Spacing Metal Frame, 16” o.c. Metal Frame, 24” o.c.	Wood-Framed, 16” o.c. Steel-Framed, 16” o.c. Steel-Framed, 24” o.c.
Windows	All Frame Types and Glass Types	All frame types and glass types are retained the same as in 90.1-1989 Code, and assumed to be ‘Fixed’ (non-operable windows).
Floor	All-Wood Joist/Truss Non-Wood Joist/Truss Concrete Floor (over unconditioned space) Unheated Slab-On-Grade Heated Slab-On-Grade	Wood-Framed Steel Joist Concrete Floor (over unconditioned space) Unheated Slab-On-Grade Heated Slab-On-Grade

D.2.3 Proposed U-Factors

This section contains the proposed U-factor calculation for all of the assembly types. The calculation methods have been derived from the tables in Appendix A of Standard 90.1-1999. Whenever possible, the table values have been calculated from equations found in the spreadsheets used in the Standard 90.1-1999 development process. For R-values not present in the following tables, U-factors are calculated using linear interpolation.

D.2.3.1 Roof

The following roof types found in Appendix A2 of Standard 90.1-1999 are included in the software:

- Insulation Entirely Above Deck
- Metal Building, Standing Seam
- Metal Building, Screw Down
- Attic with Wood Joists
- Attic with Steel Joists
- Other.

The proposed U-factor calculation for roof assemblies is based on the continuous and cavity R-values using the equations shown in Table D.7.

Table D.7. Proposed U-Factors for Roofs

Roof Type	Proposed U-Factor
Insulation Entirely Above Deck	$\frac{1}{0.78 + R_{RF\text{-}CNI}}$
Metal Building, Standing Seam Metal Building, Screw Down	$\frac{1}{\frac{1.0}{U_{R_{RF\text{-}CVI}}} + R_{RF\text{-}CNI}}$
Attic Roof with Wood Joists	$\frac{0.85}{1.63 + R_{RF\text{-}CVI} + R_{RF\text{-}CNI}} + \frac{0.05}{1.63 + (0.5 * R_{RF\text{-}CVI}) + R_{RF\text{-}CNI}} + \frac{0.10}{1.63 + R_{RF\text{-}CVI\text{-}adj} + R_{RF\text{-}CNI}}$
Attic Roof with Steel Joists	$\frac{1}{0.78 + (\mathrm{FF} * R_{RF\text{-}CVI}) + R_{RF\text{-}CNI}}$
Other	As input by user

where $R_{RF\text{-}CVI}$ = R-value for the cavity insulation as entered by the user

$R_{RF\text{-}CNI}$ = R-value for continuous insulation input by the user

$R_{RF\text{-}CVI\text{-}adj}$ = Adjusted R-value for the cavity insulation
(*4.38 for* $R_{RF\text{-}CVI} <= 13$ *or*
4.38+($R_{RF\text{-}CVI}$ *-11) for* $R_{RF\text{-}CVI} > 13$*)*

$U_{R_{RF\text{-}CVI}}$ = U-factor of base assembly for $R_{RF\text{-}CVI}$ as in Table D.8 or Table D.9

FF = Framing factor from Table D.10.

Table D.8. Base Assembly Overall U-Factor for Metal Building, Standing Seam Roofs

$\mathbf{R_{RF\text{-}CVI}}$	$U_{R_{RF\text{-}CVI}}$	$\mathbf{R_{RF\text{-}CVI}}$	$U_{R_{RF\text{-}CVI}}$
0.0	1.28	23.0	0.058
6.0	0.167	24.0	0.057
10.0	0.097	26.0	0.055
11.0	0.092	29.0	0.052
13.0	0.083	30.0	0.051
16.0	0.072	32.0	0.049
19.0	0.065	35.0	0.139
20.0	0.063	38.0	0.130
21.0	0.061	> 38.0	0.130
22.0	0.060		

Table D.9. Base Assembly Overall U-Factor for Metal Building, Screw Down Roofs

$R_{RF\text{-}CVI}$	$U_{R_{RF\text{-}CVI}}$
10.0	0.153
11.0	0.139
13.0	0.130
> 13.0	0.130

Table D.10. Framing Factor (FF) for Attic Roof with Steel Joists

$R_{RF\text{-}CVI}$	FF	$R_{RF\text{-}CVI}$	FF
0.0	1.00	20.0	0.85
4.0	0.97	21.0	0.84
5.0	0.96	24.0	0.82
8.0	0.94	25.0	0.81
10.0	0.92	30.0	0.79
11.0	0.91	35.0	0.76
12.0	0.90	38.0	0.74
13.0	0.90	40.0	0.73
15.0	0.88	45.0	0.71
16.0	0.87	50.0	0.69
19.0	0.86	55.0	0.67

D.2.3.2 Exterior Wall

The following exterior wall types from Appendix A3 of Standard 90.1-1999 are included in the software:

- Wood-Framed, 16” o.c.
- Wood-Framed, 24” o.c.
- Steel-Framed, 16” o.c.
- Steel-Framed, 24” o.c.
- Metal Building Wall
- Solid Concrete
- Concrete Block
- Other

User inputs for these assemblies are limited to cavity and continuous R-values for all framed walls. The mass walls are further described by density and furring details. The insulation position is assumed to be integral, and default heat capacity values are assumed based on the wall type, as already described in Table 3.10 of Section 3.0 of this document.

The proposed U-factor calculations for these assemblies are calculated using a combination of empirical equations and look-up tables. All framed-wall assembly U-factor calculations are listed in Table D.11. The mass wall types and their U-factor calculations are described later in this section.

Table D.11. Proposed U-Factors for Exterior Walls

Exterior Wall Type	Proposed U-Factor
Wood Frame, 16 in. o.c.	$\frac{0.75}{2.05+(FF*\mathrm{R}_{\text{WL-CVI}})+\mathrm{R}_{\text{WL-CNI}}}+\frac{0.21}{2.05+\mathrm{AC}_1+\mathrm{R}_{\text{WL-CNI}}}+\frac{0.04}{2.05+\mathrm{A}C_2+\mathrm{R}_{\text{WL-CNI}}}$
Wood Frame, 24 in. o.c.	$\frac{0.78}{2.05+(FF*\mathrm{R}_{\text{WL-CVI}})+\mathrm{R}_{\text{WL-CNI}}}+\frac{0.18}{2.05+\mathrm{AC}_1+\mathrm{R}_{\text{WL-CNI}}}+\frac{0.04}{2.05+\mathrm{A}C_2+\mathrm{R}_{\text{WL-CNI}}}$
Steel Frame, 16 in. o.c. Steel Frame, 24 in. o.c.	$\frac{1}{2.05+(FF*\mathrm{R}_{\text{WL-CVI}})+\mathrm{R}_{\text{WL-CNI}}}$
Metal Building Wall	$\frac{1}{\frac{1.0}{U_{\mathrm{R}_{\text{WL-CVI}}}}+\mathrm{R}_{\text{WL-CNI}}}$
Other	As input by user

where $\mathrm{R}_{\text{WL-CVI}}$ = R-value for the cavity insulation as input by the user
$\mathrm{R}_{\text{WL-CNI}}$ = R-value for continuous insulation input by the user
FF = framing factor (dependent on $\mathrm{R}_{\text{RF-CVI}}$ as in Table D.12 or Table D.13)
AC_1, AC_2 = adjusted equivalent cavity insulation based on $\mathrm{R}_{\text{RF-CVI}}$
$U_{\mathrm{R}_{\text{WL-CVI}}}$ = U-factor of base assembly for $\mathrm{R}_{\text{RF-CVI}}$ as in Table D.14.

Table D.12. Framing Factor and Adjusted Cavity Insulation R-Values for Wood-Frame Walls

$\mathrm{R}_{\text{WL-CVI}}$	FF	AC1	AC2
< 19.0	1.0	4.38	4.38
19.0	0.95	6.88	4.65
> 19.0	1.0	6.88	4.65

Table D.13. Framing Factor for Steel-Frame Walls

R_{WL-CVI}	FF (16 in. o.c.)	FF (24 in. o.c.)
0	0.87	1.0
11	0.50	0.60
13	0.46	0.55
15	0.43	0.52
19	0.37	0.45
>= 21	0.35	0.43

Table D.14. Base Assembly Overall U-Factor for Metal-Building Walls

R_{WL-CVI}	$U_{R_{WL-CVI}}$
0.0	1.18
6.0	0.184
10.0	0.134
11.0	0.123
13.0	0.113
19.0	0.070
23.0	0.061
26.0	0.057
32.0	0.048
> 32.0	1.41/ R_{WL-CVI}

The proposed U-factor calculations for mass wall assemblies are calculated using Tables A-6, A-7 and A-8 of Standard 90.1-1999. For all mass walls, the user is required to provide wall thickness, concrete density and furring material type, if present. The overall U-factor of the proposed assembly is determined by combining the thermal resistance of the solid wall and the cavity and continuous insulations using Equation D.5.

$$U_{WL} = 1/(R_{WL-BOA} + AF_{WL} + R_{WL-CNI}) \quad (D.5)$$

where U_{WL} = overall U-factor for the mass wall
R_{WL-BOA} = R-value for the solid portion of the wall
AF_{WL} = parallel path adjustment factor for furring
R_{WL-CNI} = R-value for continuous insulation input by the user.

The R-value (R_{WL-BOA}) for the solid portion of the wall is obtained from the U-factor for a given concrete density and wall thickness from Tables A-6 and A-7 of Standard 90.1-1999. Standard 90.1-1999 provides thermal properties for 11 density levels for solid concrete walls and 6 density levels for concrete block walls. To simplify COM*check*, three common density ranges - light, medium and normal - are supported with the properties shown in Table D.15 (taken from ASTM C90-93, as provided by Bruce Wilcox, Berkley Solar Group). All thicknesses and block types provided in Tables A-6 and A-7 of Standard 90.1-1999 are included in the software.

