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Development of Commercial Building Shell Heating and Cooling Load Factors

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Development of Commercial Building Shell Heating and Cooling Load Factors

Shell energy efficiency of a building envelope is an important determinant of the heating and cooling load. Improvements in the heating and cooling loads of buildings reduce the amount of energy these buildings need. The U.S. Energy Information Administration (EIA) contracted this report from ICF L.L.C., in order to inform modeling and analysis of domestic commercial building energy consumption. As part of its *Annual Energy Outlook (AEO)*, EIA models the consumption of commercial building energy in the Commercial model. The efficiency of building envelopes influences building energy consumption by affecting heat and/or cooling losses by the heating and cooling equipment through the envelope such as walls, floors, roofs, and windows. Building shell efficiencies were calculated for existing building stock in 2012 and for new construction in 2012 and in the AEO projection years 2020, 2030, 2040, and 2050.

The U.S. Department of Energy's (DOE's) Commercial Reference Buildings and EIA's 2012 Commercial Buildings Energy Consumption Survey data were used to develop the 2012 building stock models and estimates of building envelope values in the 2012 building stock by building, element, assembly, climate zone, and construction type. The research was paired with the prescriptive building envelope requirements of ASHRAE Standard 90.1 to project building envelope thermal performance values (U-factors and SHGCs) for new construction in 2012 and in AEO projection years 2020, 2030, 2040, and 2050. Specifically, projections were made for opaque (wall, floor, slab, and roof), fenestration (window and skylights), and whole-building infiltration rates.

The building envelope thermal performance values were used as inputs to dynamic building energy models. ICF simulated about 2,000 unique models to produce annual heating and cooling energy demand. The energy demand data were post-processed to develop commercial building shell heating and cooling load factors and represent the relative heating and cooling energy demand for new construction floorspace in the AEO projection year indexed to the heating and cooling energy demand of the 2012 building stock.

EIA's National Energy Modeling System (NEMS) uses a building shell efficiency index in the assumptions for the commercial building sector. The commercial shell heating and cooling load factors are indexed to the average base-year values by building type and Census division. These load factors affect the amount of energy needed to heat and cool the floorspace as well as the purchasing decisions for new heating and cooling technologies.

Building shell efficiencies were indexed to the existing building stock in 2012. The average improvement for new construction in 2012 compared with the existing building stock was 0.9194 for heating loads and 0.9317 for cooling loads. In other words, in the commercial module of NEMS, on average, new construction in 2012 demands 91.94% of the amount of heating and 93.17% of the amount of cooling for the same amount of existing stock floorspace.

When referencing the contract report, it should be cited as a report by ICF International, L.L.C. prepared for the U.S. Energy Information Administration.

APPENDIX

Development of Commercial Building Shell Heating and Cooling Load Factors

U.S. Energy Information Administration

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Acronyms and Abbreviations

AEO	Annual Energy Outlook
ARRA	American Recovery and Reinvestment Act of 2009 (Recovery Act)
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CBECS	Commercial Building Energy Consumption Survey
CD	U.S. Census division
CDM	Commercial Demand Module
CSV	Comma-separated value file
CZ	Climate zone
DOE	U.S. Department of Energy
EIA	U.S. Energy Information Administration
HTML	HyperText Markup Language
HVAC	Heating, ventilation, and air conditioning
ICF	ICF
IDF	EnergyPlus Input Data File
NEMS	National Energy Modeling System
NREL	National Renewable Energy Laboratory
PAT	OpenStudio Parametric Analysis Tool
U-factor	U-factor, overall assembly heat transfer coefficient
SHGC	Solar Heat Gain Coefficient
SF	Square feet
WWR	Window-to-wall ratio
W/sf	Watts per square foot
ZNE	Zero Net Energy

Definitions

AEO Projection Years: the projection years correspond to the five projection years used in EIA's 2018 Annual Energy Outlook: 2012, 2020, 2030, 2040, and 2050.

Assembly Type: the *assembly type* is a subcategory of *element type.* It describes the building envelope component as slab, wall, roof, vertical fenestration, or skylight. The definition is used to map between envelope characteristics in DOE's Commercial Building model and the prescriptive building envelope requirements of ASHRAE Standard 90.1.

Building Stock: the *building stock* was derived from estimates of the average or median construction characteristics for the existing building population in 2012, for each commercial building type. In this analysis, the building stock shell values were derived by weighting shell values from the three DOE Commercial Reference Building Models (Pre-1980, Post-1980, and New Construction) using building square footage obtained from 2012 CBECS data.

Commercial Prototype Building Models: dynamic building energy models developed by DOE and NREL, which approximate compliance with ASHRAE Standard 90.1 beginning in 2004. The library includes EnergyPlus models that describe 16 commercial building types for each version of the ASHRAE Standard.

Commercial Reference Building Models**:** dynamic building energy models developed by DOE and NREL from research and analysis of EIA's 2003 CBECS data. The library includes EnergyPlus models that describe 16 commercial building types and three vintages.

Construction Type: the *construction type* is a subcategory of *assembly type.* It describes the building *assembly type* construction in terms of metal building, mass, steel-framed, wood-framed, etc. The definition is used to map between envelope characteristics in DOE's Commercial Building model and the prescriptive building envelope requirements of ASHRAE Standard 90.1.

Cooling Load Factor: the annual space cooling energy demand (i.e., consumption) of the projection year indexed to the same energy demand of the 2012 building stock, unique to each building model.

Element Type: the *element type* refers to whether the building envelope is of opaque or fenestration construction. The definition is used to map between envelope characteristics in DOE's Commercial Building model and the prescriptive building envelope requirements of ASHRAE Standard 90.1.

Heating Load Factor: the annual space heating energy demand (i.e., consumption) of the projection year indexed to the same energy demand of the 2012 building stock, unique to each building model.

Overall U-Factor: a weighted value equal to the sum of the product of the U-factor and area of each building envelope assembly, divided by the total building envelope area, unique to each building model. Overall U-factors were developed for 2012 building stock and each projection year to derive building shell efficiency factors.

Executive Summary

ICF performed research, modeling, and analytics to support EIA in updating the *Commercial Building Shell Heating and Cooling Load Factors* used in the National Energy Modeling System (NEMS). The load factors are used in NEMS for estimating energy savings from improvements in building energy performance from improved levels of building envelope in new construction.

ICF performed secondary literature research on the adoption and compliance of building envelope systems in building energy codes and the technical and economic potential of building envelope system improvements in technology roadmaps that may be achievable through EIA's *Annual Energy Outlook* (AEO) projection period.

The U.S. Department of Energy's (DOE's) Commercial Reference Building and EIA's Commercial Building Energy Consumption Survey data were used to develop the 2012 building stock models and estimates of building envelope values in the 2012 building stock by building, element, assembly, and construction type. Our research was paired with the prescriptive building envelope requirements of ASHRAE Standard 90.1 to project building envelope thermal performance values (U-factors and SHGCs) for AEO projection years 2012, 2020, 2030, 2040, and 2050. Specifically, projections were made for opaque (wall, floor, slab, and roof), fenestration (window and skylights), and whole-building infiltration rates.

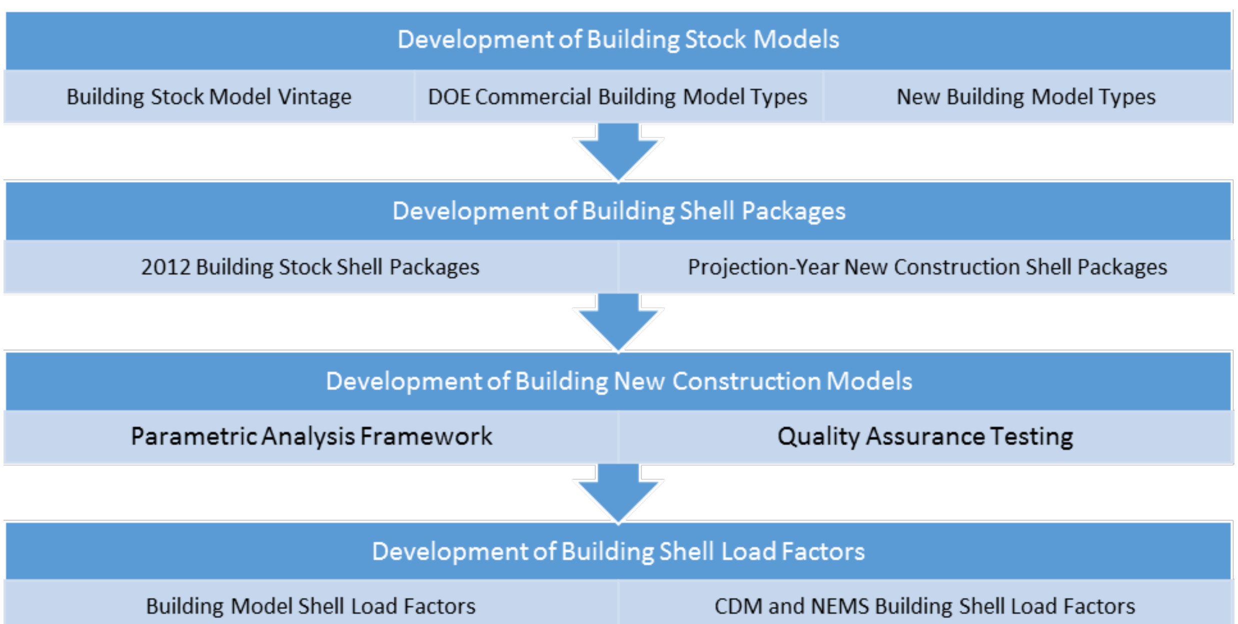
The building envelope thermal performance values were used as inputs to dynamic building energy models. ICF developed a workflow in OpenStudio to systematically modify building envelope characteristics in DOE's building models and parametrically simulate about 2,000 unique models to produce annual heating and cooling energy demand. The energy demand data were post-processed to develop *Commercial Building Shell Heating and Cooling Load Factors* and represent the relative heating and cooling energy demand for new construction floor space in the AEO projection year indexed to the heating and cooling energy demand of the 2012 building stock. The results of the analysis will be used by EIA as inputs to the Commercial Demand Module (CDM) in NEMS.

Introduction

The *Commercial Building Shell Heating and Cooling Load Factors* were developed by indexing projections of annual heating and cooling energy demand in commercial new construction to the energy demand of the building stock. In this analysis, the building stock was derived from estimates of the average or median construction characteristics of all existing commercial buildings in 2012. This method provided consistency with NEMS modeling requirements and enabled use of EIA's *2012 Commercial Building Energy Consumption Survey* data for development of new building model types and square footage weighting factors.

The analysis, which is depicted in **Figure 1,** used DOE's Commercial Reference Building[1] and Commercial Prototypical Building[2] models. They provided the framework for developing models and simulating the impacts from improvements in the building shell. Building envelope characteristics from the commercial reference models were used to derive thermal performance values for the 2012 building stock and the AEO projection years. Those values were used as inputs to dynamic building energy models and simulated in a custom OpenStudio workflow that systematically modified the building envelope characteristics and produced annual heating and cooling energy demand. The energy demand data were post-processed to develop *Commercial Building Shell Heating and Cooling Load Factors* that represent the relative heating and cooling energy demand for new construction floor space.

Figure 1 - Approach for Development of Commercial Building Shell Heating and Cooling Load Factors



[1] U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, Buildings, Commercial Reference Buildings

[2] U.S. Department of Energy, Building Energy Codes Program, Commercial Prototype Building Models

Development of Building Stock Models

The *Commercial Building Shell Heating and Cooling Load Factors* (load factors) were developed by indexing projections of annual heating and cooling energy demand in commercial new construction to the 2012 building stock. In this analysis, the building stock energy models were developed separately from the projections of the corresponding building stock shell packages. This section discusses development of the former. It discusses selection of the U.S. Department of Energy's (DOE) commercial building model type and vintage that provides the framework for modeling and simulating impacts from changes in building shell packages, the use of DOE's Commercial Reference Building and DOE's Commercial Prototypical Building models (collectively referred to herein as *DOE's commercial building models*), and development of building stock models for U.S. Energy Information Administration's (EIA's) Commercial Demand Module (CDM) commercial building types not available in those DOE building model libraries.

Building Stock Model Vintage

In this analysis, the same DOE commercial building model type and vintage were used for the building stock and EIA's *Annual Energy Outlook* (AEO) projection years. The models were modified to include the corresponding building shell packages, and they were simulated to derive the heating and cooling load factors. Because the load factors represent relative changes in annual heating and cooling energy demand from improvements made to building shell thermal performance values, a single building model vintage was required to isolate the impacts from building shell improvements. Using different model vintages would have erroneously introduced non-envelope improvements into the annual heating and cooling energy demand savings. In that context, ICF assessed DOE's commercial building models for a vintage that was reasonable for describing building asset and operational characteristics throughout the AEO projection years.

DOE's commercial building models were developed by DOE and the National Renewable Energy Laboratory (NREL) to support conducting energy policy analysis in the commercial building sector. In this study, these commercial building models provided a common basis and consistent framework for deriving the 2012 building stock shell packages, for analyzing changes in building envelope code requirements, and for parametrically simulating whole-building shell modifications.

The DOE commercial building models were developed for 16 commercial building types in each of the 16 international climate zones and describe about 60–70% of the U.S. commercial building stock. Although the building model types use similar descriptions, there are nuanced differences in building type definitions, international climate zone locations, and building construction characteristics that make them distinct from each other.

- **DOE's Commercial Reference Building models** were developed from analysis of EIA's 2003 Commercial Building Energy Consumption Survey (2003 CBECS) data. Three variants were developed to reflect average building stock characteristics for different construction vintages in the survey: Pre-1980, Post-1980, and New Construction. Building shell thermal performance values not available in the survey were approximated from previous survey research work (Pre-1980) and described by the prescriptive building envelope requirements of ASHRAE Standard 90.1 (1999 for Post-1980 and 2004 for New Construction).

- **DOE's Commercial Prototypical Building models** are similar to DOE's Commercial Reference Building models in that they generally consist of the same building types and construction characteristics. However, the building shell values are described by the prescriptive building envelope requirements of ASHRAE 90.1 (2004, 2007, 2010, and 2013).

DOE's Commercial Prototypical Building model vintage 2004 was selected as the basis for the building stock model because it balanced the building construction characteristics found in DOE's commercial building models. The preponderance of buildings in EIA's 2012 Commercial Building Energy Consumption Survey (2012 CBECS) could be represented by the Pre-1980 and Post-1980 Commercial Reference Building models, but would arguably have characteristics that are not representative of the building stock in the AEO projection years. Conversely, aside from the 2004 vintage, the Commercial Prototypical Building models were considered too recent to represent the 2012 building stock because these new construction building models represent a disproportionally smaller number of buildings and, on a national-level, code adoption and compliance tend to follow release of building energy codes by several years due to issuance of DOE state-level determinations and lack of uniformity in how the code is adopted and enforced across state jurisdictions[3]. As such, the 2004 building model vintage provided a reasonable balance of characteristics in the 2012 building stock and the AEO projection years.

DOE Commercial Building Model Types

Eight of the 11 CDM commercial building types are described by one or more of DOE's Commercial Prototypical Building models listed in **Table 1**. Those models were downloaded in OpenStudio file format from DOE's website. All building model vintages were obtained to support development of the 2012 building stock shell packages and for direct use in the parametrical analysis framework (discussed in subsequent sections of this report).

Table 1 - Comparison of Similar CDM and DOE Commercial Building Model Types

CDM Commercial Building Type	DOE Commercial Building Model Type
Education	Primary School
	Secondary School
Food Service	Quick Service Restaurant
	Full Service Restaurant
Health Care	Hospital
Lodging	High-rise Apartment
	Mid-rise Apartment
	Large Hotel
	Small Hotel

CDM Commercial Building Type	DOE Commercial Building Model Type
Office – Large	Large Office
	Medium Office
	Outpatient Healthcare
Office – Small	Small Office
	Outpatient Healthcare
Mercantile & Service	Strip Mall
	Stand-alone Retail
Warehouse	Warehouse

[3] ICF, Residential and Commercial Sector Energy Code Adoption and Compliance Rates, July 2016.

Because DOE's Commercial Prototypical Building Reference models represent the new construction prescriptive building envelope requirements of ASHRAE 2004, thermal performance values were developed for the 2012 building stock. The square footage represented by each commercial building model in 2012 CBECS was used to develop weighting factors, which were applied to the individual thermal performance values of each model to derive the 2012 building stock.

New Building Model Types

This section discusses the three CDM commercial building types not described by DOE's commercial building models: *Assembly*, *Food Sales*, and *Other*. In this study, different approaches were used to develop, obtain, and incorporate these building model types into the analysis. This section discusses how those approaches were used for developing the *Assembly* building type from DOE's *Medium Office* type model, obtaining the *Food Sales* building type from NREL, and incorporating the *Other* building type by weighting the annual heating and cooling energy demand of the other DOE commercial building model types.

Assembly Building Type

The *Assembly* building model type was developed by modifying DOE's *Medium Office* building type with predominate building characteristics and median performance values obtained from 2012 CBECS. ICF initially sought to understand the heating and cooling system types and efficiencies and building shell U-factors and SHGCs that had historically been used in EIA' s National Energy Modeling System (NEMS), as the starting point for development of a new *Assembly* building type. Review of previous EIA building shell efficiency work[4], however, revealed that DOE's Commercial Reference Building *Medium Office* type model had been used as a proxy for the *Assembly* building type.