Table D.15. Density Ranges Provided by the Software

Name	Density Range (lb/ft^3)	Assumed Density (lb/ft^3)
Light Weight	< 105	95
Medium Weight	105-124	115
Normal Weight	125 or greater	135 – CMU 144 – Solid concrete

The parallel path adjustment factor (AF_{WL}) is calculated assuming a standard framing size, based on framing material type and cavity insulation levels using the following equations. The framing thickness (T_{FR}) is inferred from the cavity insulation level ($R_{WL\text{-}CVI}$).

Wood furring:

$$AF_{WL} = \frac{1}{\dfrac{0.88}{R_{WL\text{-}CVI}} + \dfrac{0.12}{1.035\,T_{FR}}} \tag{D.6}$$

Metal furring:

$$AF_{WL} = \frac{1}{\dfrac{0.998}{R_{WL\text{-}CVI}} + \dfrac{0.002}{0.00318\ T_{FR}}} \tag{D.7}$$

where T_{FR} = thickness of framing assuming 3.5 in. for cavity R-value < = 11 and 5.5 in. for cavity R-value > 11

$R_{WL\text{-}CVI}$ = R-value for the furring cavity insulation input by the user

The above equations are empirical relations derived to match the values in Table A-8 of Standard 90.1-1999 and the adjusted cavity R-value does not include the gypsum board. There is a potential for discrepancy up to an R-2 as a result of compressed insulation or very large thickness of studs.

D.2.3.3 Basement

The basement wall types include solid concrete wall and concrete block wall assemblies, as described in the previous section, *Exterior Wall*. The user inputs for basement walls include the height of the basement wall and the depth below grade. All basement walls are assumed to have full height insulation. Basement wall U-factor is calculated from the C-factor of the mass wall, insulation thermal resistances and soil thermal resistance. C-factor represents the thermal conductivity of the wall assembly without inclusion of the soil or air film thermal resistance. The C-factor calculation uses the mass wall assembly U-factor calculation of an exterior wall, with the air film thermal resistance subtracted, as given in Equation D.8:

$$C_{WL} = 1/(R_{WL\text{-}BOA} - 0.85 + R_{WL\text{-}CVI} \times AF_{WL} + R_{WL\text{-}CNI}) \tag{D.8}$$

where C_{WL} = C-factor for the mass wall assembly without the soil R-value
$R_{WL\text{-}CVI}$ = R-value for the furring cavity insulation input by the user

AF_{WL} = parallel path adjustment factor for furring
$R_{WL\text{-}CNI}$ = R-value for continuous insulation input by the user.

The overall U-factor of the basement wall assembly is calculated using Equation C-20 in Appendix A of Standard 90.1-1999, reproduced here as Equation D.9:

$$U_{WL} = 1/((1/ C_{WL}) + 0.85 + R_{soil}) \quad \text{(D.9)}$$

where U_{WL} = overall U-factor for the mass wall
R_{soil} = The soil R-value, which is dependent on the depth of the wall below grade, as given in Table C6.10.1 of Standard 90.1-1999.

The budget C-factor from the envelope requirements table is also adjusted using Equation C-20 of Standard 90.1-1999 to include the soil R-value in the trade-off calculations.

D.2.3.4 Floor

Floors over unconditioned spaces and slabs-on-grade are combined as one category of envelope component. The following floor types are included in the software:

- Concrete Floor (over unconditioned space)
- Steel Joist
- Wood-Framed
- Slab-on-Grade (Heated / Unheated)
- Other

Slab-on-grade floor calculations are described in the next section. All other floor types are assumed to be exposed to outdoor conditions or unconditioned space. The proposed U-factor calculation for floor assemblies is given in Table D.16:

Table D.16. Proposed U-Factors for Exposed Floors

Floor Type	Proposed U-Factor
Concrete Floor	$\frac{1}{3.11 + R_{EF\text{-}CNI}}$
Steel Joist Floor	$\frac{1}{2.86 + (FF * R_{EF\text{-}CVI}) + R_{EF\text{-}CNI}}$
Wood-Framed Floor	$\frac{0.91}{3.55 + (FF * R_{EF\text{-}CVI}) + R_{EF\text{-}CNI}} + \frac{0.09}{3.55 + R_{EF\text{-}CVI\text{-}adj} + R_{EF\text{-}CNI}}$
Other	As input by user

where $R_{EF\text{-}CVI}$ = R-value for the cavity insulation
$R_{EF\text{-}CNI}$ = R-value for continuous insulation input by the user
FF = framing factor (dependent on $R_{EF\text{-}CVI}$ as in Table D.17 or Table D.18)

$R_{EF\text{-}CVI\text{-}adj}$ = adjusted R-value of cavity insulation for joists (dependent on $R_{EF\text{-}CVI}$ as in Table D.19)

Table D.17. Framing Factor for Steel-Joist Floors

$R_{EF\text{-}CVI}$	Framing Factor (FF)
0.0	0.0
4.0	0.97
8.0	0.94
12.0	0.90
16.0	0.87
20.0	0.85
24.0	0.82
30.0	0.79
>=38.0	0.74

Table D.18. Framing Factor for Wood-Framed Floors

$R_{EF\text{-}CVI}$	Framing Factor (FF)
19.0	0.95
For all other values except R-19	1.0

Table D.19. Adjusted Cavity Insulation R-Values for Wood-Framed Floors

$R_{EF\text{-}CVI}$	$R_{EF\text{-}CVI\text{-}adj}$
0.0	0.0
11.0	4.38
13.0	4.38
15.0	4.38
19.0	6.88
21.0	6.88
25.0	9.06
30.0	11.56
>= 38.0	16.58

D.2.3.5 Slab-On-Grade Floors

Slab-on-grade floors do not have a proposed U-factor, but have an F-factor representing the heat transfer coefficient per linear foot of the slab edge. The software supports the following three insulation configurations:

- Horizontal with Vertical Slab Insulation
- Horizontal without Vertical Slab Insulation
- Vertical Insulation.

The slab F-factor calculation for horizontal and vertical insulations is based on Table A-16 of Standard 90.1-1999. The horizontal insulation description in Standard 90.1-1999 does not include vertical insulation along the slab edge. Table D.20 contains empirical equations for F-factor calculations for slabs with 'Horizontal without Vertical' and 'Vertical' insulation. These equations are the same as used in the 90.1-1989 Code version of COM*check*. For slabs with both horizontal and vertical slab edge insulation, an adjustment factor was developed. Assuming that the horizontally insulated slabs with 48 in. depth and fully insulated slab F-factor values can be interpolated, the adjustment factors in Table D.21 were developed. This adjustment factor and the corresponding F-factor for 'Horizontal without Vertical' insulation values are multiplied to get the F-factor for 'Horizontal with Vertical Slab Insulation'.

Table D.20. Assembly F-Factors for Slab-on-Grade Floors for Proposed Design

Slab and Insulation Description	F-Factor	
	R-0 to R-5 Insulation R-Value	> R-5 Insulation R-Value
Unheated Slabs		
None	0.73	0.73
12 in. horizontal without vertical	$0.73-0.002*R_{SBI}$[(a)]	0.72
24 in. horizontal without vertical	$0.73-0.006*R_{SBI}$	0.70
36 in. horizontal without vertical	$0.73-0.008\ R_{SBI}$	$0.69-0.003*R_{SBI}$
48 in. horizontal without vertical	$0.73-0.012*R_{SBI}$	$0.67-0.004*R_{SBI}$
12 in. vertical	$0.73-0.024*R_{SBI}$	$0.61-0.006*R_{SBI}$
24 in. vertical	$0.73-0.030*R_{SBI}$	$0.58-0.006*R_{SBI}$
36 in. vertical	$0.73-0.034*R_{SBI}$	$0.56-0.007*R_{SBI}$
48 in. vertical	$0.73-0.038*R_{SBI}$	$0.54-0.009*R_{SBI}$
Fully insulated slab	$0.73-0.054*R_{SBI}$	$0.46-0.016*R_{SBI}$
Heated Slabs		
None	1.35	1.35
12 in. horizontal without vertical	$1.35-0.006*R_{SBI}$	1.32
24 in. horizontal without vertical	$1.35-0.014*R_{SBI}$	1.28
36 in. horizontal without vertical	$1.35-0.022*R_{SBI}$	$1.24-0.006*R_{SBI}$
48 in. horizontal without vertical	$1.35-0.030*R_{SBI}$	$1.20-0.009*R_{SBI}$
12 in. vertical	$1.35-0.058*R_{SBI}$	$1.06-0.013*R_{SBI}$
24 in. vertical	$1.35-0.072*R_{SBI}$	$0.99-0.013*R_{SBI}$
36 in. vertical	$1.35-0.080*R_{SBI}$	$0.95-0.016*R_{SBI}$
48 in. vertical	$1.35-0.088*R_{SBI}$	$0.91-0.019*R_{SBI}$
Fully insulated slab	$1.35-0.122*R_{SBI}$	$0.74-0.030*R_{SBI}$

(a) R_{SBI} = R-value of slab insulation.

Table D.21. F-Factor Adjustment Multiplier for 'Horizontal with Vertical' Insulation

Insulation Depth	Adjustment Factor	
	Unheated Slab	Heated Slab
1 ft	0.69	0.62
2 ft	0.63	0.55

3 ft	0.56	0.49
4 ft	0.48	0.40

D.2.3.6 Door

The following door types are supported by the software as provided in Section A7 of Appendix A7 of Standard 90.1-1999:

- Uninsulated Single-Layer Metal
- Uninsulated Double-Layer Metal
- Insulated Metal
- Wood
- Glass (>50% glazing)
- Other.

Although the user enters doors with more than 50% glazing as glass doors in the software, the software handles them as windows as per Standard 90.1-1999. In addition to the door type, the user is required to select the opening type – swinging or non-swinging. The opening type is used to determine the budget U-factor.

Default U-factors for these assemblies are given in Section A7 of Appendix A of Standard 90.1-1999 (and shown in Table D.22).

Table D.22. Default U-Factor for Standard Door Assemblies

Assembly Name	U-Factor
Uninsulated Single-Layer Metal	1.45
Uninsulated Double-Layer Metal	0.70
Insulated Metal	0.50
Wood	0.50
Other	0.60

D.2.3.7 Window

The glazing and frame types for windows remain unchanged for the Standard 90.1-1999 version of COM*check*. In addition, the user is required to specify whether the window is operable or fixed. The opening type is used to determine the budget U-factor.

Default values for U-factors, SHGC, and VLT of windows are provided only for fixed windows consistent with Table A-17 of Standard 90.1-1999 for a select number of glazing types and thickness of air spaces, as described in Tables 3.11 and 3.12 of this document.

D.2.3.8 Skylight

The glazing and frame types for skylights remain unchanged for the Standard 90.1-1999 version of COM*check*. An additional input is required for specifying skylight curb characteristics. Standard 90.1-1999 differentiates the skylight budget U-factor based on the glazing material – either glass or plastic.

Because all the current menu items are glass, an additional option is provided for the 'Other' skylight category for the user to specify plastic skylights.

Default values for U-factors of skylights are provided only for metal frames with glass skylights either with or without curbs; and for wood/vinyl frames with glass skylights without curb using the U-factors provided in Tables 3.11 and 3.12 of this document.

D.2.4 Daylight Credit in Envelope Trade-off

According to Equation C-2 of Standard 90.1-1999, the envelope performance factor (EPF) includes lighting load calculations providing adjustments for daylighting potential. During software testing, it was found that the lighting load calculations result in counter-intuitive compliance results while changing the SHGC, VLT and the WWR parameters. The major issue is with the ratio of HVAC and lighting loads and the difficulty in defining the floor area of zones for determining daylighting load adjustments. Hence this VLT trade-off option is not yet made available to users of COM*check*, although it is implemented in the software. The lighting load calculations are as provided below:

The EPF used in COM*check* includes adjusted lighting load converted to cost assuming 0.08 $/kWh. To maintain the same calculation units as the heating and cooling loads, Equation C-4 of Standard 90.1-1999 is implemented as shown below:

$$LL_{zone} = LPDadj_{zone} \text{ x } Area_{zone} \text{ x } 2700 \quad \text{(D.10)}$$

where LL_{zone} = the calculated lighting load for the zone
$LPDadj_{zone}$ = lighting power density for the zone adjusted for daylighting potential
$Area_{zone}$ = gross floor area of the zone as defined in Section C5 of Appendix of Standard 90.1-1999.

2700 represents the number of hours for lighting occupancy (assuming that the cost of electricity is 0.08 $/kWh, 2700*0.08 = 216, given in Standard 90.1-1999).

The adjusted lighting power density is calculated using Equations C-5, C-8, C-9 and C-10 of Standard 90.1-1999. The following assumptions are used in this calculation:

Zone Definition. The zone area assigned to each wall/roof component depends on the total floor area and the perimeter zone areas. If the total wall area to conditioned floor area ratio is > 1.25, then a zone factor of 1.25 is used to determine the area of perimeter zones as in Equation D.11:

$$Area_{zone} = ZF \text{ x } Area_{wall} \quad \text{(D.11)}$$

where ZF = ratio of total conditioned floor area to the gross wall area. This ratio is subject to a maximum limit of 1.25.
$Area_{wall}$ = the gross area of all exterior above-grade walls as entered by the user.

The interior zone area is calculated by subtracting the perimeter zone area from the total conditioned floor area entered by the user. If the calculated interior zone area is greater than the total roof area, then the total roof area is used as the interior zone area for the calculations. The total zone area is the addition of interior zone area and the perimeter zone area.

Lighting Power Density. According to Section C5.4 of Standard 90.1-1999, the lighting power density is based on the building type, as listed in Table D.23.

Table D.23. Lighting Power Density

Building Type	LPD
Non-residential buildings	1.20 W/ft^2
Residential buildings	1.00 W/ft^2
Semi-heated buildings	0.50 W/ft^2

Visible Light Transmittance (VLT). The VLT requirement is based on the SHGC requirement for the fenestration/skylight multiplied by the VLT factor, as provided in Table C3.5 of Standard 90.1-1999. If no orientation-specific input or VLT is provided, then a VLT factor of 1.0 is assumed for both the budget and proposed designs, thus providing no adjustments for daylighting potential, but including the lighting load in the EPF calculation.

Vertical Fenestration. If no orientation-specific input is provided, the fenestration area is assumed to be equally distributed along the four cardinal directions.

Skylight Geometry. If skylights are present, they are assumed to be square, with a 3-foot well depth for calculating the visible aperture.

Design Illuminance. Continuous daylight dimming is assumed according to Equation C5.4 of Standard 90.1-1999 in all spaces and set at 50 fc for residential/non-residential and 30 fc for semi-heated spaces.

D.3 Mechanical

Equipment efficiency requirements are identical to the 2001 IECC version of COM*check*, as the 2001 IECC mechanical equipment efficiency requirements are the same as Standard 90.1-1999. The following changes to the user inputs were made:

1. HVAC equipment description includes the input for heating capacity and fan power and a revised limit for economizer requirement at 135,000 Btu.
2. Water loop heat pump system and two-pipe change over system input were added to the plant equipment description.
3. The plant inputs were revised to include non-standard chiller efficiency calculations.
4. Heated swimming pool and combined space/SWH system options were added to the SWH system description. Water heater type and capacity input fields were added, and the SWH efficiency calculation was implemented.

The mechanical requirements checklist was revised to be consistent with these Standard 90.1-1999 requirements.

D.4 Lighting

D.4.1 Exemptions

The following exemptions based on exceptions to Section 9.3.1 of Standard 90.1-1999 are provided in COM*check*:

- Advertising/Directional Signage
- Athletic TV Broadcasting
- Casino Gaming
- Display Lighting in Galleries/Museums
- Exit Signs
- Food Preparation Equipment
- Lighting in Refrigerator/Freezer Cases
- Lighting for Visually Impaired
- Lighting Integral to Equipment
- Lighting Sales or Education
- Medical/Dental Procedure Lighting
- Plant Growth Lighting
- Registered Historical Landmark
- Retail Display Window
- Theatrical Lighting

D.4.2 Allowances

Additional power allowances are provided by Standard 90.1-1999 under the Area Category method of lighting compliance. Table D.24 shows the space functions and the additional power allowances available. In the first publication of Standard 90.1-1999, lighting power allowances were permitted only for a limited number of identified area categories, but the Standard was later amended removing that limitation. COM*check* does not restrict the choice of lighting allowance space types as per the amendment (published in Standard 90.1-2001). These power allowances are allowed only if the specified lighting is installed and used for the specified purpose.

Table D.24. Lighting Power Allowances

Space Type	Power Allowance (W/ft^2)
Decorative Appearance	1.0
Visual Display Terminal Use	0.35
Retail Merchandise Highlighting	1.6
Retail Fine Merchandise Highlighting	3.9

D.5 Window-to-Wall Ratio (WWR)

A change was made to the WWR calculation with the release of COM*check* version 3.1. Based on an official ASHRAE interpretation, the area of below-grade walls is now included as wall area when WWR is calculated. This change affects the 90.1-1999, 90.1-2001, and 90.1-2004 versions of COM*check*. The interpretation states that based on the definitions of building envelope, wall, and gross wall area in Section 3.2 of the Standard, "…for buildings with conditioned space below-grade, the gross wall area extends from the top of the surface of the floor of the lowest conditioned space to the bottom of the roof of the highest conditioned space".

Appendix E

90.1-2001

Appendix E

90.1-2001

This appendix describes changes that have been made to COM*check* to support Standard 90.1-2001. The Standard 90.1-2001 version of COM*check* is based on the requirements and trade-off calculations as implemented for Standard 90.1-1999.

E.1 Envelope

Standard 90.1-2001 includes changes to the slab-on-grade floor insulation requirements.

E.1.1 Unheated Slabs

The maximum F-factor requirement for unheated slabs in residential buildings in Climate Zones 19 and 20 is 0.730. There are no minimum insulation R-value requirements for unheated slabs in these climate zones.

E.1.2 Heated Slabs

The maximum F-factor requirement for heated slabs in residential buildings in Climate Zones 19 through 26 is 0.780. The minimum insulation requirement is R-10 with an insulation depth of 48 inches.

The required F-factor for non-residential buildings for heated slabs in Climate Zones 23, 24, 25, and 26 is set to be 0.780. The insulation requirement is set to be R-10 with an insulation depth of 48 inches.

E.2 Mechanical

All mechanical equipment efficiency requirements in Standard 90.1-2001 are the same as in Standard 90.1-1999 with the exception of non-standard centrifugal chillers. The COP and IPLV requirements for non-standard centrifugal chillers are calculated using the following equations provided as footnotes to Tables 6.2.1H-M of Standard 90.1-2001.

$$COP_{adj} = k_{adj} \times COP_{std} \tag{E.1}$$

$$IPLV_{adj} = k_{adj} \times IPLV_{std} \tag{E.2}$$

where

$k_{adj} = 6.1507 - 0.30244(X) + 0.0062692(X)^2 - 0.000045595(X)^3$

X = Condenser DT + LIFT

Condenser DT = Leaving Condenser Water Temp.(F) – Entering Condenser Water Temp.(F) (obtained from Table 6.2.1H for any given condenser flow rate)

The Standard COP and IPLV are calculated at a condenser flow rate of 3 gpm and LIFT = 41 degrees F.

Requirements Checklist items were modified as needed to meet the requirements of Standard 90.1-2001.

E.2.1 Window-to-Wall Ratio

A formal ASHRAE interpretation affected the WWR calculation in COM*check* with the release of Version 3.1. See Section D.5 for details.