ICF mined 2012 CBECS data and obtained predominate building construction characteristics and median performance values for the two CBECS *Principle Building Activity* types that defined the CDM *Assembly* building type: *Public Assembly* and *Religious Worship*. The purpose was to assess whether those characteristics were present in a DOE commercial building model type that could be selectively modified or whether development of a unique model was required to represent a prototypical *Assembly* building. The *Assembly* building program, form, fabric, and equipment construction characteristics obtained from CBECS were consistent with DOE's Commercial Prototypical Building *Medium Office* model type.

In that context, ICF developed a workflow in OpenStudio to create the *Assembly* building type by modifying specific building construction characteristics in DOE's Commercial Prototypical Building *Medium Office* model type to the predominate building characteristics and median performance values in 2012 CBECS. Custom measures were developed to set floor area, window-to-wall ratio, lighting power density, plug load density, occupancy density, and occupancy schedules. **Table 2** summarizes the *Assembly* building type construction characteristics.

[4] Science Applications International Corporation, Commercial Building Shell Heating and Cooling Factors for Use in the Commercial Demand Module, DOE EIA, July 2011.

Table 2 - Assembly Building Type Characteristics

Parameter	Value	Source
Building Type	Medium Office	2012 CBECS; DOE Commercial Prototypical Building Models
Geographical Location	International Climate Zone locations	DOE Commercial Prototypical Building Models
Vintage	New Construction (2004)	DOE Commercial Prototypical Building Models
Floor Area	5,720 sf	2012 CBECS – Median of Square Footage
Occupant Density	34 people / 1,000 sf	2012 CBECS – Median of Religious Worship Seating Capacity + Assembly Seating Capacity + Number of Employees
Schedules	Medium Office default schedules for weekday and Saturday; new Sunday schedule identical to Saturday	2012 CBECS – Median of Open 24 Hours a Day, Open During Week, Open on Weekend, Total Hours Open per Week;
Orientation	Medium Office	DOE Commercial Prototypical Building Models
Building Shape	Medium Office	DOE Commercial Prototypical Building Models
Building Height	Medium Office	DOE Commercial Prototypical Building Models
Building Construction	Steel-frame walls w/stucco and gypsum board (Medium Office default)	2012 CBECS – Predominate Wall Construction Material; DOE Commercial Prototypical Building Models
Envelope Characteristics – Wall	Steel-frame walls w/stucco and gypsum board (Medium Office default)	2012 CBECS – Predominate Wall Construction Material; DOE Commercial Prototypical Building Models
Envelope Characteristics – Roof	Built-up roof (Medium Office default)	2012 CBECS – Predominate Roof Construction Material; DOE Commercial Prototypical Building Models
Envelope Characteristics – WWR	5.00%	2012 CBECS – Median of Percent Exterior Glass
Envelope Characteristics – Floor	Slab-on-grade (Medium Office default)	DOE Commercial Prototypical Building Model
Fuel Type	Natural Gas; Electric	2012 CBECS; DOE Commercial Prototypical Building Models
Heat Type	Natural Gas; Electric	2012 CBECS – Predominate Primary Heating Type, Secondary Heating Type
Lighting Power Density	0.79 W/sf	2012 CBECS – Electricity Lighting Use
Space Heating	Rooftop Unit w/Natural Gas (Medium Office default)	2012 CBECS – Main Heating Equipment
Space Cooling	Packaged Air Conditioner (Medium Office default)	2012 CBECS – Main Cooling Equipment
Plug Load Density	2.95 W/sf	2012 CBECS – Electricity Miscellaneous Use

Food Sales Building Type

EIA's CDM model documentation[5] defines the *Food Sales* building type the same as *Food Sales* in 2012 CBECS[6], which includes: grocery stores, food markets, and gas stations with convenience stores. DOE's Commercial Reference Building models include a *Supermarket* building type, which is similar to a grocery store and is representative of the CDM *Food* Sales building type; however, the building model is only available from DOE in EnergyPlus IDF format.

During development of the new building model types, ICF learned that NREL had developed the *Supermarket* building type in OpenStudio. Subsequently, ICF contacted NREL and obtained that building model for use as the *Food Sales* building model type in this study.

Other Building Type

According to EIA's CDM model documentation[7], the *Other* building type is defined as an amalgamation of four CBECS principle activity types: *Laboratory*, *Public Order and Safety, Vacant*, and *Other*; and *Other* is defined by CBECS[8] as industrial, agricultural, commercial, or residential buildings not described by any of the other CBECS *Principle Building Activity* types. In that context, ICF determined the *Other* building type could not be reasonably defined by a single prototypical building model because it is made up of such dissimilar building types with varying building asset and operational characteristics. Therefore, annual heating and cooling energy demand obtained from simulation of DOE's Commercial Prototypical Building models, the *Assembly* building model, and the *Food Sales* building model were uniformly weighted to develop heating and cooling load factors, rather than developing an *Other* building model type.

Development of Building Shell Packages

Building shell packages were developed for the 2012 building stock and each of the five AEO projection years: 2012, 2020, 2030, 2040, and 2050. The 2012 building stock shell thermal performance values were derived by weighting the three DOE Commercial Reference Building models vintage (i.e., Pre-1980, Post-1980, and New Construction) with 2012 CBECS building square footage data. Projections of building shell improvements for each AEO projection year were developed by establishing an exponential decay curve that connected the historic trends of energy code prescriptive building envelope requirements to technically and economically achievable improvements in thermal performance.

[5] U.S. Energy Information Administration, Commercial Demand Module of the National Energy Modeling System: Model Documentation, pg. 116.

[6] U.S. Energy Information Administration, Commercial Buildings Energy Consumption Survey (CBECS), Building Type Definitions.

[7] U.S. Energy Information Administration, Commercial Demand Module of the National Energy Modeling System: Model Documentation, pg. 117.

[8] U.S. Energy Information Administration, Commercial Buildings Energy Consumption Survey (CBECS), Building Type Definitions.

2012 Building Stock Shell Packages

Building shell thermal performance values were obtained from DOE's commercial building models and were compared to the prescriptive building envelope requirements in ASHRAE Standard 90.1. This comparison was done to validate the accuracy and reasonableness of data obtained from the models. The building shell values were then weighted with 2012 CBECS data to derive the building stock shell packages. Much of the data obtained and analyzed in development of the building shell packages also supported development of the AEO projection year building shell packages (discussed in the following section of this report).

Opaque and fenestration building shell values were obtained from DOE's Commercial Reference Building (i.e., Pre-1980, Post-1980, and New Construction) and DOE's Commercial Prototypical Building (i.e., 2004, 2007, 2010, and 2013) model output HTML files. The output files described the building shell characteristics, including the surface area and heat transfer properties, for each building envelope element, assembly, and construction type. The characteristics were cataloged for each DOE commercial building type, international climate zone, and building model vintage. The *DOE Commercial Reference Building Models of the National Building Stock*[9] report summarizes development of DOE's buildings models and was used to cross-check the reasonableness of the values obtained from the those models and to obtain values for whole-building infiltration rates.

ASHRAE Standard 90.1 specifies new construction and major renovation commercial building envelope requirements. The standard provides multiple pathways for building envelope compliance, including prescriptive building envelope requirements and performance requirements for trade-off options between the building envelope and other building systems. It also includes mandatory material, assembly, and whole-building infiltration requirements. The prescriptive building envelope requirements and mandatory whole-building infiltration requirements are used in this analysis because they provide a quantifiable basis for defining how building envelope requirements have improved throughout code cycles, and they are directly comparable to the building shell characteristics obtained from DOE's commercial building models.

In that context, the prescriptive building envelope requirements and mandatory whole-building infiltration requirements were cataloged from the six most recent versions of ASHRAE Standard 90.1 (i.e., 1999, 2004, 2007, 2010, 2013, and 2016). The building envelope requirements were cataloged by: international climate zone; building element, assembly, and construction type; and by building sector, and the whole-building mandatory infiltration requirements were cataloged separately. DOE's building model types were then mapped to the most representative building sector following ASHRAE standard definition. The *Large Hotel*, *Small Hotel*, *High-Rise Apartment*, *Low-Rise Apartment*, and *Hospital* building model types were mapped in full to the residential building sector because they contained *living and sleeping* or other space types defined as residential in ASHRAE. All other building model types were defined as commercial.

[9] National Renewable Energy Laboratory, U.S. Department of Energy Commercial Reference Building Models of the National Building Stock.

The prescriptive building envelope requirements were compared with DOE's commercial building models for consistency and for expected trends between code cycles and international climate zones. They were individually compared by building envelope element, assembly, and construction type. **Figure 2** and **Figure 3** are illustrative of the detailed comparative analysis for building envelope opaque and fenestration thermal performance values, but as shown, the figures represent average building envelope values. The general trends observed in our analysis are summarized here

- **U-Factors (Opaque and Fenestration)** Prescriptive building energy code requirements trend towards higher efficiency levels or smaller heat transfer coefficients in heating-dominated (cooler) climate zones – with periodic incremental improvements in thermal performance across all climate zones in succeeding code editions.
- **SHGC (Fenestration)** Prescriptive building energy code requirements trend towards higher efficiency levels or smaller heat transfer coefficients in cooling-dominated (warmer) climate zones – with periodic incremental improvements in thermal performance across all climate zones in succeeding code editions.

The ASHRAE standard was the benchmark for assessing absolute values and trends and for checking consistency in building envelope characteristics for DOE commercial building models that used the ASHRAE standard for building envelope thermal performance values. As an example, DOE's Commercial Reference Building Pre-1980 model vintage is based on ASHRAE Standard 90.1-1999, and the four DOE Commercial Prototypical Building model vintages (i.e., 2004, 2007, 2010, and 2013) are based on ASHRAE Standard 90.1-2004, 2007, 2010, and 2013, respectively. These combinations of building models and building energy codes were directly compared for consistency and to ensure the reasonableness of building envelope values that underpin the building stock.

Figure 2 – Comparison of U-Factors, Building Model and Prescriptive Code Requirements

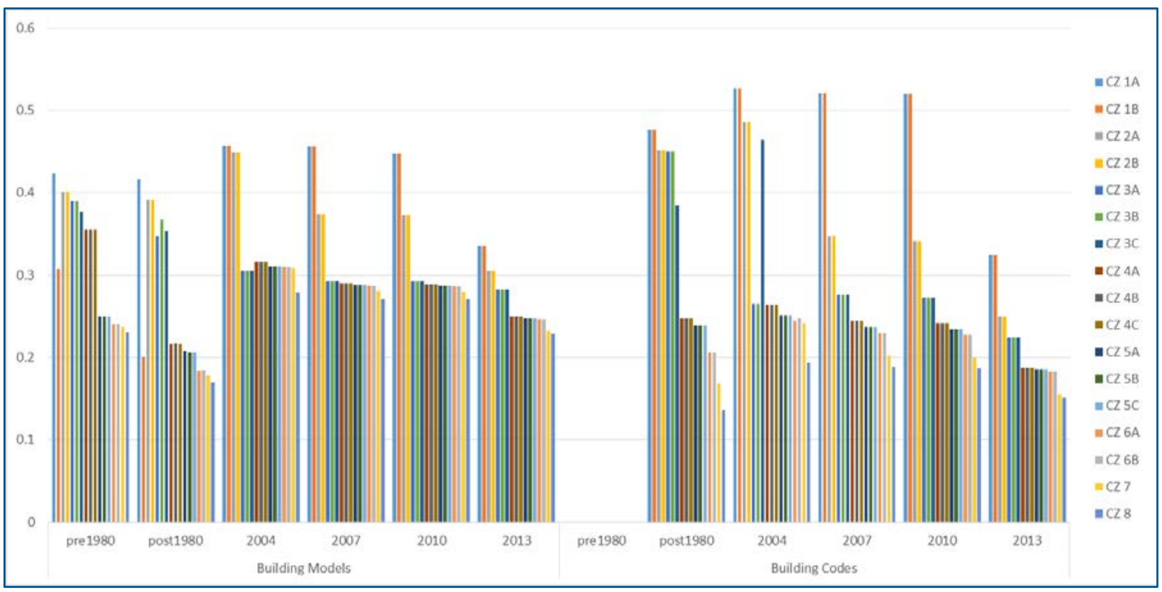
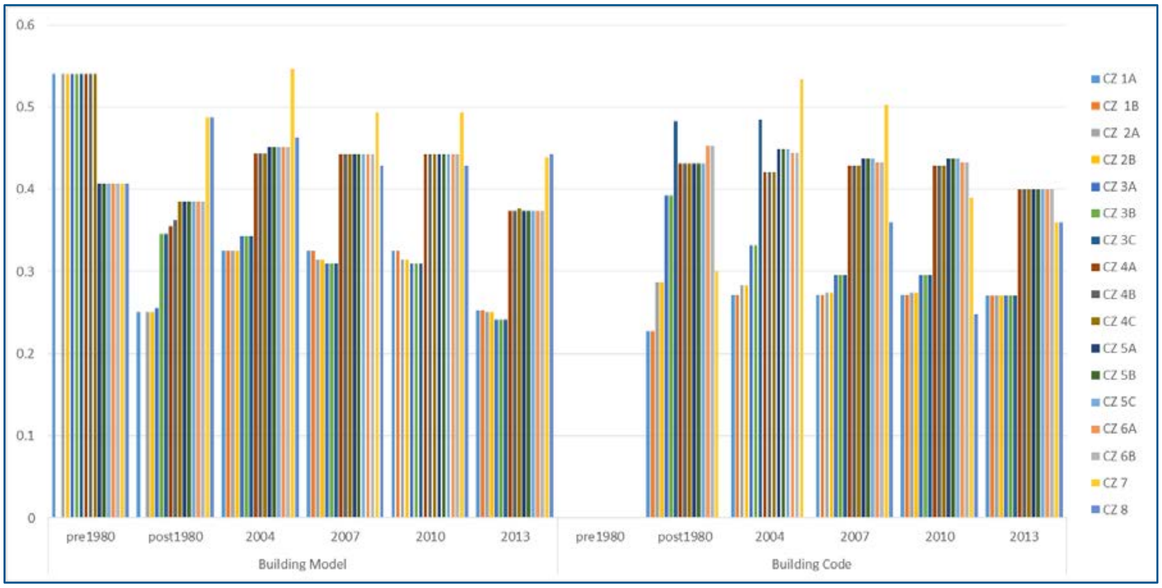


Figure 3 – Comparison of SHGC, DOE Building Model and Prescriptive Code Requirements



Relative building square footage data was used to develop the 2012 building stock shell thermal performance values from DOE's Commercial Reference Building models. The weighting factors were derived by mapping the CBECS *Principle Building Activity* data field to the 11 CDM building types and mapping the CBECS *Year of Construction* data field to the three DOE building model vintages. **Table 3** shows the resulting relative CDM building type square footage by vintage. The table in **Appendix A** provides the crosswalk used for mapping common building types between the three commercial building sources, and the figures in **Appendix B** provide comparisons between the 2012 building stock shell values and the DOE building model values that underpin them.

Table 3 – 2012 Building Stock Shell Weighting Factors

CDM Building Type	Pre-1980	Post-1980	New Construction
Assembly	53%	35%	12%
Education	51%	36%	14%
Food Sales	39%	42%	19%
Food Service	50%	39%	10%
Health Care	53%	26%	21%
Lodging	40%	45%	14%
Mercantile & Service	38%	46%	16%
Office – Large	44%	48%	8%
Office – Small	44%	42%	14%
Other	51%	41%	9%
Warehouse	36%	44%	19%

Projection Year New Construction Shell Packages

New construction building shell thermal performance values were developed for the five AEO projection years: 2012, 2020, 2030, 2040, and 2050. They were developed using exponential decay curves to project building shell values from historical energy code prescriptive building envelope requirements (discussed in the preceding section) to trends established in building energy code and envelope technology roadmaps.

The 2012 building stock values, developed in the preceding section, were compared to ICF's commercial building code adoption and compliance work[10]. The ICF study cataloged state-level energy codes or equivalencies for adoption rates and made use of state compliance studies to estimate the compliance rate for the commercial energy standard, ASHRAE Standard 90.1-2013. The rates were adjusted to account for national-level commercial building energy code adoption and compliance rates. Building energy code adoption throughout the AEO projection period was assumed to continue at the rate identified in ICF's study. In any given year, the prescriptive building envelope requirements were calculated as the weighted mix from the most recent ASHRAE Standard 90.1, and one or more of the preceding ASHRAE Standard 90.1 versions. An average code compliance value of 87%[11] was applied to all building envelope elements, assembly, and construction types due to the absence of code compliance studies that provided statistically robust results regarding compliance of building envelope systems.