Appendix F

2003 IECC

Appendix F

2003 IECC

This appendix describes features that have been changed in COM*check* to support the 2003 International Energy Conservation Code (IECC). The 2003 IECC is based on 2001 IECC with the changes identified in the following sections.

F.1 Building Use Types

The 2003 IECC building use types were revised according to Table 805.5.2 of the 2003 IECC. The list contains 26 whole building types and 28 area categories as provided in Table 805.5.2.

F.2 Envelope

The envelope trade-off calculations and requirements remain the same as the 2001 IECC version of COM*check*. The internal load densities were recalculated based on the lighting power densities from Table 805.5.2 of the 2003 IECC. The methods and assumptions used to determine the internal loads are the same as those used in developing the values for the 90.1-1989 Code version of COM*check*, except based on the 2003 IECC lighting power densities.

The envelope requirements checklist items were revised to be consistent with these 2003 IECC requirements: stair, elevator shaft vents, and other dampers integral to the building envelope; cargo doors and loading dock doors; vestibules; and recessed lighting fixtures. The vestibule requirement in Section 802.3.6 of the 2003 IECC is exempted and is not required in Climate Zones 1a through 4b.

F.3 Mechanical

The mechanical section contains no software changes from the 2001 IECC for HVAC equipment and plant system requirements, but new requirements for service water heating system efficiencies were added. The 2003 IECC service water heating efficiencies are the same as Standard 90.1-1999. The service water heating equipment efficiency requirement is determined based on water heater type, fuel type, and capacity.

Additional changes include minor revisions to the Mandatory Requirements and Requirements Checklist to address the requirements in the 2003 IECC. These revisions are related to: two-pipe changeover systems, water loop heat pump systems, heat rejection devices as part of the plant equipment, and duct construction.

F.4 Lighting

The allowable lighting power densities were changed significantly along with the update to building use types as per Table 805.5.2 in the 2003 IECC. The option to claim lighting power allowances for the whole building method was removed in the 2003 version of the software to reflect changes to Section 805.5.2.1 in the 2003 IECC. Mandatory Requirements text and Requirements Checklist were changed to reflect the requirements in the 2003 IECC for manual controls for uniform light reduction and separate metering of individual dwelling units.

Appendix G

Minnesota

Appendix G

Minnesota

This section describes changes that have been made to COM*check* to support the Minnesota Commercial Code. The Envelope and Mechanical requirements are the same as the 90.1-1989 Code. Lighting compliance is based on a Minnesota-specific list of whole building types and area categories and provides lighting control credits.

G.1 Building Use Types

G.1.1 Whole Building Types

In the Minnesota version of COM*check*, each whole building type is further defined by the gross lighted area, as shown in Table G.1. The Minnesota lighting whole building types are similar to the 90.1-1989 Code Table 401.3.2a, but with different lighting power densities.

The Minnesota Code allows the use of multiple whole building types to be specified for the whole building method, unlike the 90.1-1989 Code in which only one whole building type can be specified. If the building has secondary functions that are 10% or more of the gross lighted area, these secondary portions must also be listed. The software uses an area-weighted average of the power densities for each portion of the building listed.

G.1.2 Area Categories

The Minnesota Code provides a list of area categories different from that of the 90.1-1989 Code. The area category LPDs are similar to the 1992 Federal Commercial Code. The Minnesota area category LPD table was implemented in COM*check* as a two-level structured list under two major headings: Common Activity Areas and Specific Building Area/Activity, as shown in Table G.2. The Minnesota version of COM*check* includes default area factors for all area categories and these are used to adjust the lighting power density. These area factors were derived from three standard room geometries used by the 90.1 Lighting Subcommittee for development of Standard 90.1-1999. The budget LPD used in the software is given by Equation G.1.

Table G.1. Minnesota Whole Building Types and Lighting Power Densities

Building Use Type	0 to 2,000 ft^2	2,001 to 10,000 ft^2	10,001 to 25,000 ft^2	25,001 to 50,000 ft^2	50,001 to 250,000 ft^2	> 250,000 ft^2
Food Service - Fast Food/Cafeteria	0.92	0.85	0.82	0.81	0.81	0.8
Garages	0.25	0.24	0.23	0.22	0.21	0.2
Leisure Dining/Bar	1.6	1.56	1.52	1.48	1.44	1.4
Mall Concourse/Public Spaces	0.69	0.68	0.65	0.63	0.61	0.6
Offices	1.4	1.34	1.27	1.22	1.16	1.11
Retail[(a)]	2.7	2.52	2.32	2.05	1.87	1.72
Service Establishment	2.81	2.03	1.78	1.65	1.54	1.46
Schools	1.77	1.72	1.6	1.49	1.36	1.26
Warehouse/Storage	0.6	0.5	0.42	0.36	0.32	0.3

(a) Includes general, merchandising, and display lighting.

Table G.2. Minnesota Area Categories

	Activity Type	MN LPD W/ft^2	Area Factors
COMMON ACTIVITY AREAS			
Common/Misc.	Auditorium	1.4	1.32
	Classrooms/Lecture Hall	1.7	1.32
	Computer/Office Equipment	2.1	1.32
	Conference/Meeting Room	1.3	1.32
	Conference/Meeting Room (Multifunction)	1.95	1.32
	Corridor	0.8	1
	Electrical/ Mechanical Room - Control Room	1.5	1
	Electrical/ Mechanical Room - General	0.7	1
	Filing - Inactive	1.0	1.54
	Laboratory	2.2	1
	Locker Rm./Shower	0.6	1.32
	Mail Room	1.8	1.32
	Recreation/Lounge	0.5	1.32
	Stair - Active Traffic	0.6	1.54
	Stair - Emergency Exit	0.4	1.54
	Toilet & Washing	0.5	1.54
	Unlisted Space	0.2	1
Food Service	Fast Food	0.8	1.32
	Leisure Dining	1.4	1.32
	Bar/Lounge	1.3	1.32
	Kitchen	1.4	1.32
Garage	Auto/Pedestrian. Circulation	0.25	1
	Parking Area	0.2	1
Library	Audio Visual	1.1	1.32
	Stack Visual	1.5	1.54
	Card Filing & Cataloging	0.8	1.32
	Reading Area	1.0	1.32
Lobby (General)	Reception & Waiting	0.55	1.32
	Elevator lobbies	0.4	1.54
	Atrium - First three floors	0.4	1.54
	Atrium - Each additional floor	0.15	1.54
Office	Category 1 - Reading, Typing and Filing	1.3	1.32
	Category 1 - Drafting	2.2	1.32
	Category 1 - Accounting	1.8	1.32
	Category 2 - Reading, Typing and Filing	1.5	1.0
	Category 2 - Drafting	2.6	1.0
	Category 2 - Accounting	2.1	1.0
	Category 3 - Reading, Typing and Filing	1.7	1.0
	Category 3 - Drafting	3.0	1.0
	Category 3 - Accounting	2.4	1.0

Table G.2. (contd)

	Activity Type	MN LPD W/ft^2	Area Factors
Shop (Non-Industrial)	Machinery	2.5	1.32
	Electrical/Electronics	2.5	1.32
	Painting	1.6	1.32
	Carpentry	2.3	1.32
	Welding	1.2	1.32
Storage/Warehouse	Inactive Storage	0.2	1.54
	Active Storage/Bulky	0.3	1.54
	Active Storage/Fine	0.9	1.54
	Material Handling	1.0	1.54
SPECIFIC BUILDING AREA/ACTIVITY			
Airport, Bus & Rail Station	Baggage Area	0.75	1.32
	Concourse/Main Throughway	0.45	1.54
	Ticket Counter	1.3	1.32
	Waiting and Lounge Area	0.6	1.0
Bank	Customer Area	0.8	1.32
	Banking Activity Area	2.2	1.32
Church/Synagogue/Chapel	Worship/Congregational	1.3	1.54
	Preaching and Sermon/Choir	1.8	1.54
Dormitory	Bedroom	0.6	1.32
	Bedroom with Study	1.3	1.32
	Study Hall	0.9	1.32
Fire & Police Dept.	Fire Engine Room	0.7	1.32
	Jail Cell	0.4	1.32
Hospital/Nursing Home	Corridor	0.9	1.54
	Dental Suite/Exam/Treatment	1.4	1.32
	Emergency	2.0	1.32
	Laboratory	1.7	1.0
	Lounge/Waiting Room	0.6	1.32
	Medical Supplies	2.4	1.32
	Nursery	1.6	1.0
	Nurse Station	1.8	1.32
	Occupational/Physical Therapy	1.4	1.32
	Patient Room	0.9	1.32
	Pharmacy	1.5	1.32
	Radiology	1.8	1.32
	Surgical and OB Suites - General	1.8	1.32
	Surgical and OB Suites - Operating	6.0	1.32
	Surgical and OB Suites - Recovery	2.0	1.32
Hotel/Conference Center	Banquet Room/Multifunction	1.4	1.32
	Bathroom/Powder Room	0.6	1.54
	Guest Room	0.7	1.32

Table G.2. (contd)

	Activity Type	MN LPD W/ft^2	Area Factors
	Public Area	0.8	1.32
	Exhibition Hall	1.3	1.0
	Conference/Meeting	1.5	1.0
	Lobby	1.3	1.0
	Reception Desk	2.4	1.32
Museum & Gallery	General Exhibition	1.2	1.32
	Inspection/Restoration	3.0	1.32
	Storage (Artifacts) – Inactive	0.25	1.54
	Storage (Artifacts) – Active	0.5	1.54
Post Office	Lobby	0.8	1.32
	Sorting & Mailing	2.1	1.32
Service	Barber & Beauty Parlor	1.6	1.32
	Laundry – Washing	0.6	1.0
	Laundry – Ironing & Sorting	1.3	1.0
	Service Station/Auto Repair	0.8	1.32
Theater	Performing Arts	1.1	1.32
	Motion Picture	0.75	1.32
	Lobby	1.0	1.32
Retail Establishments	Type A	6.0	1.32
	Type B	2.9	1.32
	Type C	2.7	1.32
	Type D	2.5	1.0
	Type E	2.4	1.0
	Type F	2.6	1.32
	Mall Concourse	0.6	1.32
	Retail Support Area – Tailoring	2.1	1.0
	Retail Support Area – Dressing/Fitting Room	1.1	1.0
Indoor Athletic Area/Activity	Seating Area (All Sports)	0.4	1.0
	Badminton Club	0.5	1.0
	Badminton Tournament	0.8	1.0
	Basketball/Volleyball – Intramural	0.8	1.0
	Basketball/Volleyball – College/Pro	1.9	1.0
	Bowling – Approach Area	0.5	1.0
	Bowling – Lanes	1.1	1.0
	Boxing or Wrestling (Platform) – Amateur	2.4	1.0
	Boxing or Wrestling (Platform) – Professional	4.8	1.0
	Gymnasium – Gen. Exercise & Recreation	1.0	1.0
	Handball/Racquetball/Squash – Club	1.3	1.0
	Handball/Racquetball/Squash – Tournament	2.6	1.0
	Ice Hockey – Amateur	1.3	1.0
	Ice Hockey – College or Pro	2.6	1.0

Table G.2. (contd)

Activity Type	MN LPD W/ft^2	Area Factors
Skating Rink – Recreational	0.6	1.0
Skating Rink – Exhibition/Pro	2.6	1.0
Swimming – Recreational	0.9	1.0
Swimming – Exhibition	1.5	1.0
Swimming – Underwater	1.0	1.0
Tennis – Recreational (Class III)	1.3	1.0
Tennis – Club/College (Class II)	1.9	1.0
Tennis – Professional (Class I)	2.6	1.0
Table Tennis – Club	1.0	1.0
Table Tennis – Tournament	1.6	1.0

$$LPD_{BUDGET} = LPD \times AF \tag{G.1}$$

where LPD = Lighting Power Density (MN LPD) from Table H.2
AF = Area Factor from Table H.2

G.2 Lighting

G.2.1 Controls Credit

The Minnesota version of COM*check* implements the control credits available for luminaires automatically controlled by occupancy sensors, daylight sensors, programmable timing controls, or lumen maintenance controls. Table G.3 lists the lighting controls and their corresponding power adjustment factors available in the software. The user can select the type of control from a list, and the proposed fixture wattage will be reduced using the appropriate power adjustment factor.

Table G.3. Minnesota Control Types and Power Adjustment Factors

Control Type	Adjustment Factor
Daylight Sensing Controls (DS), continuous dimming	0.30
DS, multiple step dimming	0.20
DS, ON/OFF	0.10
DS, continuous dimming, programmable timing	0.35
DS, multiple step dimming, programmable timing	0.25
DS, ON/OFF, programmable timing	0.15
DS, continuous dimming, programmable timing, lumen maintenance	0.40
DS, multiple step dimming, programmable timing, lumen maintenance	0.30
DS, ON/OFF, programmable timing, lumen maintenance	0.20
Lumen maintenance	0.10
Lumen maintenance, programmable timing	0.15
Programmable timing	0.15
Occupancy sensor	0.30
Occupancy sensor, DS, continuous dimming	0.40
Occupancy sensor, DS, multiple step dimming	0.35
Occupancy sensor, DS, ON/OFF	0.35
Occupancy sensor, DS, continuous dimming, lumen maintenance	0.45
Occupancy sensor, DS, multiple step dimming, lumen maintenance	0.40
Occupancy sensor, DS, ON/OFF, lumen maintenance	0.35
Occupancy sensor, lumen maintenance	0.35
Occupancy sensor, programmable timing	0.35

Appendix H

New York

Appendix H

New York

This appendix describes changes that have been made to COM*check* to support the New York Energy Conservation Construction Code, which is based on the 2003 IECC.

H.1 Building Use Types

All building use types are the same as the 2003 IECC version of COM*check*.

H.2 Envelope

All envelope trade-off calculations and requirements are the same as the 2003 IECC. An ‘Electric Resistance’ or ‘Other’ heating type option is available for multifamily dwellings. If a multifamily dwelling with electric resistance heating is indicated, the New York residential electric requirements are applied. This option is applicable to envelope and mechanical compliance only, as lighting compliance isn’t required for multifamily dwellings.

The envelope compliance report includes a requirements checklist item requiring fireplaces (solid fuel type) to be installed with tight fitting non-combustible fireplace doors.

H.3 Mechanical

All mechanical equipment efficiencies are the same as the 2003 IECC requirements, as listed in Appendix C of this document. Requirements specific to hydronic system controls and water source heat pump systems were added.

H.4 Lighting

All lighting requirements are the same as the 2003 IECC version of COM*check*. The Lighting and Power Compliance Certificate was modified to include requirements for metering individual dwelling units and transformer efficiency requirements according to Tables 805.6.1 and 805.6.2 of the New York Commercial Code.

Appendix I

Vermont

Appendix I

Vermont

This appendix describes changes that have been made to COM*check* to support the 2005 Vermont Guidelines for Energy Efficient Commercial Construction. The envelope requirements are based on the 2004 IECC with Vermont-specific amendments, and lighting system requirements are based on Standard 90.1-2004 lighting power densities and 2004 IECC exemptions and allowances. Mechanical requirements are based on the 2004 IECC and Vermont-specific amendments. All mandatory requirements were updated to reflect the Vermont amendments to the 2004 IECC and Standard 90.1-2004.

I.1 Building Use Types

The Vermont whole building types and area categories are identical to those in the Standard 90.1-2004 version of COM*check*.

I.2 Envelope

All envelope requirements are based on the prescriptive table provided in the Vermont guidelines. The R-value requirements in the Vermont prescriptive requirements Tables 802.2(1) and 802.2(2) are converted to budget U-factors based on the assembly type. These budget U-factors are used in the envelope trade-off calculations. Glass doors (doors exceeding 50% of glazing area) are treated as windows, and all other doors are treated as opaque doors. All non-swinging doors are required to meet a U-factor requirement of R-10.85 (including the interior and exterior air films). The maximum area of skylights is limited to 5% of the gross roof area. The skylight U-factor requirements are independent of the curb type, but default values for skylight U-factors are provided based on the curb type according to Table A8.1A of Standard 90.1-2004. All envelope assembly U-factor calculations are consistent with Appendix A of Standard 90.1-2004. Burlington weather data is used in trade-off calculations for all locations. All Vermont envelope requirements checklist items are the same as the 2004 IECC, and the mandatory requirements were revised to include reference to Tables 102.1.3(1), 102.1.3(2), and 102.1.3(3) of the 2004 IECC.

To check compliance for buildings with window and glazed door area exceeding 50% of the gross above-grade wall area, users are required to use the Section 11: Energy Cost Budget Method of Standard 90.1-2004, which requires the use of energy simulation software. The Vermont guidelines limit the use of prescriptive tables and COM*check* trade-off compliance to buildings with a window-wall ratio (WWR) < 50%.

I.3 Mechanical

All mechanical equipment efficiencies and requirements checklist items are the same as the 2004 IECC requirements, which in turn are based on the 2003 IECC, as listed in Appendix F of this document, with the exception of air conditioners and heat pumps < 65 kBtu/h, which are required to meet Standard

90.1-2004 efficiency requirements that became effective in January 2006. In addition, the following changes were made to the mechanical section:

- All references to electrical resistance heating were removed.
- No high efficiency equipment exception is provided for the economizer requirement.
- Electric service water heating units are limited to a maximum of 5 kW total power input.
- The heat trace tape option was removed from service water heating because the Vermont Energy Office does not have any field inspectors to verify the controls and preferred not to provide the option.

I.4 Lighting

The Vermont requirements for lighting power densities and the list of building use types for whole building and area category methods are the same as Standard 90.1-2004. Lighting allowances are also based on Standard 90.1-2004 without video display terminals. Lighting exemptions are the same as the 2004 IECC.

The Vermont lighting requirements checklist includes the following items:

- Exterior lighting requirements need to be documented separately and should comply with Section 805.6 of the Vermont Guidelines, which is the same as Standard 90.1-2004.
- Transformers are required to meet the minimum efficiency requirements as per Tables 806.2 and 806.3 of the Vermont Guidelines.
- Voltage drop requirements are included and are same as the Standard 90.1-2004 requirements.

Appendix J

Georgia

Appendix J

Georgia

This appendix describes changes that have been made to COM*check* to support the Georgia Commercial Code. The Georgia version of COM*check* uses the envelope trade-off calculations, lighting power densities and mechanical requirements of Standard 90.1-2004, which is referenced in the Georgia Code.

J.1 Envelope

In 2006, Georgia amendments provided assembly U-factors for metal building roofs taking into account the purlin spacing and a lab-tested U-factor of R-19 for screw down roofs without thermal blocks. A new Figure 9-3 was included in the Georgia amendments to calculate the effect of purlin spacing on the overall assembly U-factor. Table J.1 lists the adjustment factors derived from Figure 9-3. This adjustment factor was applied to assembly U-factors provided in Table A2.3 of Standard 90.1-2004 for standing seam and screw-down metal roofs. In 2008, Figure 6-2 was added to the Georgia Code, and the U-factors from this Figure, as shown in Table J.2 are used with the adjustment factors in Table J.1.