Next, a secondary literature review was conducted to understand potential trends in building envelope technologies that could reasonably be expected throughout the AEO projection period. Building envelope technology and future code roadmap reports were researched and reviewed to understand how advances in building envelope technologies and changes to commercial building codes may influence trends in building envelope requirements. Our research found that DOE's Building Technologies Office has goals for reducing building energy use by 50%[12] by 2030 and DOE's Building Envelope Research and Development Program has goals for improving building envelope components such as roof and insulation materials up to 50%[13] by 2025. It also suggested that cost curves for high-efficiency building envelope materials and technologies that are available today may become economical by 2030 at the same time building energy codes are projected to reach ZNE (zero net energy), as depicted in **Figure 4**.

[10] ICF, Residential and Commercial Sector Energy Code Adoption and Compliance Rates, July 2016.

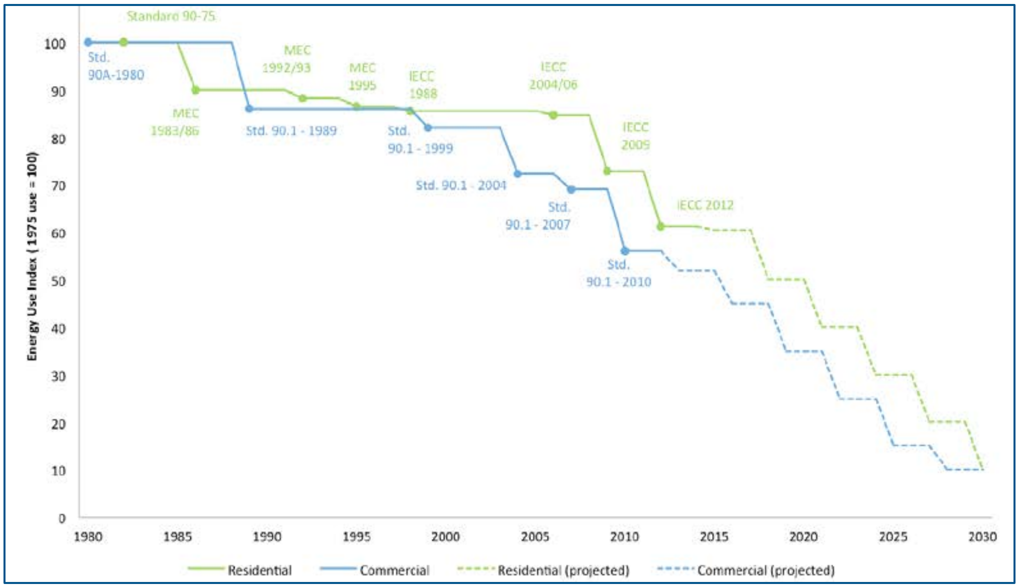
[11] ICF, Residential and Commercial Sector Energy Code Adoption and Compliance Rates, July 2016.

[12] Sawyer, Roof Coatings Manufacturers Association, Internal Roof Coatings Conference, DOE's Building Envelope R&D Program

[13] U.S. Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Office, Windows and Building Envelope Research and Development: Roadmap for Emerging Technologies; February 2014

In that context, exponential decay curves were developed to produce approximately 50% improvement in thermal performance by 2030. They were developed by halving the code adoption- and compliance-adjusted 2013 prescriptive building envelope values for each unique building envelope element, assembly, and construction type by international climate zone and building sector. Consequently, each prescriptive building envelope requirement has a unique projection based on its historical trend and projected thermal performance value in 2030.

Figure 4 - Commercial & Residential Building Energy Code Projections[14]



There are two exceptions to the analysis that warranted special consideration: slab insulation and window and skylight SHGC. Uniformly improving the thermal performance of these building envelope systems across international climate zones would have led to increased energy demand and would have been inconsistent with common criteria used in the development of commercial building energy codes. These unique conditions and mitigation actions are summarized in the bullets below:

- **Slab Insulation** Improvements in slab insulation increase annual cooling consumption in all international climate zones. In contrast to cooling-dominated climate zones, in heating-dominated climate zones, the decrease in annual heating consumption from improved slab insulation often outweighs the increased cooling requirements. Therefore, in cooling-dominated climate zones, the slab insulation thermal performance values were set equal to the current energy code prescriptive envelope requirements for all AEO projection years.
- **SHGC** Improvements in SHGC increase annual heating consumption in all international climate zones. In contrast to heating-dominated climate zones, in cooling-dominated climate zones, the decrease in annual cooling consumption often outweighs the increased heating requirements. Therefore, in heating-dominated climate zones, the SHGCs were set equal to current energy code prescriptive envelope requirements for all AEO projection years.

[14] American Council for an Energy-Efficient Economy, Energy Codes for Ultra-Low Energy Buildings: A Critical Pathway to Zero Net Energy Buildings.

Although improvements in building envelope thermal performance values were not explicitly capped in this analysis, building envelope systems exhibit diminishing returns in energy demand savings with each similarly sized incremental improvement in thermal efficiency. In other words, the thermal performance is self-capping in that successive layers of insulation produce less savings or reductions in annual heating or cooling energy demand.

Development of Building New Construction Models

This section discusses how the *building new construction* models were developed using the OpenStudio Parametric Analysis Tool[15] (PAT) and how custom measures were used to systematically update the building models during simulation. It also discusses quality assurance testing used to validate functionality of the analytical framework and validate that the building model inputs produce expected, reasonable, and then defensible results.

Parametric Analysis Framework

Approximately 2,000 unique building energy models were created in OpenStudio. They represented every combination of the building stock and new construction models for each DOE Commercial Prototypical Building type, vintage, and international climate zone. To alleviate the time commitment required for building model analysis setup and execution, ICF developed a workflow to efficiently perform large-scale analysis of the building models. It was built upon the cloud computing capability of PAT and allowed for the systematic creation of thousands of individual design alternatives that would have otherwise been generated by hand.

The workflow included custom OpenStudio measures that systematically modified the 2012 building stock model building shell thermal parameters with new construction projections for whole-building infiltration; wall, roof, floor, and slab U-factors; and window and skylight U-factors and SHGCs; and then simulated all combinations of the building stock and new construction models for each commercial building type, vintage, and international climate zone.

Testing for Quality Assurance

ICF conducted ad hoc test simulations to understand the impact of interactive effects from select improvements in building shell performance. As an example, we simulated slab insulation and window SHGCs to assess how changes in thermal performance would affect annual heating and cooling energy consumption in various climate zones. These analyses enabled the team to the further evaluate, research, and recommend solutions for addressing nuanced conditions where, for example, improving slab insulation in cooling-dominated climate zones increases building energy demand; whereas, in heating-dominated climate zones the increase in annual cooling energy demand is often offset by reductions in annual heating energy demand.

[15] OpenStudio, User Documentation, Parametric Analysis Tool (PAT) Interface Guide

ICF also tested the parametric routines for simulation efficiency. We found the automated workflow enabled the team to spend more time quality controlling the simulation results so that potential errors in the building model input, framework, or simulation could be detected, assessed, and corrected. ICF used an iterative process that included re-simulation of the building models until the results were deemed reasonable and defensible.

Development of Building Shell Load Factors

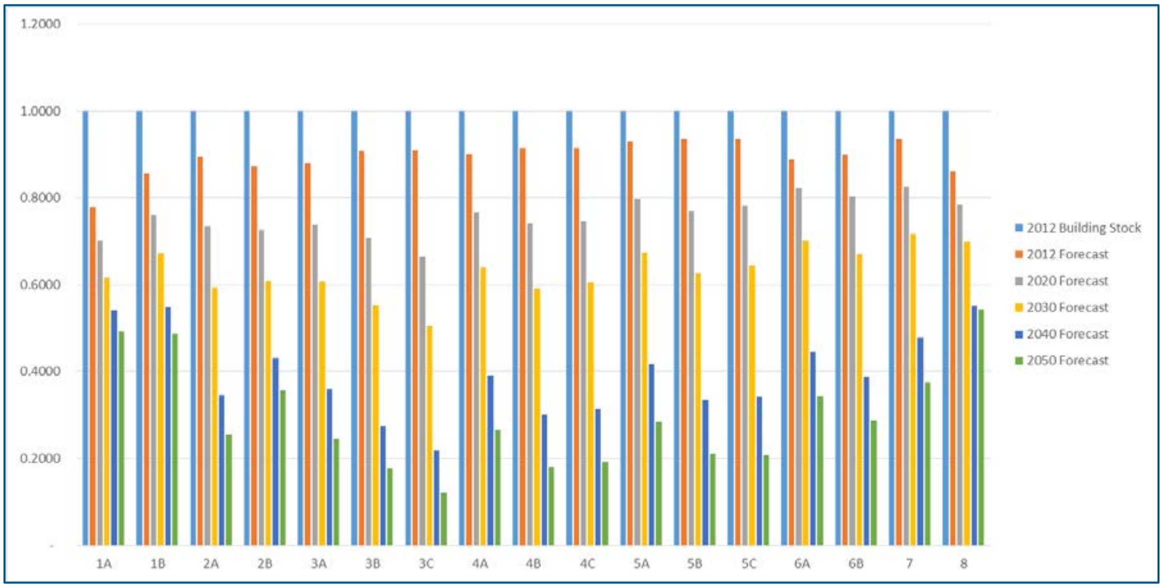
Annual heating and cooling consumption (energy demand) outputs from the parametric simulation of DOE's commercial building models were post-processed to derive the *Commercial Building Shell Heating and Cooling Load Factors* (load factors). The load factors represent reductions in annual heating and cooling energy demand, for corresponding improvements in building shell thermal performance values. Heating and cooling load factors were developed for the 2012 building stock and each of the five AEO projection years and were then weighted to CDM commercial building type and U.S. Census division as required for NEMS.

Building Model Shell Load Factors

Annual heating and cooling energy demand was produced from simulation of DOE's Commercial Prototypical Building models, making use of the building envelope parameter input values developed in the preceding sections. The simulation outputs were summed to produce separate total heating and total cooling consumption values for each unique combination of building type, climate zone, and vintage (i.e., building stock and five AEO projection years). Raw building shell heating and cooling load factors were developed separately by indexing the AEO projection year annual heating and cooling energy demand to the respective 2012 building stock annual heating and cooling energy demand. As an example, in **Figure 5**, the 2012 projections represent the relative change in annual heating and cooling energy demand between the 2012 building stock and new construction in 2012 from improvements in the building shell thermal performance values; while the 2012 building stock, which all AEO projections are indexed, is set equal 1.0 in all cases because it is the baseline.

Improvements in building shell thermal performance resulted in reductions of total building heating and cooling energy demand requirements as illustrated in **Figure 5**; although, individually there are trends and unique cases where either the heating or cooling load factors exhibited an increased energy demand that is offset by a corresponding decrease in energy demand by the other load factor.

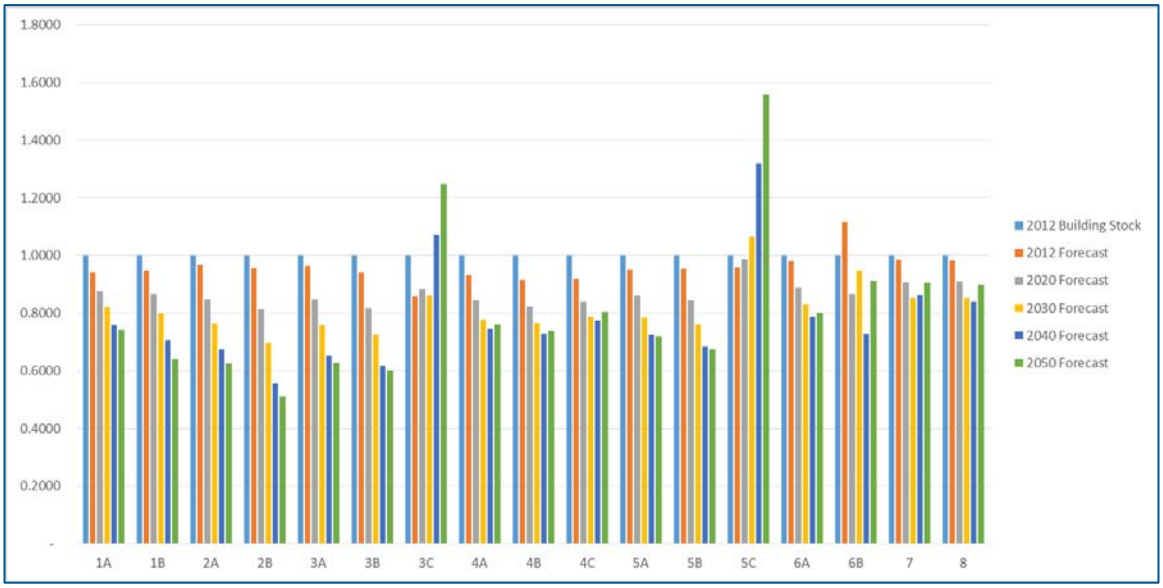
Figure 5 - DOE Model Total Heating and Cooling Load Factors (all building types)



In most cases, the building shell cooling load factors decrease throughout the AEO projection years as illustrated in **Figure 6**. However, there are cases in moderate- and cold-climate zones when the improved floor or slab U-factor reduces heat transfer with the ground and increases the building's annual cooling consumption. When this occurs, the increase in cooling consumption is often more than offset by a corresponding reduction in heating consumption. In heating-dominated climate zones with small cooling requirements, the load factor is often exaggerated, because even minor changes in consumption can result in relatively large impacts.

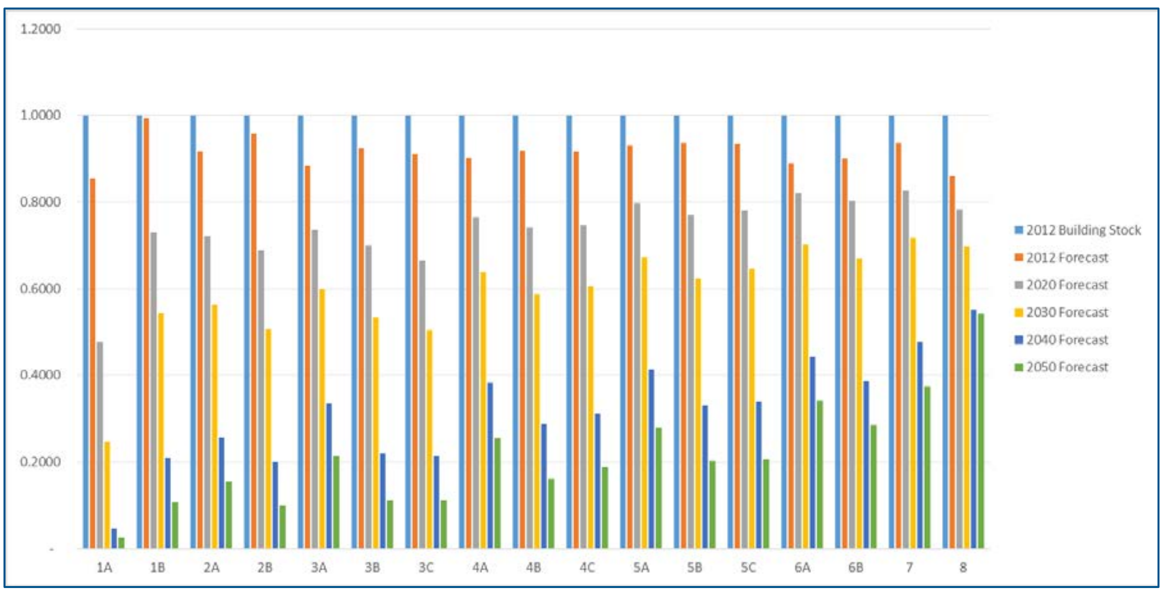
There are unique combinations of building shell thermal performance values that produced increased cooling consumption requirements throughout the AEO projection years. As an example, in mild climate zones, there are cases where the improvement in window and skylight SHGC is small and the increase in cooling consumption from improvements to the floor or slab U-factors are not offset by improvements from other building shell components.

Figure 6 - Aggregate DOE Model Cooling Load Factors



Similar to the cooling load factors, there are select conditions where the heating load factors for cooling-dominated climate zones exhibit an increase in consumption because the absolute heating consumption is comparatively small. Otherwise, the heating load factors illustrated in **Figure 7** are almost exclusively the product of reduced heating consumption.

Figure 7 - Aggregate DOE Model Heating Load Factors



ICF performed a thorough quality assurance process that included reviewing trends in heating and cooling load factors by building type and international climate zone and comparing the results against known building shell parameters. ICF used an iterative process to identify potential input or modeling errors and used that information to refine building shell inputs values for re-simulation to produce reasonable and defensible results. As an example, there are select cases in the energy code where building envelope thermal performance values become less efficient, and then more efficient in succeeding years, creating heating or cooling load factors that oscillate throughout the AEO projection period. In this case, the impact on heating and cooling load factors could not be known without first simulating the models. The automated workflow and simulation process allowed the ICF team to assess these types of nuanced conditions by enabling robust quality control on both the inputs and outputs that influence the heating and cooling load factors.

CDM and NEMS Building Shell Load Factors

The raw DOE building model heating and cooling load factors were weighted to derive load factors by CDM commercial building type and U.S. Census division, as required by NEMS. They were weighted with building square footage obtained from 2012 CBECS data to derive load factors for each CDM building type and then re-weighted with U.S. Census county population data to obtain the Commercial Building Shell Heating and Cooling Load Factors by U.S. Census division.

CDM building type heating and cooling load factors were derived by developing a common mapping between DOE's building model and CDM building type classifications and using that relationship to weight DOE's building model shell load factors. The two building classifications were separately mapped to the 2012 CBECS *Principle Building Activity* type, following the CDM and CBECS building type definitions. In select cases, the CBECS type was altered and adapted for consistency with the CDM building type definitions – as was the case for the *Office* and *Outpatient* building types. The relationship between building classifications was derived using CBECS building square footage data to define the relative mix of DOE building types in each CDM building type.

Table 4 provides the weighting factors when the CDM building type is made up of more than one DOE building model type. The table is inclusive of all building types except the *Warehouse*, *Assembly*, *Food Sales (Supermarket)*, *Food Service (Quick Service Restaurant),* and *Hospital (Healthcare)* building types that were directly mapped between the two building classifications.

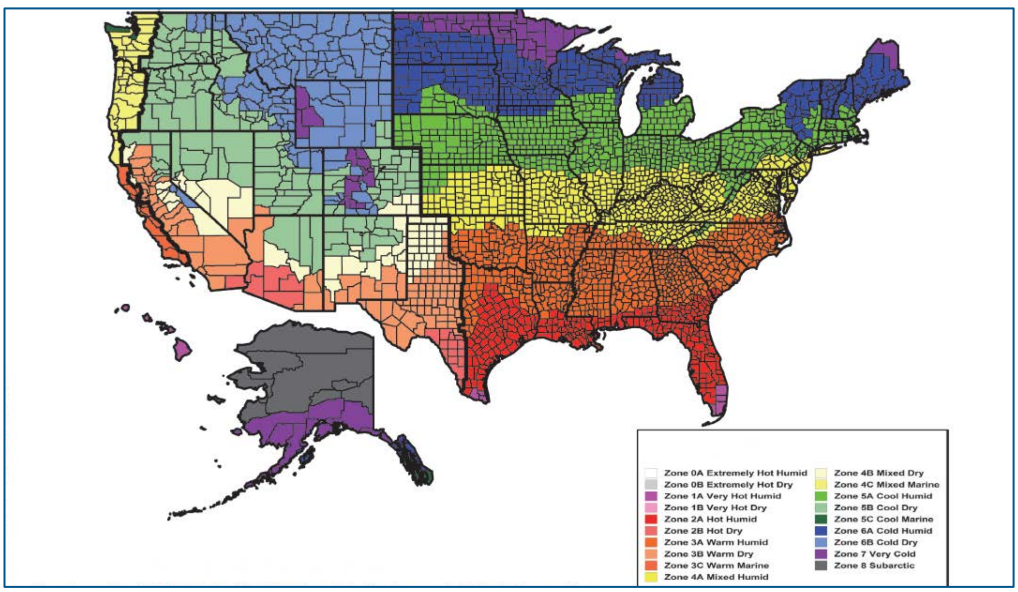
Table 4 - DOE Building Model Type to CDM Building Type Weighting Factors

DOE Building Model Type	CDM Building Type				
	Education	Lodging	Mercantile & Service	Office - Large	Office - Small
High-rise Apartment	0.00%	54.96%	0.00%	0.00%	0.00%
Large Hotel	0.00%	8.51%	0.00%	0.00%	0.00%
Large Office	0.00%	0.00%	0.00%	92.85%	0.00%
Medium Office	0.00%	0.00%	0.00%	0.00%	51.91%
mid-rise apartment	0.00%	22.76%	0.00%	0.00%	0.00%
Other	0.00%	0.00%	0.00%	0.00%	0.00%
Outpatient Healthcare	0.00%	0.00%	0.00%	7.15%	13.03%

DOE Building Model Type	CDM Building Type				
	Education	Lodging	Mercantile & Service	Office - Large	Office - Small
Primary School	78.48%	0.00%	0.00%	0.00%	0.00%
Secondary School	21.52%	0.00%	0.00%	0.00%	0.00%
Small Hotel	0.00%	13.77%	0.00%	0.00%	0.00%
Small Office	0.00%	0.00%	0.00%	0.00%	35.07%
Stand-alone Retail	0.00%	0.00%	68.17%	0.00%	0.00%
Strip Mall	0.00%	0.00%	31.83%	0.00%	0.00%

Building energy codes, such as ASHRAE Standard 90.1, prescribe new construction building envelope requirements according to the international climate zone where they are located. Each U.S. County is assigned a climate zone that represents a geographically distinct area in the U.S. with similar climatic conditions, as defined by heating and cooling degree days. Because climate zones and energy code prescriptive building envelope requirements vary across individual states and U.S. Census divisions, the CDM heating and cooling load factors were weighted from the climate zones depicted in **Figure 8** to U.S. Census divisions depicted in **Figure 9**. The weighting factors are shown in **Table 5** and were developed by mapping the climate zone and U.S. Census population to each U.S. County and deriving the relative Census population (proxy for building population) of each climate zone in each U.S. Census division.

Figure 8 - International Climate Zone Map[16]



[16] Figure taken from ANSI/ASHRAE/IES Standard 90.1-2016; Energy Standard for Buildings Except Low-Rise Residential Buildings.

Figure 9 – U.S. Census division Map[17]

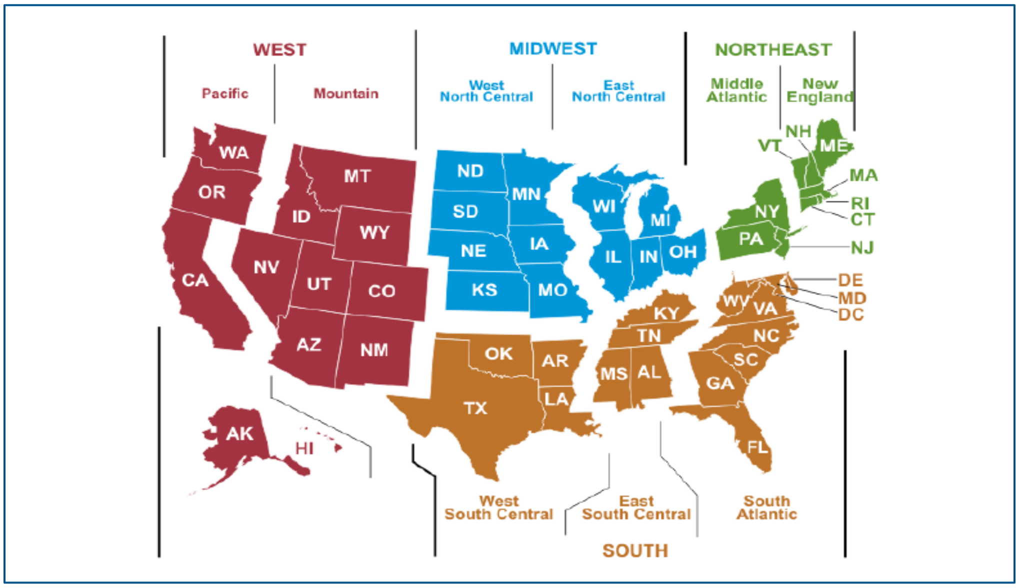


Table 5 - International Climate Zone to US Census division Weighting Factors

International Climate Zone	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific
1A	0.00%	0.00%	0.00%	0.00%	9.56%	0.00%	3.32%	0.00%	2.73%
2A	0.00%	0.00%	0.00%	0.00%	24.68%	7.53%	56.97%	0.00%	0.00%
2B	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.41%	24.50%	0.35%
3A	0.00%	0.00%	0.00%	0.24%	38.04%	52.29%	28.53%	0.00%	0.00%
3B	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.65%	13.61%	56.54%
3C	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	16.15%
4A	0.00%	53.83%	17.52%	41.04%	26.26%	40.18%	2.67%	0.00%	0.00%
4B	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.44%	6.36%	0.84%
4C	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	16.66%
5A	84.19%	42.79%	76.18%	25.37%	1.47%	0.00%	0.00%	0.00%	0.00%
5B	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	45.04%	4.31%
5C	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.89%
6A	15.32%	3.39%	6.15%	29.27%	0.00%	0.00%	0.00%	0.00%	0.10%
6B	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	9.62%	0.16%
7	0.49%	0.00%	0.15%	4.08%	0.00%	0.00%	0.00%	0.87%	1.00%
8	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.28%

[17] Table taken from U.S. Energy Information Administration, Chapter 4. Residential Demand Module.

Results and Conclusions

Figure 10 and **Figure 11** illustrate the average *Commercial Building Shell Heating and Cooling Load Factors* for all building types, respectively. The complete list of heating and cooling load factors is located in **Appendix C**.

At the individual building level, the load factors exhibit similar trends across all U.S. Census divisions with nuanced variances across the building types and minor changes in inflection points for the cooling load factors. In these results, it is less obvious what is driving changes in performance than with the DOE building models types that were developed by international climate zone. This occurs because the load factors are two-steps removed from the load factors developed from the simulated DOE building models. First, they are a weighted mix of DOE building model types that correspond to the CDM commercial building types. Finally, the geographical boundaries of the U.S. Census divisions are not well correlated with the primary drivers of building energy consumption that the building shell improvements are based on.

Figure 10 – Commercial Building Shell Heating Load Factors (all building types)

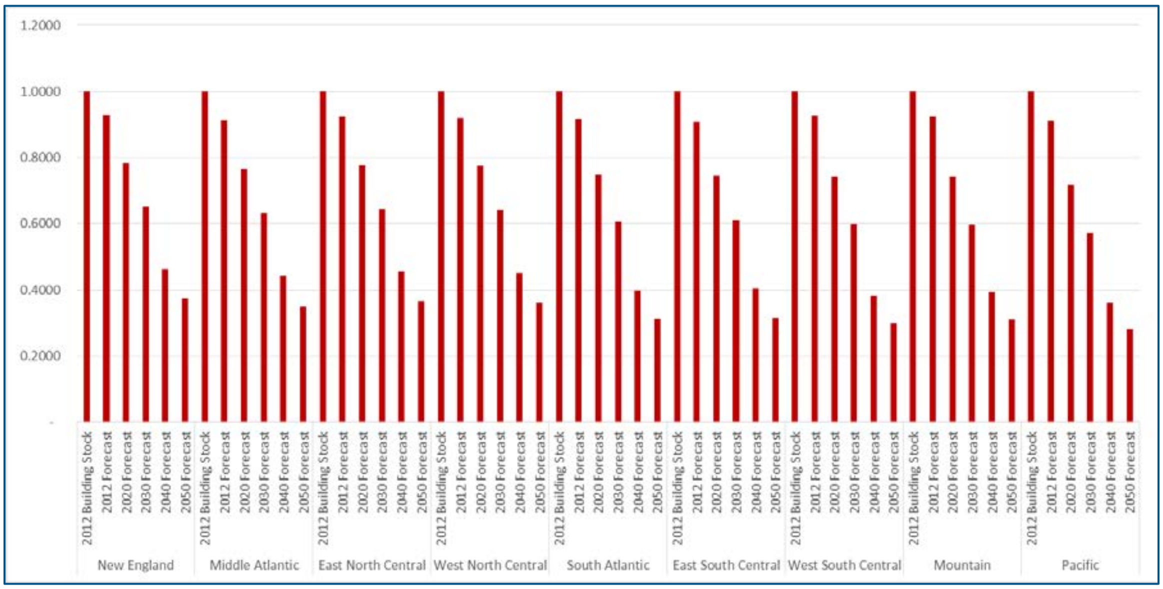
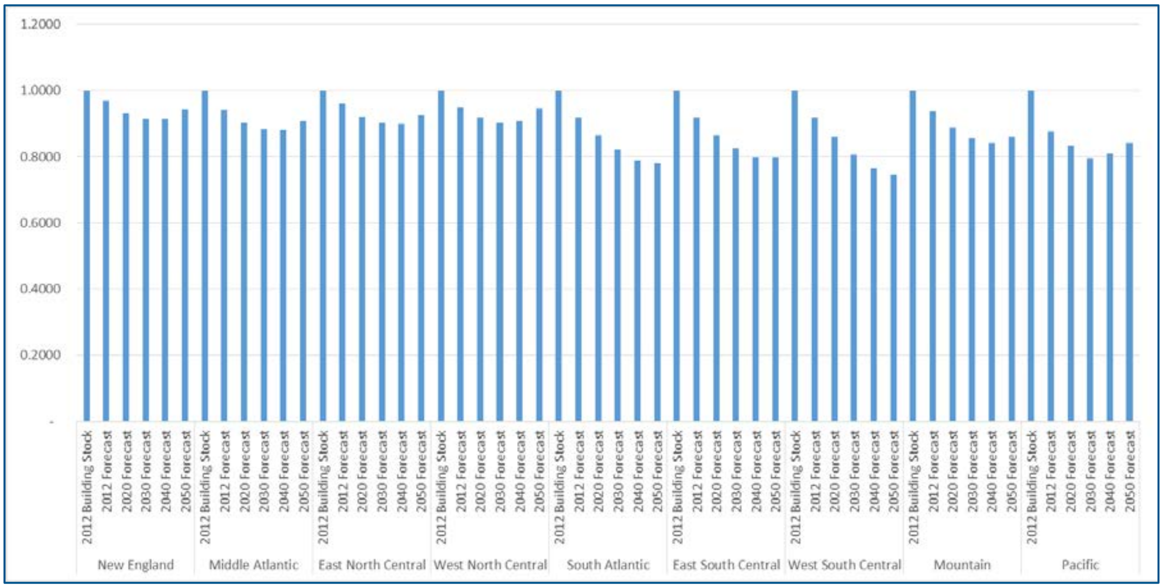


Figure 11 – Commercial Building Shell Cooling Load Factors (all building types)



Appendix A – Crosswalk of Commercial Building Types

ICF developed a crosswalk between the CDM commercial building types, DOE's commercial building models, and 2012 CBECS *Principle Building Activity* field. It provided a common mapping between the commercial building sources that enabled development of building weighting factors for estimating (1) building stock shell thermal performance values from DOE's Commercial Reference Building models and (2) CDM commercial building load factors from simulation of DOE's Commercial Prototypical Building models. The 2012 CBECS was used as the parent data source for mapping because it contained building square footage data and included all the CDM and DOE commercial building types. As such, the CDM and DOE commercial building model types were separately mapped to 2012 CBECS using building type definitions from the CDM model documentation and CBECS.

CBECS Principal Building Activity	CDM Building Type
Inpatient health care	Health Care
Food Sales	Food Sales
Vacant	Other
Laboratory	Other
Public order and safety	Other
Other	Other
Nonrefrigerated warehouse	Warehouse
Refrigerated warehouse	Warehouse
Strip shopping mall	Mercantile & Service
Enclosed mall	Mercantile & Service
Retail other than mall	Mercantile & Service
Service	Mercantile & Service
Education	Education
Food Service	Food Service
Religious worship	Assembly
Public assembly	Assembly
Lodging	Lodging
Office	Office - Large
	Office - Small
Outpatient Healthcare	Outpatient - Small
	Outpatient - Large

CBECS Principal Building Activity	DOE Commercial Building Model Type
Inpatient health care	Hospital
Food Sales	Supermarket
Vacant	Other
Laboratory	Other
Public order and safety	Other
Other	Other
Nonrefrigerated warehouse	Warehouse
Refrigerated warehouse	Warehouse
Strip shopping mall	Strip Mall
Enclosed mall	Stand-alone Retail
Retail other than mall	Stand-alone Retail
Service	Stand-alone Retail
Education	Primary School
	Secondary School
Food Service	Quick Service Restaurant
	Full Service Restaurant
Religious worship	Assembly
Public assembly	Assembly
Lodging	High-rise Apartment
	Mid-rise Apartment
	Large Hotel
	Small Hotel
Office	Large Office
	Medium Office
	Small Office
Outpatient health care	Outpatient Healthcare

Appendix B – Building Shell Comparisons

Figure 12 – U-Factor, Walls Above-Grade, Building Model, Building Stock, and Projections