Table J.1. Adjustment Factors for Calculating Assembly U-factors of Standing Seam and Screw-down Roofs

Purlin Spacing (*d*)	Adjustment Factor
$d \leq 2$	1.729
$2 < d \leq 2.5$	1.482
$2.5 < d \leq 3.0$	1.329
$3.0 < d \leq 3.5$	1.212
$3.5 < d \leq 4.0$	1.118
$4.0 < d \leq 4.5$	1.047
$4.5 < d \leq 5.0$	1.0

Table J.2. Metal Roof U-Factors with R-19 Fiberglass Insulation Installed Over the Purlins

THROUGH-FASTENED METAL ROOF		STANDING SEAM METAL ROOF[2]	
PURLIN SPACING[3]	*U*-FACTOR	PURLIN SPACING[3]	*U*-FACTOR
2.0 feet	0.147	2.0 feet	0.112
2.5 feet	0.126	2.5 feet	0.096
3.0 feet	0.113	3.0 feet	0.086
3.5 feet	0.103	3.5 feet	0.079
4.0 feet	0.095	4.0 feet	0.073
4.5 feet	0.089	4.5 feet	0.068
5.0 feet	0.085	5.0 feet	0.065

1. Through-fastened metal roof values are based on ORNL/MBMA November 2004 User Agreement Report, “Tests of Through-Fastened Metal Roof Assemblies”. Standing seam metal roof values are based on ASHRAE/IESNA Standard 90.1 for 5-foot purlin spacing and conservatively estimated for other spacing using the same relationship as through-fastened test data.
2. 1-inch by 3-inch (25 mm by 76 mm) thermal block is required between metal roof and purlins.
3. For roofs with mixed spacing, calculate the average roof *U*-factor as shown below.
   Example: Total roof is 8000 ft^2 (743.22 m^2) standing seam metal roof. 1600 ft^2 (148.64 m^2)—20% of it—is on purlins spaced at $2^1/_2$ feet (762 mm). 6400 ft^2 (594.58 m^2)—80% of it—is on purlins spaced at 5 feet (1524 mm). Average Roof *U*-Factor = 0.20 x 0.096 + 0.80 x 0.065 = 0.071.

J.2 Mechanical

New minimum efficiency requirements for air conditioners and unitary heat pump systems are included.

J.2.1.1 Heat Pumps

Heat pumps changed from HSPF = 7.4/SEER = 12 to HSPF = 7.7/SEER = 13 for the following air-cooled systems < 54 kBtu/h and 54-65 kBtu/h: Rooftop Packaged Unit and Split System Heat Pump.

Beginning January 1, 2010, the following efficiencies will be applied for Rooftop Package Unit, Split System Heat Pump:

Cooling Capacity (kBtu/h)	COP	EER/IPLV
≤ 90 - <135	3.3	11.0
135 - 240	3.2	10.6
240 - < 760	3.2	9.5/9.2

J.2.1.2 Air Conditioners

Air conditioners change SEER = 12 to SEER = 13 for the following air-cooled systems < 54 kBtu/h and 54-65 kBtu/h: Rooftop Package DX Unit, Split DX System, and Field-Assembled DX Systems.

Beginning January 1, 2010, the following efficiencies will be applied for Rooftop Package DX Unit, Split DX System, and Field-Assembled DX System:

Cooling Capacity (kBtu/h)	EER/IPLV
≤ 90 - <135	11.2
135 - 240	11.0
240 - < 760	10.0/9.7
≥760	9.7/9.4

Appendix K

90.1-2004

Appendix K

90.1-2004

This appendix documents changes that have been made to COM*check* to support Standard 90.1-2004. New minimum equipment efficiencies went into effect in January 2006.

K.1 Building Use Types

K.1.1 Whole Building Types

The whole building types are identical to Standard 90.1-1999, although the internal load densities (ILDs) and lighting power densities (LPDs) were revised to be consistent with Standard 90.1-2004.

Table K.1. Whole Building Use Types

Whole Building Use Type	ILD W/ft^2	LPD W/ft^2
Automotive Facility	0.75	0.9
Convention Center	1.95	1.2
Court House	1.95	1.2
Dining: Bar Lounge/Leisure	1.95	1.3
Dining: Cafeteria/Fast Food	1.95	1.4
Dining: Family	1.95	1.6
Dormitory	1.25	1
Exercise Center	1.95	1
Gymnasium	1.95	1.1
Health Care-Clinic	1.95	1
Hospital	1.95	1.2
Hotel	1.25	1
Library	1.95	1.3
Manufacturing Facility	0.75	1.3
Motel	1.25	1
Motion Picture Theater	1.95	1.2
Multifamily	1.25	0.7
Museum	1.95	1.1
Office	1.95	1
Parking Garage	0.75	0.3
Penitentiary	1.25	1
Performing Arts Theater	1.95	1.6
Police/Fire Station	1.95	1
Post Office	1.95	1.1
Religious Building	1.95	1.3
Retail	1.95	1.5
School/University	1.95	1.2
Sports Arena	1.95	1.1
Town Hall	1.95	1.1
Transportation	1.95	1
Warehouse	0.75	0.8
Workshop	0.75	1.4

K.1.2 Area Categories

Table K.2 shows the Standard 90.1-2004 area categories.

Table K.2. Area Categories

Area Category Type	ILD W/ft^2	LPD W/ft^2
Common Space Types		
Active Storage	0.75	0.8
Atrium - Each Additional Floor	1.95	0.2
Atrium - First Three Floors	1.95	0.6
Audience/Seating Area	1.95	0.9
Classroom/Lecture/Training	1.95	1.4
Conference/Meeting/Multipurpose	1.95	1.3
Corridor/Transition	1.95	0.5
Dining Area – General	1.95	0.9
Dining Area - Bar Lounge/Leisure	1.95	1.4
Dining Area - Family Restaurant	1.95	2.1
Dressing/Locker/Fitting Room	1.95	0.6
Electrical/Mechanical	1.95	1.5
Food Preparation	1.95	1.2
Inactive Storage	0.75	0.3
Laboratory	1.95	1.4
Lobby	1.95	1.3
Lounge/Recreation	1.95	1.2
Office – Enclosed	1.95	1.1
Office - Open Plan	1.95	1.1
Restrooms	1.95	0.9
Stairs-Active	1.95	0.6
Workshop	0.75	1.9
Gymnasium/Exercise Center		
Playing Area	1.95	1.4
Exercise Area	1.95	0.9
Gymnasium Audience/Seating Area	1.95	0.4
Exercise Center Audience/Seating Area	1.95	0.3
Courthouse/Police Station/Penitentiary		
Courtroom	1.95	1.9
Confinement Cell	1.25	0.9
Judges Chambers	1.95	1.3
Penitentiary Audience/Seating Area	1.95	0.7
Penitentiary Classroom/Lecture/Training	1.95	1.3
Penitentiary Dining Area	1.95	1.3
Fire Stations		
Fire Station Engine Room	1.95	0.8
Fire Station Sleeping Quarters	1.25	0.3
Post Office		
Sorting Area	1.95	1.2
Convention Center		
Exhibit Space	1.95	1.3
Audience/Seating Area	1.95	0.7
Library		
Card File and Cataloging	1.95	1.1
Reading Area	1.95	1.2
Stacks	1.95	1.7
Sports Arena		
Audience/Seating Area	1.95	0.4
Court Sports Area	1.95	2.3
Indoor Playing Field Area	1.95	1.4
Ring Sports Area	1.95	2.7
Warehouse		
Fine Material Storage	0.75	1.4
Medium/Bulky Material Storage	0.75	0.9
Parking Garage		
Garage Area	0.75	0.2

Area Category Type	ILD W/ft^2	LPD W/ft^2
Hospital		
Active Storage	0.75	0.9
Corridors /Transition	1.95	1
Emergency	1.95	2.7
Exam/Treatment	1.95	1.5
Laundry – Washing	1.95	0.6
Lounge/Recreation	1.95	0.8
Medical Supply	1.95	1.4
Nurse Station	1.95	1
Nursery	1.95	0.6
Operating Room	1.95	2.2
Patient Room	1.25	0.7
Pharmacy	1.95	1.2
Physical Therapy	1.95	0.9
Radiology	1.95	0.4
Recovery	1.95	0.8
Automotive		
Service/Repair	0.75	0.7
Manufacturing		
Detailed Manufacturing	0.75	2.1
Control Room	0.75	0.5
Corridor/Transition	0.75	0.5
Equipment Room	0.75	1.2
Low Bay (< 25 ft. Floor to Ceiling Height)	0.75	1.2
High Bay (>= 25 ft. Floor to Ceiling Height)	0.75	1.7
Hotel/Motel		
Hotel Dining Area	1.95	1.3
Hotel Lobby	1.95	1.1
Guest Rooms	1.25	1.1
Motel Dining Area	1.95	1.2
Dormitory		
Living Quarters	1.5	1.1
Museum		
Active Storage	0.75	0.8
General Exhibition	1.95	1
Inactive Storage	0.75	1.4
Restoration	1.95	1.7
Bank/Office		
Banking Activity Area	1.95	1.5
Religious Buildings		
Audience/Seating Area	1.95	1.7
Fellowship Hall	1.95	0.9
Worship Pulpit, Choir	1.95	2.4
Retail		
Sales Area	1.95	1.7
Mall Concourse	1.95	1.7
Transportation		
Air/Train/Bus - Baggage Area	1.95	1
Airport - Concourse	1.95	0.6
Seating Area	1.95	0.5
Terminal - Ticket Counter	1.95	1.5
Motion Picture Theater		
Audience/Seating Area	1.95	1.2
Lobby	1.95	1.1
Performing Arts Theater		
Audience/Seating Area	1.95	2.6
Lobby	1.95	3.3

K.2 Envelope

New DOE climate zones were mapped to Standard 90.1-1999 based bins, and the envelope requirements were obtained from Standard 90.1-1999 Appendix B tables. The climate zone mapping is listed in Table K.3.

Table K.3. Climate Zone Mapping

90.1-2004 Requirements Table	90.1-1999 Appendix-B Tables
5.5-1	B.2
5.5-1	B-5
5.5-3a,b	B-10
5.53c	B-9
5.5-4	B-13
5.5-4	B-17
5.5-4	B-19
5.5-4	B-22
5.5-4	B-24

The envelope requirements in Standard 90.1-2004 are the same for all moisture regimes (moist, dry, and marine) within each climate zone, except for fenestration requirements in Climate Zone 3 marine.

K.2.1 High Albedo Roof

The implementation of compliance for high albedo roofs when 90.1-2004 is the selected code uses the 90.1-2007 requirements and table. For 90.1-2004, conditioned cooling spaces are not a qualifying condition, only semiheated is considered. Additionally, in this code the U-value adjustment is made by multiplying the proposed U-value by a multiplier associated with the climate zone.

K.3 Mechanical

Equipment efficiency requirements were modified for applicable air-cooled (split systems and roof top) AC units and heat pump systems with capacity < 65 kBtu/h to reflect the changes required in January 2006. Additional changes include:

- SPV (single package vertical) AC and SPVHP (single package vertical heat pump) were added.
- Air cooled (split systems and roof top) AC units with capacity < 65 kBtu/h, the cooling efficiency requirement was revised to be 10.0 SEER, effective January 2006.
- Air cooled (split systems and roof top) heat pump systems with capacity < 65 kBtu/h, the efficiency requirement was revised to be 12.0 SEER and 7.4 HSPF, effective January 2006.
- Fan power limitation was reduced from 30 hp to 15 hp.
- Supply and return air duct insulation requirements were revised according to the new climate zones (implemented in the Requirements Checklist).
- Economizer requirements were updated based on Table 6.5.1 in Standard 90.1-2004.

- The high-efficiency equipment exception is now based on Table 6.3.2, which does not allow this exception to be claimed in Climate Zones 5, 6, 7, and 8. For all economizers in Climate Zones 2, 3, and 4, a new set of efficiency requirements was implemented according to Table 6.3.2.

K.4 Lighting

The lighting power densities (LPDs) were changed and the lighting menu structure was revised to be consistent with the new format in Standard 90.1-2004. The revised list of whole building types, area categories and internal load densities (ILD) and LPDs is given in Tables K.1 and K.2.

The exterior lighting requirements in 90.1-2004 provide lighting power density (LPD) limits for the various exterior applications expected to be found as part of commercial building installations. These LPDs are separated into "tradable" and "non-tradable" applications.

The "tradable" LPDs operate in a similar manner to the existing interior LPDs. This means that the individual "Tradable" allowances are calculated for each application based on length or area of the application and then summed to provide a total allowance for all of those "tradable" applications. This total allowed wattage can then be used in any manner among the "tradable" applications only, along with an additional 5% bonus allowance (see below).

The "non-tradable" applications function on a use-it-or-lose-it basis. These applications have specific allowances that can only be used for that application and cannot be "traded" to other applications. Where additional lighting might be needed for these specific applications, an additional 5% bonus allowance is available to cover these (see below).

"Tradable" exterior lighting areas and LPDs:

Attached canopy	1.25	ft^2
Driveway	0.15	ft^2
Free standing canopy	1.25	ft^2
Main entry/exit	30	ft of door width
Other entry/exit	20	ft of door width
Outdoor sales area/lot	0.5	ft^2
Parking area(s)	0.15	ft^2
Plaza area	0.2	ft^2
Special feature area	0.2	ft^2
Stairway	1.0	ft^2
Vehicle sales street frontage	20	ft
Walkway < 10 feet wide	1.0	ft
Walkway >= 10 feet wide	0.2	ft^2

"Non-tradable" exterior lighting areas and LPDs:

ATM/Depository site	90	machine(s) + 180 per site
Drive-up window	400	window(s)
Emergency services, uncovered loading area	0.5	ft^2
Guarded facility, uncovered entrance/inspection area	1.25	ft^2
Illuminated wall or surface area	0.2	ft^2
Illuminated wall or surface length	5.0	ft
Parking near 24-hour retail entrance	800	main entry(s)

The "5% bonus allowance" is an additional allowance of 5% of the total allowed wattage for both "tradable" and "non-tradable" applications. This 5% can be used for any application or combination of applications in the "tradable" and "non-tradable" sections.

Specific application notes:

- "Parking Lots and Drives" area is meant to include any minor medians and separation strips that are included within the parking area.
- "Outdoor Sales" applies to any permanently planned outdoor sales activity including vehicles.
- "Building Façade" application provides two methods for compliance. Use either W/ft2 of surface to be illuminated OR W/linear foot of the ground or base length of the surface (base/ground edge only – not entire perimeter)
- "Automated teller machines and night depositories" allowance is applied as 270 W per location which includes one machine in that specific location and an additional 90 W for each additional machine in that location. The first machine at each of two separate locations (i.e. opposite sides or ends of the building) would each get the initial 270 W per location. This is also the same as applying 180 W for each ATM type location and an additional 90 W for each machine at each location.

"Drive up windows at fast food restaurants" applies to all drive-up windows regardless of its application (i.e. applies also to pharmacies, banks, etc.).

The Mandatory Requirements text was modified to reflect the changes in Standard 90.1-2004 related to interior space controls, exterior lighting controls and new exceptions were added to the interior automatic lighting shut off requirements. Standard 90.1-2004 revised the requirements for exterior lighting power densities and provides a trade-off calculation methodology.

K.5 Window-to-Wall Ratio (WWR)

A formal ASHRAE interpretation affected the WWR calculation in COM*check* with the release of Version 3.1. See Section D.5 for details.

Appendix L

2004 IECC

Appendix L

2004 IECC

This appendix documents changes that have been made to COM*check* to support the 2004 International Energy Conservation Code (IECC). The envelope requirements in the 2004 IECC are based on new climate zones and assembly types. The lighting requirements are the same as the 2003 IECC. The mechanical requirements are based on the 2003 IECC with minor changes to economizer requirements and other prescriptive requirements.

L.1 Building Use Types

The building use types for the 2004 IECC are the same as the 2003 IECC for both the whole building and area category types.

L.2 Envelope

The envelope requirements in the 2004 IECC are specified as R-values for generic assembly types. The trade-off calculations require assembly U-factors, and these are calculated based on the R-value requirements in Tables 802.2(1) and 802.2(2) of the 2004 IECC. The U-factor calculations are based on assembly types described in Appendix A tables in Standard 90.1-2001. The envelope assembly types in the 2004 IECC version of COM*check* are different from the earlier IECC versions of COM*check*. These are same as the Standard 90.1-2001 version, and the mapping table described in Table D.5 is used to calculate the required assembly U-factors for each proposed assembly type. For example, if an 'Attic Roof with Wood Joists' roof is selected, the R-value requirement from Table 802.2(1) for 'Attic and Other' for that climate zone is used in the assembly U-factor calculation for 'Attic Roof with Wood Joists'. This approach maintains consistency in assembly U-factor calculations for the proposed and budget building. For windows and glazed doors, the requirements are determined based on whether these are factory assembled or site-built. Whenever there are no requirements specified for an assembly in Table 802.2(1) of the 2004 IECC, the base assembly U-factor is used as the code requirement such that no trade-off is provided for the uninsulated assembly.

The Standard 90.1-2001 based envelope performance factor calculations are used for determining trade-off compliance. The budget building is based on proposed window-to-wall ratio (WWR). For buildings with WWR > 40%, users are advised to use the Standard 90.1-2001 version of COM*check*, IECC Section 806: Total Building Performance, or Standard 90.1 Section 11: Energy Cost Budget Method.

L.3 Mechanical

The mechanical requirements description report and requirements checklist were revised to be consistent with the following 2004 IECC requirements:

- For all plant equipment with heat capacity exceeding 300 kBtu/h, hydronic system control requirements based on 803.3.3.7 already implemented in COM*check* are added to the compliance report.
- Economizer requirements were revised according to Table 803.2.6(1) using the new climate zones. The high-efficiency equipment exception is based on Table 803.2.6(2) and the required efficiency (EER and IPLV) are increased by the percentages specified by this table.
- The Requirements Checklist and descriptive requirements for duct sealing tapes and mastics were revised to include reference to UL standards based on duct type.
- The heated swimming pool option was added to the service water heating system description and the requirements for controls and pool covers were added.

L.4 Lighting

The requirements checklist item for the manual controls requirement was changed to include an exemption for ‘guest rooms’.

Appendix M

2006 IECC

Appendix M

2006 IECC

This appendix documents changes that have been made to the 2004 IECC version of COM*check* to support the 2006 International Energy Conservation Code (IECC). The most significant change affecting the software is the elimination of the area category method of interior lighting compliance.

M.1 Building Use Types

The building use types for the 2006 IECC are significantly changed from the 2004 IECC. Instead of having both whole building and area category types, the 2006 IECC includes only "building area types". This new method requires users to specify the building by the Building Area Types, which are provided in Table 505.5.2 of the 2006 IECC.

M.2 Envelope

The envelope requirements in the 2006 IECC are specified as R-values for generic assembly types. The trade-off calculations require assembly U-factors, and these are calculated based on the R-value requirements in Table 502.2(1) of the 2006 IECC. The U-factor calculations are based on assembly types described in the Appendix A tables in Standard 90.1-2004. For windows and glazed doors, the requirements are determined based on the framing material (metal or non-metal). Glazed doors must be specified as either "entrance" or "non-entrance" doors. The proposed and required assembly U-factor calculations use the same balance of assembly U-factors. All COM*check* assembly types are mapped to equivalent generic assembly types in Table 502.2(1).

The Standard 90.1-2004 based envelope performance factor calculations are used for determining trade-off compliance. The budget building is based on proposed window-to-wall ratio (WWR). For buildings with WWR > 40%, users are advised to use the Standard 90.1-2004 version of COM*check*, IECC Section 506: Total Building Performance, or Standard 90.1 Section 11: Energy Cost Budget Method.

The 2006 IECC introduced a skylight area limit of 3% of the gross roof area. The interior wall requirements were removed. Curtain walls are a new window assembly type, with the applicable U-factors taken from Table 502.3 of the 2006 IECC. These changes were all implemented in the 2006 IECC version of COM*check*.