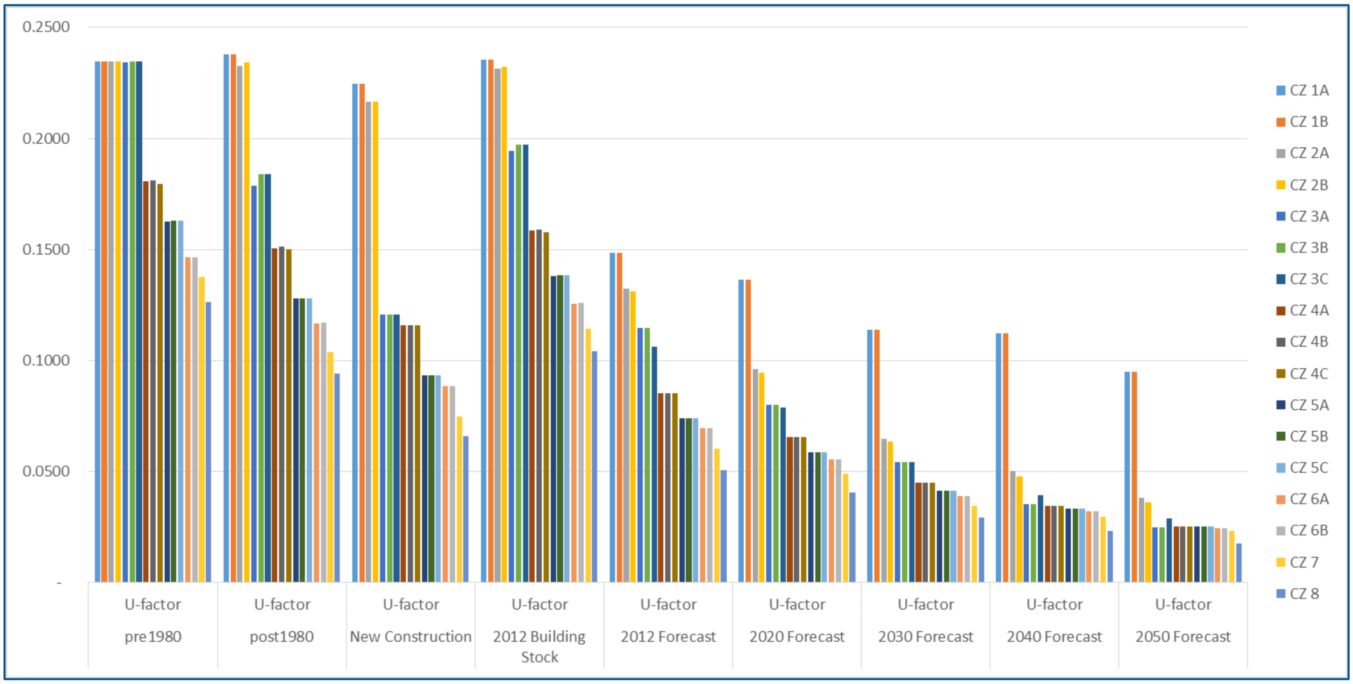


Figure 13 – U-Factor, Walls Below-Grade, Building Model, Building Stock, and Projections

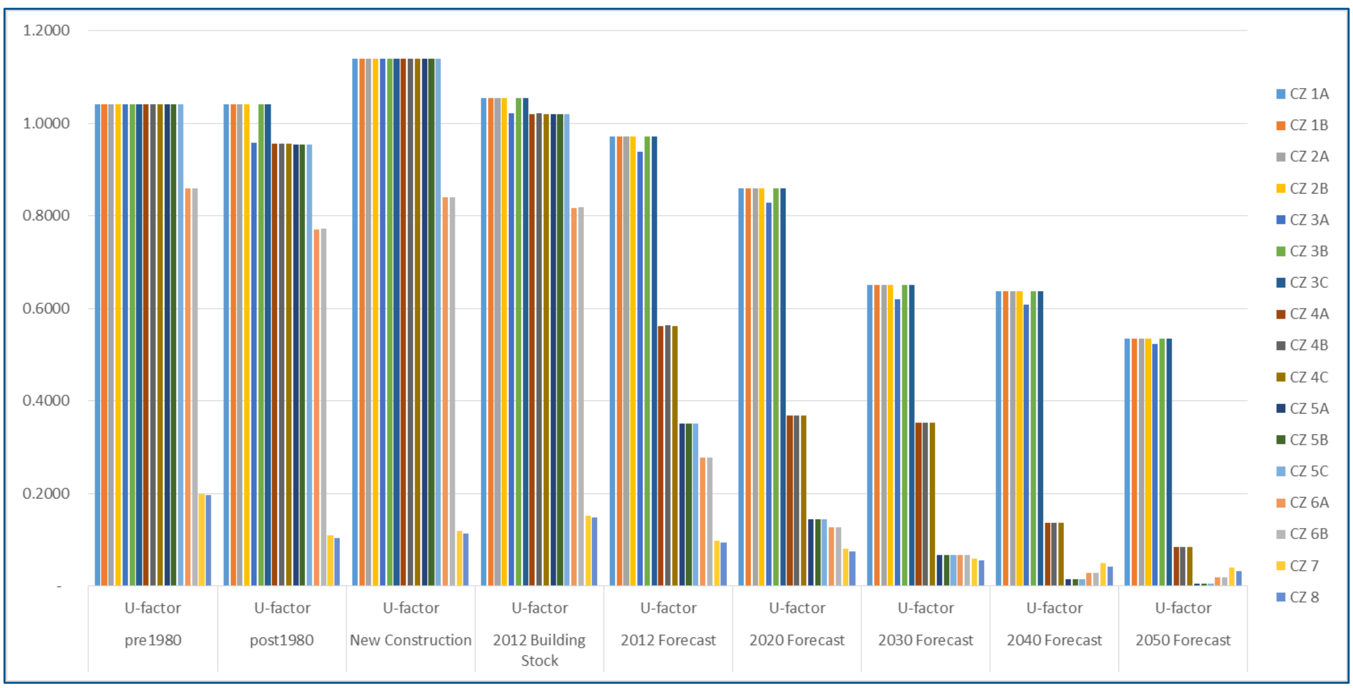


Figure 14 – U-Factor, Floors/Slabs, Building Model, Building Stock, and Projections