M.3 Mechanical

The software was modified to require variable speed drives for all fan systems over 10 hp and also to exempt the automatic bypass valve requirement in Climate Zones 1 and 2. The 2006 IECC EF calculation for gas storage water heaters was implemented as per Table 504.2 of the 2006 IECC. The mechanical requirements were revised to be consistent with the following 2006 IECC requirements:

- Economizer requirements were revised to include the new requirement for providing a means of relieving outdoor air to prevent building over pressurization during economizer operation. The economizer requirement was reduced from 65 kBtu/h to 54 kBtu/h.
- The shut-off damper control exceptions were modified to include gravity dampers as per Section 503.2.4.4 of the 2006 IECC.
- The heat pump pool heater option was added to the service water heating inputs and the heat pump water heater efficiency requirement of 4.0 COP was added.

M.4 Lighting

The list of building area types and associated lighting power densities are implemented as provided in Table 505.5.2 of the 2006 IECC. Lighting allowances and exemptions for Retail are implemented. Allowances are limited to Retail buildings, as per Table 505.5.2, Footnote ‘b’. Only merchandise and fine merchandise display allowances are supported.

For the merchandise display allowance, the maximum allowance is the smaller of:

- the actual wattage of the lighting equipment installed specifically for merchandise, or
- 1.6 W/ft^2 times the area of the specific display, but not to exceed 50% of the floor area.

For the fine merchandise display allowance, the maximum allowance is the smaller of:

- the actual wattage of the lighting equipment installed specifically for fine merchandise, or
- 3.9 W/ft^2 times the actual case or shelf area for displaying and selling jewelry, china or silver. Additionally, up to two times the floor area of fine merchandise display areas is permitted.

The automatic lighting shutoff requirements were modified to include the exemptions as per Section 505.2.2.2 of the 2006 IECC.

The exterior lighting requirements in the 2006 IECC provide lighting power density (LPD) limits for the various exterior applications expected to be found as part of commercial building installations. These LPDs are separated into “tradable” and “non-tradable” applications.

The “tradable” LPDs operate in a similar manner to the existing interior LPDs. This means that the individual “Tradable” allowances are calculated for each application based on length or area of the application and then summed to provide a total allowance for all of those “tradable” applications. This total allowed wattage can then be used in any manner among the “tradable” applications only, along with an additional 5% bonus allowance (see below).

The “non-tradable” applications function on a use-it-or-lose-it basis. These applications have specific allowances that can only be used for that application and cannot be “traded” to other applications. Where additional lighting might be needed for these specific applications, an additional 5% bonus allowance is available to cover these (see below).

“Tradable” exterior lighting areas and LPDs:

Attached canopy	1.25	ft^2
Driveway	0.15	ft^2
Free standing canopy	1.25	ft^2
Main entry/exit	30	ft of door width
Other entry/exit	20	ft of door width
Outdoor sales area/lot	0.5	ft^2
Parking area(s)	0.15	ft^2
Plaza area	0.2	ft^2
Special feature area	0.2	ft^2
Stairway	1.0	ft^2
Vehicle sales street frontage	20	ft
Walkway < 10 feet wide	1.0	ft
Walkway >= 10 feet wide	0.2	ft^2

“Non-tradable” exterior lighting areas and LPDs:

ATM/Depository site	90	machine(s) + 180 per site
Drive-up window	400	window(s)
Emergency services, uncovered loading area	0.5	ft^2
Guarded facility, uncovered entrance/inspection area	1.25	ft^2
Illuminated wall or surface area	0.2	ft^2
Illuminated wall or surface length	5.0	ft
Parking near 24-hour retail entrance	800	main entry(s)

The “5% bonus allowance” is an additional allowance of 5% of the total allowed wattage for both “tradable” and “non-tradable” applications. This 5% can be used for any application or combination of applications in the “tradable” and “non-tradable” sections.

Specific application notes:

- “Parking Lots and Drives” area is meant to include any minor medians and separation strips that are included within the parking area.
- “Outdoor Sales” applies to any permanently planned outdoor sales activity including vehicles.
- “Building Façade” application provides two methods for compliance. Use either W/ft2 of surface to be illuminated OR W/linear foot of the ground or base length of the surface (base/ground edge only – not entire perimeter)
- “Automated teller machines and night depositories” allowance is applied as 270 W per location which includes one machine in that specific location and an additional 90 W for each additional machine in that location. The first machine at each of two separate locations (i.e. opposite sides or ends of the building) would each get the initial 270 W per location. This is also the same as applying 180 W for each ATM type location and an additional 90 W for each machine at each location.
- “Drive up windows at fast food restaurants” applies to all drive-up windows regardless of its application (i.e. applies also to pharmacies, banks, etc.).

Appendix N

Pima County, AZ

Appendix N

Pima County, AZ

This appendix documents changes that have been made to COM*check* to support the implementation of the 2006 International Energy Conservation Code (IECC) for Pima County, AZ, and the Sustainable Energy Standard. The Pima County version is identical to the 2006 IECC, but certain location and corresponding weather data restrictions have been applied.

- For the code selection: “2006 IECC < 4000 ft”, Tucson weather data is used.
- For the code selection: “2006 IECC for locations >=4000 ft”, McNary weather data is used.
- For the code selection: “Sustainable Energy Standard”, McNary weather data is used.

Appendix O

New Hampshire

Appendix O – New Hampshire

This appendix documents changes that have been made to COM*check* to support the implementation of the 2006 International Energy Conservation Code (IECC) for New Hampshire. The New Hampshire version is identical to the 2006 IECC, but the weather data for the city of Concord (Climate Zone 6) is used for all locations.

Appendix P

90.1-2007

Appendix P

90.1-2007

This appendix documents changes that have been made to COM*check* to support Standard 90.1-2007.

P.1 Building Use Types

P.1.1 Whole Building Types

The whole building types are identical to Standard 90.1-2004. See Appendix K for details.

P.1.2 Area Categories

The area categories are identical to Standard 90.1-2004. See Appendix K for details.

P.2 Envelope

High Albedo Roof

Compliance for high albedo roofs is implemented starting in COM*check* 3.6.0 for projects with unventilated attic spaces over cooled conditioned spaces in Climate Zones 1-3. Conditioned cooling is an added qualifying condition and there is an additional validation option of using the Solar Reflective Index. A U-factor consideration is made on the required U-factor and is determined by the climate zone and the high albedo roof assembly type. COM*check* makes the necessary adjustments to required U-factors based on Table 5.5.3.1 in Standard 90.1-2007.

P.3 Mechanical

- Equipment efficiency requirements that go into effect in January 2010 were implemented.
- Fan system power limitation “Option 1”, per Table 6.5.3.1.1A in Standard 90.1-2007, was implemented for systems with total fan motor horsepower greater than 5 hp.
- Part-load fan power limitation was modified to apply to individual VAV fans with motors 10 hp and larger.
- The requirements checklist text was modified for ventilation controls for high-occupancy areas and part-load fan power limitation.

P.4 Lighting

The exterior lighting requirements in 90.1-2007 provide the same lighting power density (LPD) limits for the various exterior applications expected to be found as part of commercial building installations as 90.1-2004. See Appendix K for details.

90.1-2007 has modifications to the retail merchandise highlighting display allowances. If Decorative Appearance is selected, 1.0 times the area entered will be added to the allowed wattage of the area. (Note: Decorative Appearance is applicable to all other area categories as well.) This is actually the same as it was in earlier codes.

If one of the Retail Merchandise Highlighting options is selected, then the dialog will again be presented for the user to enter the applicable floor area. The floor area entered is stored along with the associated power allowance for the particular retail merchandise highlighting type (e.g., jewelry, crystal, china has a power allowance of 4.2).

The area entered is programmatically evaluated to be sure the sum of all claimed Allowances within the space does not exceed the area of the space. Also, no "allowance claim" will be transferable to other spaces. Also, an "allowance claim" will only be transferable to other fixtures so long as it is offsetting a equal amount of base wattage. That is, if a claim is made for a particular retail type then allowances can only be claimed up to the amount "needed" for that fixture in order for it to pass. For example, if 100 ft2 of jewelry highlighting allowance is claimed for supplementing a "proposed fixture" wattage of 300, then only 300 allowance watts will be applied even though a possible 420 exists. The net 120 watts will only be applied if the "proposed fixture" wattage for that particular fixture is increased accordingly.

If there is any retail highlighting allowance claims specified, an additional 1000 allowance watts are available for application to retail highlighting fixtures (i.e., those fixtures with a highlighting allowance claim).

More specifically, if interior lighting compliance fails, the software checks to see if there are any spaces with Retail Highlighting allowances claimed. If there are then it goes to each of those spaces in turn and for each of the fixtures with highlighting allowance claims the net wattage (proposed – required) will be calculated and summed together. Up to 1000 watts of the sum wattage will then be added to the allowance toward compliance.

The Mandatory Requirements text was modified to reflect the changes in Standard 90.1-2007 related to interior space controls, exterior lighting controls and new exceptions were added to the interior automatic lighting shut off requirements.

P.5 Window-to-Wall Ratio (WWR)

A formal ASHRAE interpretation affected the WWR calculation in COM*check* with the release of Version 3.1. See Section D.5 for details.

Distribution

No. of
Copies

\# Name
Organization
Address
City, State and ZIP Code

\# Organization
Address
City, State and ZIP Code
Name
Name
Name
Name
Name (#)

\# Name
Organization
Address
City, State and ZIP Code

No. of
Copies

\# **Foreign Distribution**

\# Name
Organization
Address
Address line 2
COUNTRY

\# **Local Distribution**
Pacific Northwest National Laboratory

Name	Mailstop
Name	Mailstop
Name	Mailstop
Name	Mailstop
Name	(PDF)

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

U.S. DEPARTMENT OF
ENERGY

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99352
1-888-375-PNNL (7665)
www.pnl.gov