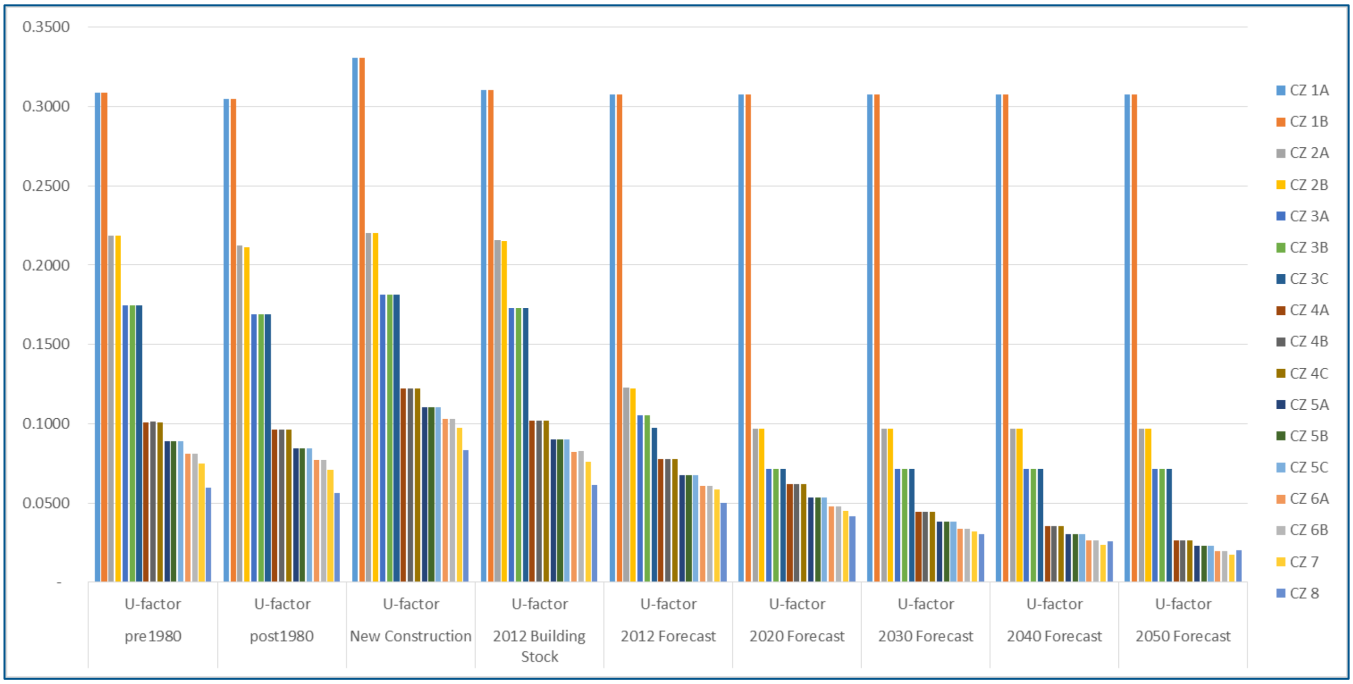


Figure 15 – U-Factor, Roofs, Building Model, Building Stock, and Projections

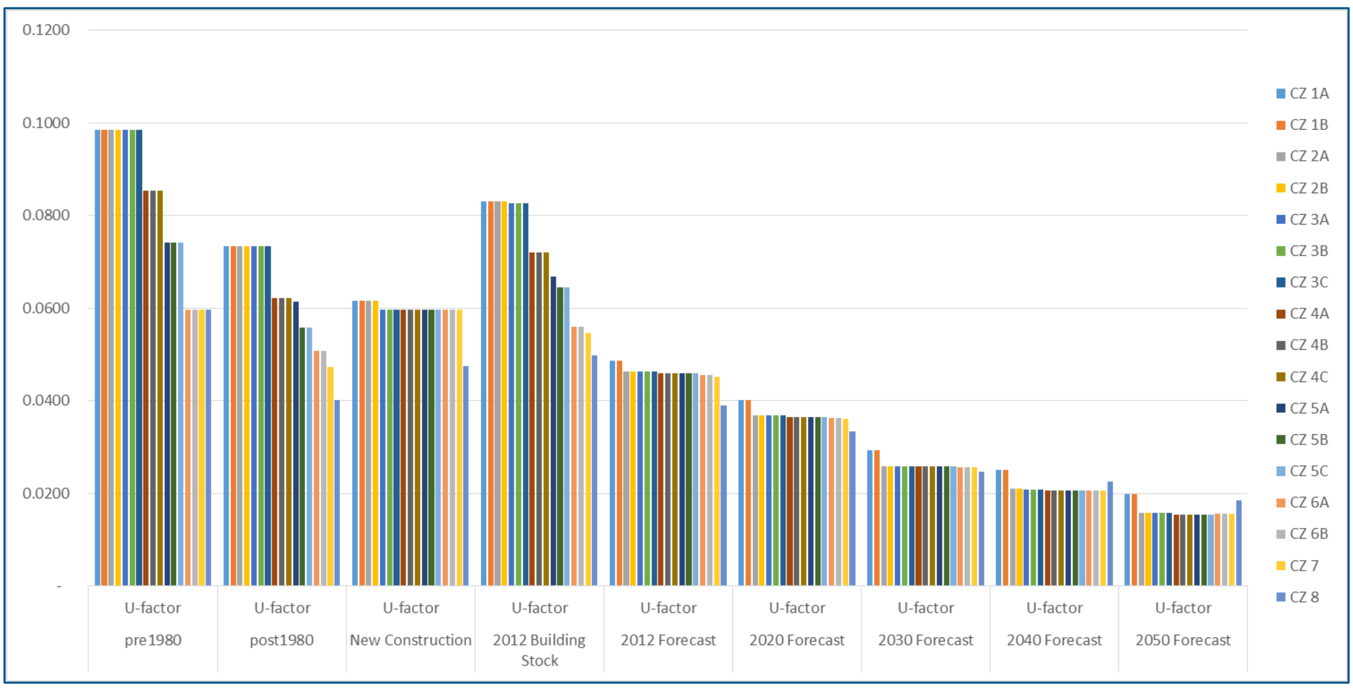


Figure 16 – U-Factor, Windows, Building Model, Building Stock, and Projections

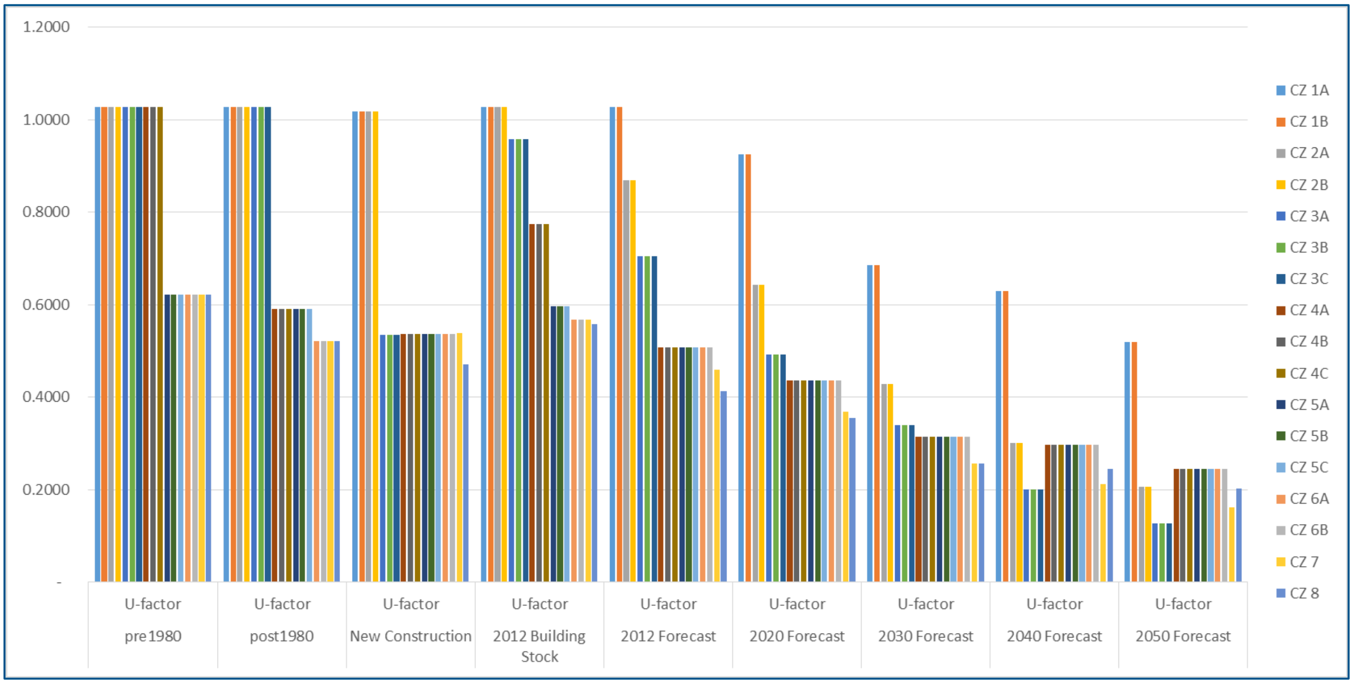


Figure 17 – U-Factor, Skylights, Building Model, Building Stock, and Projections

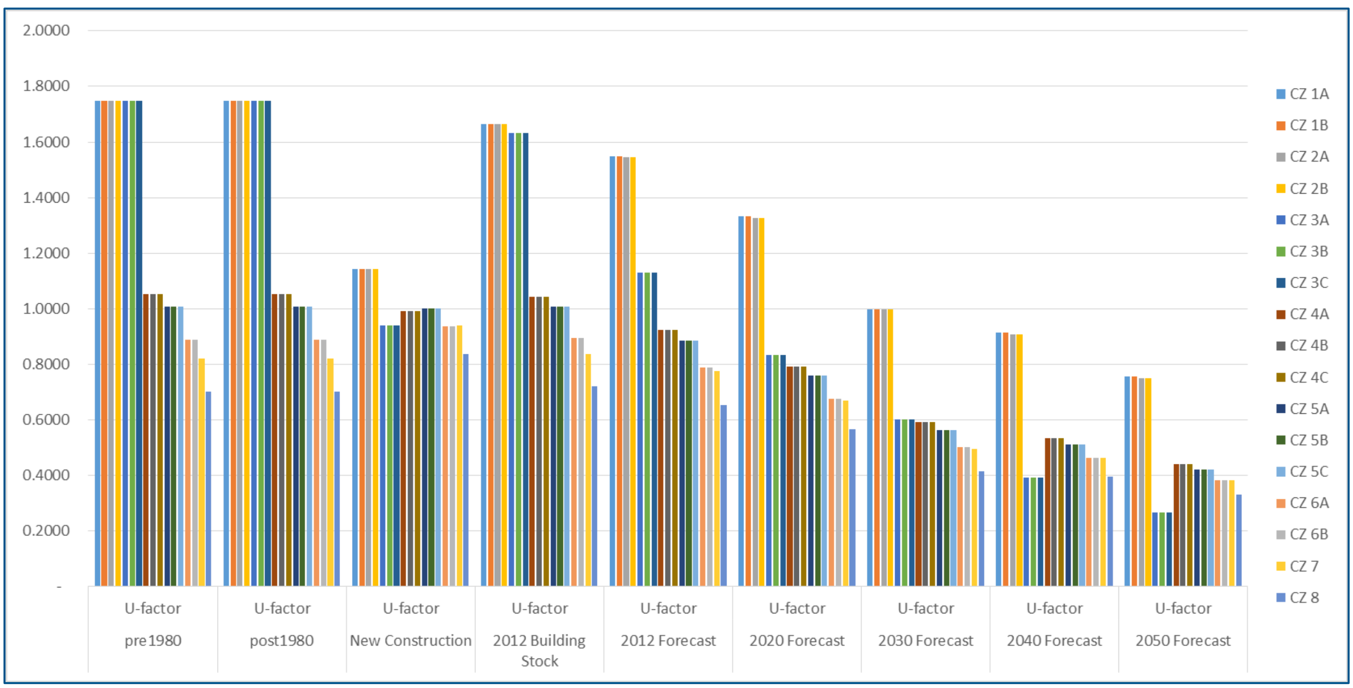


Figure 18 – SHGCs, Windows, Building Model, Building Stock, and Projections

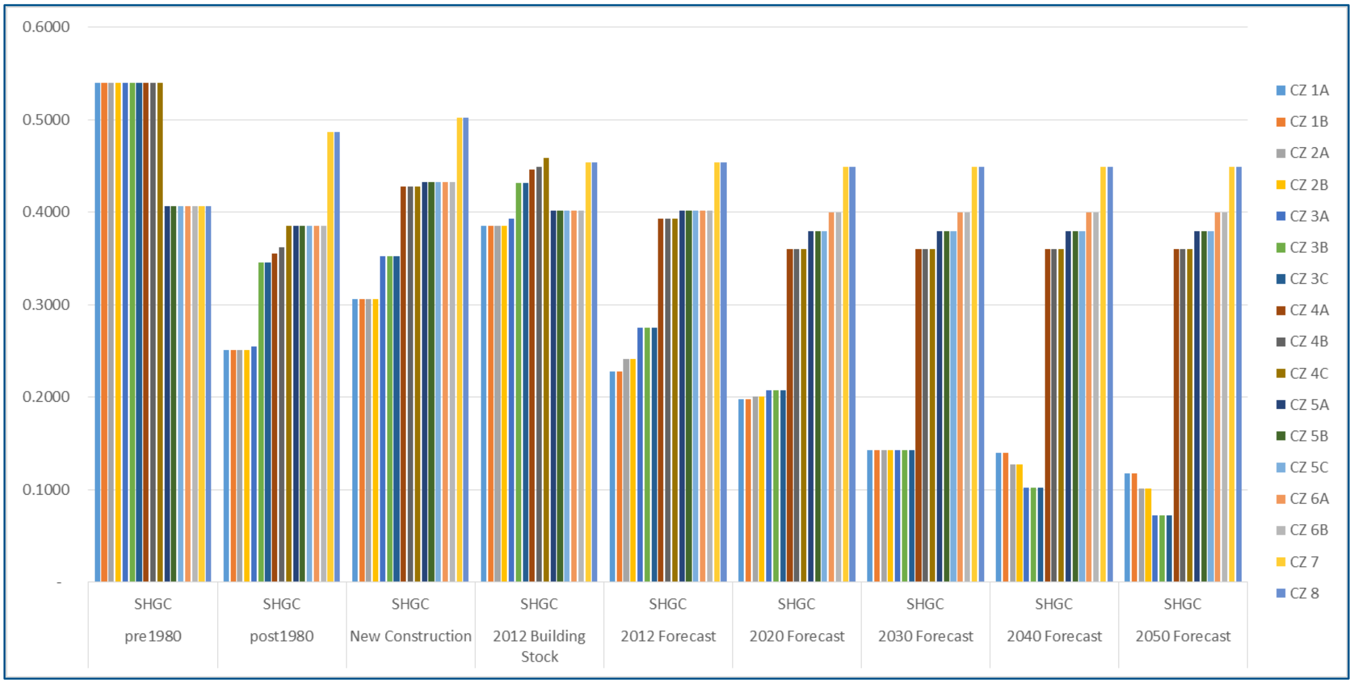
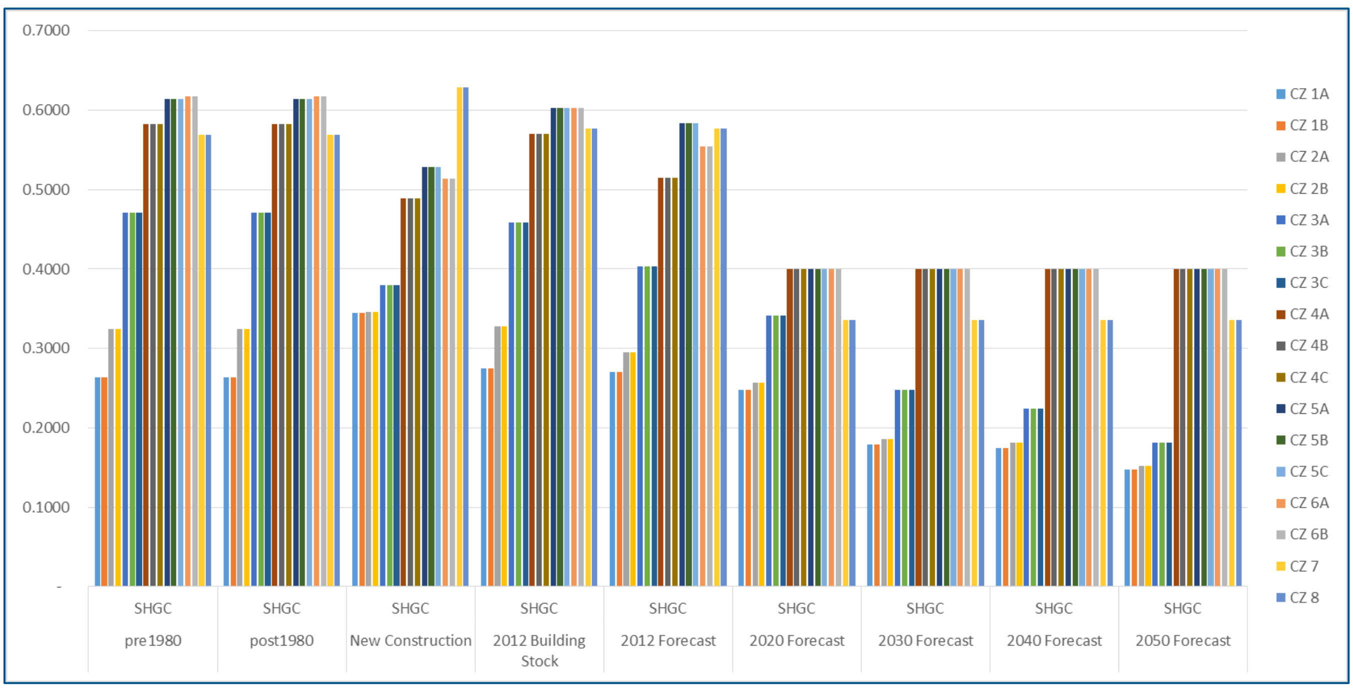


Figure 19 – SHGCs, Skylights, Building Model, Building Stock, and Projections



Appendix C – Commercial Building Shell Heating and Cooling Load Factors

US Census division	Building Type	Vintage	Heating Load Factor	Cooling Load Factor
New England	Assembly	2012 Building Stock	1.0000	1.0000
New England	Assembly	2012 Projection	0.8534	1.0251
New England	Assembly	2020 Projection	0.6277	1.0439
New England	Assembly	2030 Projection	0.4114	1.1040
New England	Assembly	2040 Projection	0.1883	1.1802
New England	Assembly	2050 Projection	0.0929	1.2653
New England	Education	2012 Building Stock	1.0000	1.0000
New England	Education	2012 Projection	0.9530	0.9632
New England	Education	2020 Projection	0.7560	0.8321
New England	Education	2030 Projection	0.6035	0.7388
New England	Education	2040 Projection	0.3807	0.6631
New England	Education	2050 Projection	0.2870	0.6689
New England	Food Sales	2012 Building Stock	1.0000	1.0000
New England	Food Sales	2012 Projection	0.9674	0.9557
New England	Food Sales	2020 Projection	0.8548	0.8667
New England	Food Sales	2030 Projection	0.7652	0.7937
New England	Food Sales	2040 Projection	0.6139	0.7361
New England	Food Sales	2050 Projection	0.5446	0.7337
New England	Food Service	2012 Building Stock	1.0000	1.0000
New England	Food Service	2012 Projection	0.9572	0.9773
New England	Food Service	2020 Projection	0.9042	0.9847
New England	Food Service	2030 Projection	0.8517	0.9952
New England	Food Service	2040 Projection	0.7652	1.0184
New England	Food Service	2050 Projection	0.7143	1.0371
New England	Health Care	2012 Building Stock	1.0000	1.0000
New England	Health Care	2012 Projection	0.9309	0.9851
New England	Health Care	2020 Projection	0.8518	0.9676
New England	Health Care	2030 Projection	0.7802	0.9540
New England	Health Care	2040 Projection	0.6958	0.9372
New England	Health Care	2050 Projection	0.6541	0.9293
New England	Lodging	2012 Building Stock	1.0000	1.0000
New England	Lodging	2012 Projection	0.9386	0.9671
New England	Lodging	2020 Projection	0.7713	0.9211
New England	Lodging	2030 Projection	0.6226	0.9083
New England	Lodging	2040 Projection	0.3940	0.9114
New England	Lodging	2050 Projection	0.2869	0.9628
New England	Office - Large	2012 Building Stock	1.0000	1.0000
New England	Office - Large	2012 Projection	0.8929	0.9972
New England	Office - Large	2020 Projection	0.7032	0.9912

US Census division	Building Type	Vintage	Heating Load Factor	Cooling Load Factor
New England	Office - Large	2030 Projection	0.5128	0.9940
New England	Office - Large	2040 Projection	0.3440	0.9947
New England	Office - Large	2050 Projection	0.2598	1.0022
New England	Office - Small	2012 Building Stock	1.0000	1.0000
New England	Office - Small	2012 Projection	0.9166	0.9856
New England	Office - Small	2020 Projection	0.7681	0.9653
New England	Office - Small	2030 Projection	0.6141	0.9675
New England	Office - Small	2040 Projection	0.4137	0.9924
New England	Office - Small	2050 Projection	0.3003	1.0415
New England	Other	2012 Building Stock	1.0000	1.0000
New England	Other	2012 Projection	0.9331	0.9696
New England	Other	2020 Projection	0.7860	0.9288
New England	Other	2030 Projection	0.6530	0.9090
New England	Other	2040 Projection	0.4587	0.9039
New England	Other	2050 Projection	0.3691	0.9316
New England	Warehouse	2012 Building Stock	1.0000	1.0000
New England	Warehouse	2012 Projection	0.9249	0.8692
New England	Warehouse	2020 Projection	0.8010	0.8463
New England	Warehouse	2030 Projection	0.6778	0.7952
New England	Warehouse	2040 Projection	0.4185	0.8172
New England	Warehouse	2050 Projection	0.2892	0.8845
New England	Mercantile & Service	2012 Building Stock	1.0000	1.0000
New England	Mercantile & Service	2012 Projection	0.9564	0.9563
New England	Mercantile & Service	2020 Projection	0.7955	0.9052
New England	Mercantile & Service	2030 Projection	0.6563	0.8810
New England	Mercantile & Service	2040 Projection	0.4157	0.8933
New England	Mercantile & Service	2050 Projection	0.3140	0.9150
Middle Atlantic	Assembly	2012 Building Stock	1.0000	1.0000
Middle Atlantic	Assembly	2012 Projection	0.8217	0.9827
Middle Atlantic	Assembly	2020 Projection	0.5875	0.9917
Middle Atlantic	Assembly	2030 Projection	0.3688	1.0407
Middle Atlantic	Assembly	2040 Projection	0.1538	1.1045
Middle Atlantic	Assembly	2050 Projection	0.0698	1.1839
Middle Atlantic	Education	2012 Building Stock	1.0000	1.0000
Middle Atlantic	Education	2012 Projection	0.9387	0.9186
Middle Atlantic	Education	2020 Projection	0.7551	0.7996
Middle Atlantic	Education	2030 Projection	0.6115	0.7257
Middle Atlantic	Education	2040 Projection	0.3811	0.6627
Middle Atlantic	Education	2050 Projection	0.2756	0.6654
Middle Atlantic	Food Sales	2012 Building Stock	1.0000	1.0000
Middle Atlantic	Food Sales	2012 Projection	0.9681	0.9422
Middle Atlantic	Food Sales	2020 Projection	0.8588	0.8541
Middle Atlantic	Food Sales	2030 Projection	0.7697	0.7831

US Census division	Building Type	Vintage	Heating Load Factor	Cooling Load Factor
Middle Atlantic	Food Sales	2040 Projection	0.6064	0.7386
Middle Atlantic	Food Sales	2050 Projection	0.5312	0.7451
Middle Atlantic	Food Service	2012 Building Stock	1.0000	1.0000
Middle Atlantic	Food Service	2012 Projection	0.9550	0.9578
Middle Atlantic	Food Service	2020 Projection	0.8977	0.9602
Middle Atlantic	Food Service	2030 Projection	0.8395	0.9684
Middle Atlantic	Food Service	2040 Projection	0.7377	0.9865
Middle Atlantic	Food Service	2050 Projection	0.6766	1.0051
Middle Atlantic	Health Care	2012 Building Stock	1.0000	1.0000
Middle Atlantic	Health Care	2012 Projection	0.9104	0.9755
Middle Atlantic	Health Care	2020 Projection	0.8309	0.9581
Middle Atlantic	Health Care	2030 Projection	0.7597	0.9456
Middle Atlantic	Health Care	2040 Projection	0.6761	0.9300
Middle Atlantic	Health Care	2050 Projection	0.6359	0.9245
Middle Atlantic	Lodging	2012 Building Stock	1.0000	1.0000
Middle Atlantic	Lodging	2012 Projection	0.9311	0.9251
Middle Atlantic	Lodging	2020 Projection	0.7614	0.8717
Middle Atlantic	Lodging	2030 Projection	0.6082	0.8548
Middle Atlantic	Lodging	2040 Projection	0.3725	0.8440
Middle Atlantic	Lodging	2050 Projection	0.2611	0.8881
Middle Atlantic	Office - Large	2012 Building Stock	1.0000	1.0000
Middle Atlantic	Office - Large	2012 Projection	0.8467	0.9820
Middle Atlantic	Office - Large	2020 Projection	0.6638	0.9747
Middle Atlantic	Office - Large	2030 Projection	0.4748	0.9789
Middle Atlantic	Office - Large	2040 Projection	0.3073	0.9807
Middle Atlantic	Office - Large	2050 Projection	0.2326	0.9919
Middle Atlantic	Office - Small	2012 Building Stock	1.0000	1.0000
Middle Atlantic	Office - Small	2012 Projection	0.8778	0.9417
Middle Atlantic	Office - Small	2020 Projection	0.7271	0.9123
Middle Atlantic	Office - Small	2030 Projection	0.5722	0.9094
Middle Atlantic	Office - Small	2040 Projection	0.3728	0.9287
Middle Atlantic	Office - Small	2050 Projection	0.2549	0.9825
Middle Atlantic	Other	2012 Building Stock	1.0000	1.0000
Middle Atlantic	Other	2012 Projection	0.9180	0.9421
Middle Atlantic	Other	2020 Projection	0.7716	0.8981
Middle Atlantic	Other	2030 Projection	0.6385	0.8780
Middle Atlantic	Other	2040 Projection	0.4407	0.8702
Middle Atlantic	Other	2050 Projection	0.3463	0.8959
Middle Atlantic	Warehouse	2012 Building Stock	1.0000	1.0000
Middle Atlantic	Warehouse	2012 Projection	0.9142	0.8651
Middle Atlantic	Warehouse	2020 Projection	0.7809	0.8189
Middle Atlantic	Warehouse	2030 Projection	0.6556	0.7638
Middle Atlantic	Warehouse	2040 Projection	0.3982	0.7699

US Census division	Building Type	Vintage	Heating Load Factor	Cooling Load Factor
Middle Atlantic	Warehouse	2050 Projection	0.2681	0.7997
Middle Atlantic	Mercantile & Service	2012 Building Stock	1.0000	1.0000
Middle Atlantic	Mercantile & Service	2012 Projection	0.9596	0.9341
Middle Atlantic	Mercantile & Service	2020 Projection	0.7980	0.8880
Middle Atlantic	Mercantile & Service	2030 Projection	0.6585	0.8694
Middle Atlantic	Mercantile & Service	2040 Projection	0.4101	0.8822
Middle Atlantic	Mercantile & Service	2050 Projection	0.2962	0.9062
East North Central	Assembly	2012 Building Stock	1.0000	1.0000
East North Central	Assembly	2012 Projection	0.8416	1.0107
East North Central	Assembly	2020 Projection	0.6133	1.0246
East North Central	Assembly	2030 Projection	0.3964	1.0796
East North Central	Assembly	2040 Projection	0.1763	1.1501
East North Central	Assembly	2050 Projection	0.0849	1.2323
East North Central	Education	2012 Building Stock	1.0000	1.0000
East North Central	Education	2012 Projection	0.9472	0.9480
East North Central	Education	2020 Projection	0.7547	0.8217
East North Central	Education	2030 Projection	0.6053	0.7357
East North Central	Education	2040 Projection	0.3803	0.6655
East North Central	Education	2050 Projection	0.2827	0.6705
East North Central	Food Sales	2012 Building Stock	1.0000	1.0000
East North Central	Food Sales	2012 Projection	0.9671	0.9497
East North Central	Food Sales	2020 Projection	0.8555	0.8611
East North Central	Food Sales	2030 Projection	0.7661	0.7877
East North Central	Food Sales	2040 Projection	0.6108	0.7334
East North Central	Food Sales	2050 Projection	0.5396	0.7328
East North Central	Food Service	2012 Building Stock	1.0000	1.0000
East North Central	Food Service	2012 Projection	0.9562	0.9709
East North Central	Food Service	2020 Projection	0.9018	0.9757
East North Central	Food Service	2030 Projection	0.8475	0.9851
East North Central	Food Service	2040 Projection	0.7559	1.0054
East North Central	Food Service	2050 Projection	0.7015	1.0235
East North Central	Health Care	2012 Building Stock	1.0000	1.0000
East North Central	Health Care	2012 Projection	0.9232	0.9816
East North Central	Health Care	2020 Projection	0.8441	0.9639
East North Central	Health Care	2030 Projection	0.7727	0.9505
East North Central	Health Care	2040 Projection	0.6889	0.9339
East North Central	Health Care	2050 Projection	0.6478	0.9267
East North Central	Lodging	2012 Building Stock	1.0000	1.0000
East North Central	Lodging	2012 Projection	0.9353	0.9528
East North Central	Lodging	2020 Projection	0.7675	0.9023
East North Central	Lodging	2030 Projection	0.6173	0.8864
East North Central	Lodging	2040 Projection	0.3873	0.8808
East North Central	Lodging	2050 Projection	0.2779	0.9271

US Census division	Building Type	Vintage	Heating Load Factor	Cooling Load Factor
East North Central	Office - Large	2012 Building Stock	1.0000	1.0000
East North Central	Office - Large	2012 Projection	0.8761	0.9920
East North Central	Office - Large	2020 Projection	0.6887	0.9852
East North Central	Office - Large	2030 Projection	0.4987	0.9882
East North Central	Office - Large	2040 Projection	0.3307	0.9890
East North Central	Office - Large	2050 Projection	0.2497	0.9977
East North Central	Office - Small	2012 Building Stock	1.0000	1.0000
East North Central	Office - Small	2012 Projection	0.9027	0.9710
East North Central	Office - Small	2020 Projection	0.7537	0.9466
East North Central	Office - Small	2030 Projection	0.5994	0.9463
East North Central	Office - Small	2040 Projection	0.3992	0.9677
East North Central	Office - Small	2050 Projection	0.2845	1.0173
East North Central	Other	2012 Building Stock	1.0000	1.0000
East North Central	Other	2012 Projection	0.9274	0.9605
East North Central	Other	2020 Projection	0.7804	0.9173
East North Central	Other	2030 Projection	0.6473	0.8967
East North Central	Other	2040 Projection	0.4524	0.8891
East North Central	Other	2050 Projection	0.3608	0.9146
East North Central	Warehouse	2012 Building Stock	1.0000	1.0000
East North Central	Warehouse	2012 Projection	0.9236	0.8760
East North Central	Warehouse	2020 Projection	0.7931	0.8340
East North Central	Warehouse	2030 Projection	0.6690	0.7805
East North Central	Warehouse	2040 Projection	0.4102	0.7941
East North Central	Warehouse	2050 Projection	0.2789	0.8379
East North Central	Mercantile & Service	2012 Building Stock	1.0000	1.0000
East North Central	Mercantile & Service	2012 Projection	0.9564	0.9474
East North Central	Mercantile & Service	2020 Projection	0.7946	0.8982
East North Central	Mercantile & Service	2030 Projection	0.6554	0.8753
East North Central	Mercantile & Service	2040 Projection	0.4124	0.8851
East North Central	Mercantile & Service	2050 Projection	0.3070	0.9063
West North Central	Assembly	2012 Building Stock	1.0000	1.0000
West North Central	Assembly	2012 Projection	0.8354	0.9968
West North Central	Assembly	2020 Projection	0.6027	1.0170
West North Central	Assembly	2030 Projection	0.3844	1.0758
West North Central	Assembly	2040 Projection	0.1657	1.1519
West North Central	Assembly	2050 Projection	0.0776	1.2390
West North Central	Education	2012 Building Stock	1.0000	1.0000
West North Central	Education	2012 Projection	0.9475	0.9325
West North Central	Education	2020 Projection	0.7601	0.8055
West North Central	Education	2030 Projection	0.6134	0.7218
West North Central	Education	2040 Projection	0.3835	0.6476
West North Central	Education	2050 Projection	0.2812	0.6503
West North Central	Food Sales	2012 Building Stock	1.0000	1.0000

US Census division	Building Type	Vintage	Heating Load Factor	Cooling Load Factor
West North Central	Food Sales	2012 Projection	0.9704	0.9534
West North Central	Food Sales	2020 Projection	0.8607	0.8649
West North Central	Food Sales	2030 Projection	0.7714	0.7987
West North Central	Food Sales	2040 Projection	0.6110	0.7574
West North Central	Food Sales	2050 Projection	0.5369	0.7684
West North Central	Food Service	2012 Building Stock	1.0000	1.0000
West North Central	Food Service	2012 Projection	0.9570	0.9627
West North Central	Food Service	2020 Projection	0.9003	0.9710
West North Central	Food Service	2030 Projection	0.8438	0.9819
West North Central	Food Service	2040 Projection	0.7459	1.0078
West North Central	Food Service	2050 Projection	0.6879	1.0293
West North Central	Health Care	2012 Building Stock	1.0000	1.0000
West North Central	Health Care	2012 Projection	0.9202	0.9798
West North Central	Health Care	2020 Projection	0.8400	0.9637
West North Central	Health Care	2030 Projection	0.7682	0.9517
West North Central	Health Care	2040 Projection	0.6830	0.9369
West North Central	Health Care	2050 Projection	0.6419	0.9312
West North Central	Lodging	2012 Building Stock	1.0000	1.0000
West North Central	Lodging	2012 Projection	0.9366	0.9381
West North Central	Lodging	2020 Projection	0.7659	0.8977
West North Central	Lodging	2030 Projection	0.6138	0.8906
West North Central	Lodging	2040 Projection	0.3758	0.9075
West North Central	Lodging	2050 Projection	0.2692	0.9712
West North Central	Office - Large	2012 Building Stock	1.0000	1.0000
West North Central	Office - Large	2012 Projection	0.8651	0.9867
West North Central	Office - Large	2020 Projection	0.6802	0.9817
West North Central	Office - Large	2030 Projection	0.4916	0.9864
West North Central	Office - Large	2040 Projection	0.3216	0.9896
West North Central	Office - Large	2050 Projection	0.2443	0.9997
West North Central	Office - Small	2012 Building Stock	1.0000	1.0000
West North Central	Office - Small	2012 Projection	0.8928	0.9538
West North Central	Office - Small	2020 Projection	0.7413	0.9326
West North Central	Office - Small	2030 Projection	0.5873	0.9346
West North Central	Office - Small	2040 Projection	0.3879	0.9652
West North Central	Office - Small	2050 Projection	0.2699	1.0245
West North Central	Other	2012 Building Stock	1.0000	1.0000
West North Central	Other	2012 Projection	0.9252	0.9499
West North Central	Other	2020 Projection	0.7793	0.9129
West North Central	Other	2030 Projection	0.6463	0.8961
West North Central	Other	2040 Projection	0.4469	0.8986
West North Central	Other	2050 Projection	0.3556	0.9340
West North Central	Warehouse	2012 Building Stock	1.0000	1.0000
West North Central	Warehouse	2012 Projection	0.9070	0.8306

US Census division	Building Type	Vintage	Heating Load Factor	Cooling Load Factor
West North Central	Warehouse	2020 Projection	0.7922	0.8416
West North Central	Warehouse	2030 Projection	0.6691	0.7933
West North Central	Warehouse	2040 Projection	0.4123	0.8222
West North Central	Warehouse	2050 Projection	0.2909	0.9195
West North Central	Mercantile & Service	2012 Building Stock	1.0000	1.0000
West North Central	Mercantile & Service	2012 Projection	0.9639	0.9478
West North Central	Mercantile & Service	2020 Projection	0.8058	0.8993
West North Central	Mercantile & Service	2030 Projection	0.6663	0.8813
West North Central	Mercantile & Service	2040 Projection	0.4189	0.9081
West North Central	Mercantile & Service	2050 Projection	0.3069	0.9386
South Atlantic	Assembly	2012 Building Stock	1.0000	1.0000
South Atlantic	Assembly	2012 Projection	0.8775	0.9149
South Atlantic	Assembly	2020 Projection	0.5904	0.8887
South Atlantic	Assembly	2030 Projection	0.3639	0.8732
South Atlantic	Assembly	2040 Projection	0.1229	0.8913
South Atlantic	Assembly	2050 Projection	0.0526	0.9121
South Atlantic	Education	2012 Building Stock	1.0000	1.0000
South Atlantic	Education	2012 Projection	0.9055	0.8734
South Atlantic	Education	2020 Projection	0.7243	0.7798
South Atlantic	Education	2030 Projection	0.5783	0.6999
South Atlantic	Education	2040 Projection	0.3362	0.6322
South Atlantic	Education	2050 Projection	0.2332	0.6051
South Atlantic	Food Sales	2012 Building Stock	1.0000	1.0000
South Atlantic	Food Sales	2012 Projection	0.9714	0.9543
South Atlantic	Food Sales	2020 Projection	0.8715	0.8496
South Atlantic	Food Sales	2030 Projection	0.7934	0.7704
South Atlantic	Food Sales	2040 Projection	0.6478	0.6935
South Atlantic	Food Sales	2050 Projection	0.5816	0.6747
South Atlantic	Food Service	2012 Building Stock	1.0000	1.0000
South Atlantic	Food Service	2012 Projection	0.9607	0.9454
South Atlantic	Food Service	2020 Projection	0.8901	0.9379
South Atlantic	Food Service	2030 Projection	0.8221	0.9256
South Atlantic	Food Service	2040 Projection	0.6874	0.9269
South Atlantic	Food Service	2050 Projection	0.6198	0.9276
South Atlantic	Health Care	2012 Building Stock	1.0000	1.0000
South Atlantic	Health Care	2012 Projection	0.8976	0.9671
South Atlantic	Health Care	2020 Projection	0.8127	0.9446
South Atlantic	Health Care	2030 Projection	0.7425	0.9262
South Atlantic	Health Care	2040 Projection	0.6609	0.9055
South Atlantic	Health Care	2050 Projection	0.6225	0.8962
South Atlantic	Lodging	2012 Building Stock	1.0000	1.0000
South Atlantic	Lodging	2012 Projection	0.9596	0.8891
South Atlantic	Lodging	2020 Projection	0.7632	0.7992

US Census division	Building Type	Vintage	Heating Load Factor	Cooling Load Factor
South Atlantic	Lodging	2030 Projection	0.6056	0.7330
South Atlantic	Lodging	2040 Projection	0.3341	0.6649
South Atlantic	Lodging	2050 Projection	0.2242	0.6477
South Atlantic	Office - Large	2012 Building Stock	1.0000	1.0000
South Atlantic	Office - Large	2012 Projection	0.8481	0.9651
South Atlantic	Office - Large	2020 Projection	0.6065	0.9460
South Atlantic	Office - Large	2030 Projection	0.4059	0.9326
South Atlantic	Office - Large	2040 Projection	0.2189	0.9262
South Atlantic	Office - Large	2050 Projection	0.1661	0.9264
South Atlantic	Office - Small	2012 Building Stock	1.0000	1.0000
South Atlantic	Office - Small	2012 Projection	0.8905	0.9040
South Atlantic	Office - Small	2020 Projection	0.7033	0.8566
South Atlantic	Office - Small	2030 Projection	0.5345	0.8146
South Atlantic	Office - Small	2040 Projection	0.2985	0.8006
South Atlantic	Office - Small	2050 Projection	0.1869	0.8095
South Atlantic	Other	2012 Building Stock	1.0000	1.0000
South Atlantic	Other	2012 Projection	0.9244	0.9181
South Atlantic	Other	2020 Projection	0.7564	0.8616
South Atlantic	Other	2030 Projection	0.6171	0.8145
South Atlantic	Other	2040 Projection	0.4008	0.7768
South Atlantic	Other	2050 Projection	0.3097	0.7676
South Atlantic	Warehouse	2012 Building Stock	1.0000	1.0000
South Atlantic	Warehouse	2012 Projection	0.8943	0.8350
South Atlantic	Warehouse	2020 Projection	0.7160	0.7808
South Atlantic	Warehouse	2030 Projection	0.5674	0.7071
South Atlantic	Warehouse	2040 Projection	0.3020	0.6539
South Atlantic	Warehouse	2050 Projection	0.1925	0.6230
South Atlantic	Mercantile & Service	2012 Building Stock	1.0000	1.0000
South Atlantic	Mercantile & Service	2012 Projection	0.9699	0.9331
South Atlantic	Mercantile & Service	2020 Projection	0.7894	0.8799
South Atlantic	Mercantile & Service	2030 Projection	0.6436	0.8354
South Atlantic	Mercantile & Service	2040 Projection	0.3726	0.8062
South Atlantic	Mercantile & Service	2050 Projection	0.2531	0.7982
East South Central	Assembly	2012 Building Stock	1.0000	1.0000
East South Central	Assembly	2012 Projection	0.8269	0.9202
East South Central	Assembly	2020 Projection	0.5543	0.8988
East South Central	Assembly	2030 Projection	0.3410	0.8951
East South Central	Assembly	2040 Projection	0.1097	0.9219
East South Central	Assembly	2050 Projection	0.0404	0.9556
East South Central	Education	2012 Building Stock	1.0000	1.0000
East South Central	Education	2012 Projection	0.9157	0.8694
East South Central	Education	2020 Projection	0.7379	0.7685
East South Central	Education	2030 Projection	0.5966	0.6918

US Census division	Building Type	Vintage	Heating Load Factor	Cooling Load Factor
East South Central	Education	2040 Projection	0.3451	0.6213
East South Central	Education	2050 Projection	0.2370	0.5990
East South Central	Food Sales	2012 Building Stock	1.0000	1.0000
East South Central	Food Sales	2012 Projection	0.9755	0.9518
East South Central	Food Sales	2020 Projection	0.8653	0.8460
East South Central	Food Sales	2030 Projection	0.7789	0.7657
East South Central	Food Sales	2040 Projection	0.6102	0.6913
East South Central	Food Sales	2050 Projection	0.5341	0.6817
East South Central	Food Service	2012 Building Stock	1.0000	1.0000
East South Central	Food Service	2012 Projection	0.9528	0.9421
East South Central	Food Service	2020 Projection	0.8857	0.9358
East South Central	Food Service	2030 Projection	0.8236	0.9264
East South Central	Food Service	2040 Projection	0.7016	0.9294
East South Central	Food Service	2050 Projection	0.6346	0.9332
East South Central	Health Care	2012 Building Stock	1.0000	1.0000
East South Central	Health Care	2012 Projection	0.8962	0.9672
East South Central	Health Care	2020 Projection	0.8041	0.9446
East South Central	Health Care	2030 Projection	0.7300	0.9271
East South Central	Health Care	2040 Projection	0.6398	0.9070
East South Central	Health Care	2050 Projection	0.5993	0.8989
East South Central	Lodging	2012 Building Stock	1.0000	1.0000
East South Central	Lodging	2012 Projection	0.9369	0.8864
East South Central	Lodging	2020 Projection	0.7550	0.8011
East South Central	Lodging	2030 Projection	0.6066	0.7435
East South Central	Lodging	2040 Projection	0.3485	0.6830
East South Central	Lodging	2050 Projection	0.2372	0.6770
East South Central	Office - Large	2012 Building Stock	1.0000	1.0000
East South Central	Office - Large	2012 Projection	0.8400	0.9655
East South Central	Office - Large	2020 Projection	0.6090	0.9480
East South Central	Office - Large	2030 Projection	0.4210	0.9389
East South Central	Office - Large	2040 Projection	0.2346	0.9346
East South Central	Office - Large	2050 Projection	0.1842	0.9384
East South Central	Office - Small	2012 Building Stock	1.0000	1.0000
East South Central	Office - Small	2012 Projection	0.8647	0.9007
East South Central	Office - Small	2020 Projection	0.6922	0.8530
East South Central	Office - Small	2030 Projection	0.5388	0.8166
East South Central	Office - Small	2040 Projection	0.3158	0.8057
East South Central	Office - Small	2050 Projection	0.2005	0.8252
East South Central	Other	2012 Building Stock	1.0000	1.0000
East South Central	Other	2012 Projection	0.9142	0.9166
East South Central	Other	2020 Projection	0.7543	0.8607
East South Central	Other	2030 Projection	0.6215	0.8181
East South Central	Other	2040 Projection	0.4074	0.7842

US Census division	Building Type	Vintage	Heating Load Factor	Cooling Load Factor
East South Central	Other	2050 Projection	0.3130	0.7825
East South Central	Warehouse	2012 Building Stock	1.0000	1.0000
East South Central	Warehouse	2012 Projection	0.8933	0.8428
East South Central	Warehouse	2020 Projection	0.7462	0.7910
East South Central	Warehouse	2030 Projection	0.6120	0.7200
East South Central	Warehouse	2040 Projection	0.3483	0.6753
East South Central	Warehouse	2050 Projection	0.2255	0.6523
East South Central	Mercantile & Service	2012 Building Stock	1.0000	1.0000
East South Central	Mercantile & Service	2012 Projection	0.9685	0.9285
East South Central	Mercantile & Service	2020 Projection	0.7944	0.8777
East South Central	Mercantile & Service	2030 Projection	0.6515	0.8380
East South Central	Mercantile & Service	2040 Projection	0.3851	0.8188
East South Central	Mercantile & Service	2050 Projection	0.2649	0.8193
West South Central	Assembly	2012 Building Stock	1.0000	1.0000
West South Central	Assembly	2012 Projection	0.9131	0.9000
West South Central	Assembly	2020 Projection	0.5949	0.8640
West South Central	Assembly	2030 Projection	0.3594	0.8304
West South Central	Assembly	2040 Projection	0.1090	0.8371
West South Central	Assembly	2050 Projection	0.0414	0.8398
West South Central	Education	2012 Building Stock	1.0000	1.0000
West South Central	Education	2012 Projection	0.9015	0.8712
West South Central	Education	2020 Projection	0.7078	0.7860
West South Central	Education	2030 Projection	0.5492	0.7005
West South Central	Education	2040 Projection	0.2987	0.6339
West South Central	Education	2050 Projection	0.1999	0.5996
West South Central	Food Sales	2012 Building Stock	1.0000	1.0000
West South Central	Food Sales	2012 Projection	0.9769	0.9618
West South Central	Food Sales	2020 Projection	0.8745	0.8457
West South Central	Food Sales	2030 Projection	0.7982	0.7607
West South Central	Food Sales	2040 Projection	0.6588	0.6690
West South Central	Food Sales	2050 Projection	0.5981	0.6321
West South Central	Food Service	2012 Building Stock	1.0000	1.0000
West South Central	Food Service	2012 Projection	0.9601	0.9500
West South Central	Food Service	2020 Projection	0.8844	0.9405
West South Central	Food Service	2030 Projection	0.8172	0.9223
West South Central	Food Service	2040 Projection	0.6745	0.9196
West South Central	Food Service	2050 Projection	0.6058	0.9146
West South Central	Health Care	2012 Building Stock	1.0000	1.0000
West South Central	Health Care	2012 Projection	0.8922	0.9649
West South Central	Health Care	2020 Projection	0.8066	0.9401
West South Central	Health Care	2030 Projection	0.7363	0.9190
West South Central	Health Care	2040 Projection	0.6565	0.8960
West South Central	Health Care	2050 Projection	0.6181	0.8844

US Census division	Building Type	Vintage	Heating Load Factor	Cooling Load Factor
West South Central	Lodging	2012 Building Stock	1.0000	1.0000
West South Central	Lodging	2012 Projection	0.9635	0.8854
West South Central	Lodging	2020 Projection	0.7626	0.7811
West South Central	Lodging	2030 Projection	0.6053	0.6999
West South Central	Lodging	2040 Projection	0.3230	0.6159
West South Central	Lodging	2050 Projection	0.2118	0.5811
West South Central	Office - Large	2012 Building Stock	1.0000	1.0000
West South Central	Office - Large	2012 Projection	0.8631	0.9617
West South Central	Office - Large	2020 Projection	0.5852	0.9378
West South Central	Office - Large	2030 Projection	0.3792	0.9172
West South Central	Office - Large	2040 Projection	0.1809	0.9076
West South Central	Office - Large	2050 Projection	0.1362	0.9032
West South Central	Office - Small	2012 Building Stock	1.0000	1.0000
West South Central	Office - Small	2012 Projection	0.9152	0.9047
West South Central	Office - Small	2020 Projection	0.7151	0.8547
West South Central	Office - Small	2030 Projection	0.5384	0.8018
West South Central	Office - Small	2040 Projection	0.2812	0.7823
West South Central	Office - Small	2050 Projection	0.1695	0.7761
West South Central	Other	2012 Building Stock	1.0000	1.0000
West South Central	Other	2012 Projection	0.9332	0.9175
West South Central	Other	2020 Projection	0.7538	0.8566
West South Central	Other	2030 Projection	0.6092	0.8005
West South Central	Other	2040 Projection	0.3832	0.7546
West South Central	Other	2050 Projection	0.2937	0.7340
West South Central	Warehouse	2012 Building Stock	1.0000	1.0000
West South Central	Warehouse	2012 Projection	0.9054	0.8316
West South Central	Warehouse	2020 Projection	0.7170	0.7754
West South Central	Warehouse	2030 Projection	0.5619	0.6958
West South Central	Warehouse	2040 Projection	0.2730	0.6256
West South Central	Warehouse	2050 Projection	0.1662	0.5799
West South Central	Mercantile & Service	2012 Building Stock	1.0000	1.0000
West South Central	Mercantile & Service	2012 Projection	0.9749	0.9384
West South Central	Mercantile & Service	2020 Projection	0.7808	0.8801
West South Central	Mercantile & Service	2030 Projection	0.6284	0.8252
West South Central	Mercantile & Service	2040 Projection	0.3480	0.7803
West South Central	Mercantile & Service	2050 Projection	0.2315	0.7606
Mountain	Assembly	2012 Building Stock	1.0000	1.0000
Mountain	Assembly	2012 Projection	0.8639	0.9644
Mountain	Assembly	2020 Projection	0.5608	0.9597
Mountain	Assembly	2030 Projection	0.3233	0.9874
Mountain	Assembly	2040 Projection	0.1061	1.0439
Mountain	Assembly	2050 Projection	0.0424	1.1023
Mountain	Education	2012 Building Stock	1.0000	1.0000

US Census division	Building Type	Vintage	Heating Load Factor	Cooling Load Factor
Mountain	Education	2012 Projection	0.9102	0.9142
Mountain	Education	2020 Projection	0.6941	0.8088
Mountain	Education	2030 Projection	0.5291	0.7330
Mountain	Education	2040 Projection	0.3010	0.6806
Mountain	Education	2050 Projection	0.2159	0.6778
Mountain	Food Sales	2012 Building Stock	1.0000	1.0000
Mountain	Food Sales	2012 Projection	0.9875	0.9659
Mountain	Food Sales	2020 Projection	0.8762	0.8349
Mountain	Food Sales	2030 Projection	0.8110	0.7598
Mountain	Food Sales	2040 Projection	0.6645	0.6524
Mountain	Food Sales	2050 Projection	0.6105	0.6531
Mountain	Food Service	2012 Building Stock	1.0000	1.0000
Mountain	Food Service	2012 Projection	0.9585	0.9580
Mountain	Food Service	2020 Projection	0.8907	0.9527
Mountain	Food Service	2030 Projection	0.8266	0.9491
Mountain	Food Service	2040 Projection	0.7124	0.9586
Mountain	Food Service	2050 Projection	0.6480	0.9669
Mountain	Health Care	2012 Building Stock	1.0000	1.0000
Mountain	Health Care	2012 Projection	0.9152	0.9677
Mountain	Health Care	2020 Projection	0.8325	0.9429
Mountain	Health Care	2030 Projection	0.7605	0.9222
Mountain	Health Care	2040 Projection	0.6776	0.9001
Mountain	Health Care	2050 Projection	0.6373	0.8887
Mountain	Lodging	2012 Building Stock	1.0000	1.0000
Mountain	Lodging	2012 Projection	0.9477	0.9125
Mountain	Lodging	2020 Projection	0.7504	0.8447
Mountain	Lodging	2030 Projection	0.5839	0.8140
Mountain	Lodging	2040 Projection	0.3130	0.8183
Mountain	Lodging	2050 Projection	0.2012	0.8719
Mountain	Office - Large	2012 Building Stock	1.0000	1.0000
Mountain	Office - Large	2012 Projection	0.8480	0.9753
Mountain	Office - Large	2020 Projection	0.5952	0.9573
Mountain	Office - Large	2030 Projection	0.3875	0.9476
Mountain	Office - Large	2040 Projection	0.2204	0.9435
Mountain	Office - Large	2050 Projection	0.1518	0.9457
Mountain	Office - Small	2012 Building Stock	1.0000	1.0000
Mountain	Office - Small	2012 Projection	0.9130	0.9362
Mountain	Office - Small	2020 Projection	0.7198	0.9032
Mountain	Office - Small	2030 Projection	0.5399	0.8854
Mountain	Office - Small	2040 Projection	0.2976	0.9090
Mountain	Office - Small	2050 Projection	0.1881	0.9544
Mountain	Other	2012 Building Stock	1.0000	1.0000
Mountain	Other	2012 Projection	0.9277	0.9378

US Census division	Building Type	Vintage	Heating Load Factor	Cooling Load Factor
Mountain	Other	2020 Projection	0.7479	0.8840
Mountain	Other	2030 Projection	0.6001	0.8503
Mountain	Other	2040 Projection	0.3865	0.8358
Mountain	Other	2050 Projection	0.2993	0.8540
Mountain	Warehouse	2012 Building Stock	1.0000	1.0000
Mountain	Warehouse	2012 Projection	0.9353	0.8376
Mountain	Warehouse	2020 Projection	0.7423	0.7927
Mountain	Warehouse	2030 Projection	0.5860	0.7257
Mountain	Warehouse	2040 Projection	0.2871	0.7014
Mountain	Warehouse	2050 Projection	0.1721	0.7243
Mountain	Mercantile & Service	2012 Building Stock	1.0000	1.0000
Mountain	Mercantile & Service	2012 Projection	0.9648	0.9429
Mountain	Mercantile & Service	2020 Projection	0.7765	0.8763
Mountain	Mercantile & Service	2030 Projection	0.6214	0.8286
Mountain	Mercantile & Service	2040 Projection	0.3553	0.8154
Mountain	Mercantile & Service	2050 Projection	0.2468	0.8193
Pacific	Assembly	2012 Building Stock	1.0000	1.0000
Pacific	Assembly	2012 Projection	0.8537	0.8963
Pacific	Assembly	2020 Projection	0.5163	0.8869
Pacific	Assembly	2030 Projection	0.2934	0.8941
Pacific	Assembly	2040 Projection	0.0771	0.9515
Pacific	Assembly	2050 Projection	0.0272	0.9996
Pacific	Education	2012 Building Stock	1.0000	1.0000
Pacific	Education	2012 Projection	0.8724	0.8236
Pacific	Education	2020 Projection	0.6596	0.7308
Pacific	Education	2030 Projection	0.4950	0.6536
Pacific	Education	2040 Projection	0.2615	0.6112
Pacific	Education	2050 Projection	0.1816	0.6012
Pacific	Food Sales	2012 Building Stock	1.0000	1.0000
Pacific	Food Sales	2012 Projection	0.9799	0.9266
Pacific	Food Sales	2020 Projection	0.8821	0.8382
Pacific	Food Sales	2030 Projection	0.8104	0.7675
Pacific	Food Sales	2040 Projection	0.6783	0.7342
Pacific	Food Sales	2050 Projection	0.6130	0.7607
Pacific	Food Service	2012 Building Stock	1.0000	1.0000
Pacific	Food Service	2012 Projection	0.9652	0.9117
Pacific	Food Service	2020 Projection	0.8886	0.9047
Pacific	Food Service	2030 Projection	0.8185	0.8902
Pacific	Food Service	2040 Projection	0.6877	0.9074
Pacific	Food Service	2050 Projection	0.6228	0.9184
Pacific	Health Care	2012 Building Stock	1.0000	1.0000
Pacific	Health Care	2012 Projection	0.9031	0.9605
Pacific	Health Care	2020 Projection	0.8155	0.9339

US Census division	Building Type	Vintage	Heating Load Factor	Cooling Load Factor
Pacific	Health Care	2030 Projection	0.7453	0.9124
Pacific	Health Care	2040 Projection	0.6611	0.8903
Pacific	Health Care	2050 Projection	0.6232	0.8795
Pacific	Lodging	2012 Building Stock	1.0000	1.0000
Pacific	Lodging	2012 Projection	0.9645	0.7686
Pacific	Lodging	2020 Projection	0.7538	0.6931
Pacific	Lodging	2030 Projection	0.5949	0.6476
Pacific	Lodging	2040 Projection	0.2982	0.6828
Pacific	Lodging	2050 Projection	0.1846	0.7846
Pacific	Office - Large	2012 Building Stock	1.0000	1.0000
Pacific	Office - Large	2012 Projection	0.7800	0.9441
Pacific	Office - Large	2020 Projection	0.4956	0.9237
Pacific	Office - Large	2030 Projection	0.3083	0.9089
Pacific	Office - Large	2040 Projection	0.1393	0.9070
Pacific	Office - Large	2050 Projection	0.0963	0.9089
Pacific	Office - Small	2012 Building Stock	1.0000	1.0000
Pacific	Office - Small	2012 Projection	0.8919	0.8488
Pacific	Office - Small	2020 Projection	0.6840	0.8096
Pacific	Office - Small	2030 Projection	0.5116	0.7789
Pacific	Office - Small	2040 Projection	0.2465	0.8390
Pacific	Office - Small	2050 Projection	0.1476	0.9105
Pacific	Other	2012 Building Stock	1.0000	1.0000
Pacific	Other	2012 Projection	0.9166	0.8713
Pacific	Other	2020 Projection	0.7245	0.8235
Pacific	Other	2030 Projection	0.5792	0.7838
Pacific	Other	2040 Projection	0.3563	0.7975
Pacific	Other	2050 Projection	0.2736	0.8321
Pacific	Warehouse	2012 Building Stock	1.0000	1.0000
Pacific	Warehouse	2012 Projection	0.9196	0.7905
Pacific	Warehouse	2020 Projection	0.7016	0.7719
Pacific	Warehouse	2030 Projection	0.5410	0.7033
Pacific	Warehouse	2040 Projection	0.2387	0.7668
Pacific	Warehouse	2050 Projection	0.1315	0.8346
Pacific	Mercantile & Service	2012 Building Stock	1.0000	1.0000
Pacific	Mercantile & Service	2012 Projection	0.9702	0.8926
Pacific	Mercantile & Service	2020 Projection	0.7632	0.8480
Pacific	Mercantile & Service	2030 Projection	0.5983	0.8019
Pacific	Mercantile & Service	2040 Projection	0.3199	0.8138
Pacific	Mercantile & Service	2050 Projection	0.2109	0.8283

Appendix D – Resources

DOE and EIA Resources

- U.S. Energy Information Administration, Commercial Demand Module of the National Energy Modeling System: Model Documentation; [online] Available at: https://www.eia.gov/outlooks/aeo/nems/documentation/commercial/pdf/m066(2017).pdf
- U.S. Energy Information Administration, Commercial Demand Module; [online] Available at: https://www.eia.gov/outlooks/aeo/assumptions/pdf/commercial.pdf
- U.S. Energy Information Administration, Chapter 4. Residential Demand Module; [online] Available at: https://www.eia.gov/outlooks/aeo/assumptions/pdf/residential.pdf
- Science Applications International Corporation, Commercial Building Shell Heating and Cooling Factors for Use in the Commercial Demand Module, DOE EIA, July 2011.
- Science Applications International Corporation, Data Analysis for Enhanced Representation of Commercial Thermal Shell Efficiency in the Commercial Demand Module, DOE EIA, February 2011.
- Science Applications International Corporation, Thermal Efficiency Indicators Characterizing Existing Commercial Buildings, DOE EIA, December 2008.
- ICF, Residential and Commercial Sector Energy Code Adoption and Compliance Rates, July 2016.
- National Renewable Energy Laboratory, U.S. Department of Energy Commercial Reference Building Models of the National Building Stock; NREL/TP-5500-46861; February 2011; [online] Available at: http://www.nrel.gov/docs/fy11osti/46861.pdf
- National Renewable Energy Laboratory, DOE Commercial Building Benchmark Models; NREL/CP-550-43291; July 2008; [online] Available at: https://www.nrel.gov/docs/fy08osti/43291.pdf
- U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, Buildings, Commercial Reference Buildings; [online] Available at: http://energy.gov/eere/buildings/commercial-reference-buildings
- U.S. Department of Energy, Building Energy Codes Program, Commercial Prototype Building Models; [online] Available at: https://www.energycodes.gov/development/commercial/prototype_models
- U.S. Energy Information Administration, 2012 Commercial Building Energy Consumption Survey Data; [online] Available at: https://www.eia.gov/consumption/commercial/data/2012/index.php?view=microdata

Building Energy Codes and Standards

- ANSI/ASHRAE/IES Standard 90.1-2016; Energy Standard for Buildings Except Low-Rise Residential Buildings
- ANSI/ASHRAE/IES Standard 90.1-2013; Energy Standard for Buildings Except Low-Rise Residential Buildings

- ANSI/ASHRAE/IES Standard 90.1-2010; Energy Standard for Buildings Except Low-Rise Residential Buildings
- ANSI/ASHRAE/IES Standard 90.1-2007; Energy Standard for Buildings Except Low-Rise Residential Buildings
- ANSI/ASHRAE/IES Standard 90.1-2004; Energy Standard for Buildings Except Low-Rise Residential Buildings
- ANSI/ASHRAE/IES Standard 90.1-1999; Energy Standard for Buildings Except Low-Rise Residential Buildings
- ANSI/ASHRAE Standard 62.1-2013; Ventilation for Acceptable Indoor Air Quality
- ANSI/ASHRAE Standard 169-2006; Standard 169, Climatic Data for Building Design Standards
- U.S. Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Program, Building America Best Practices Series, Volume 7.3, Higher Performance Home Technologies, Guide to Determining Climate Regions by County, August 2015; [online] Available at: https://energy.gov/sites/prod/files/2015/10/f27/ba_climate_region_guide_7.3.pdf
- ASHRAE Advanced Energy Design Guide for Small to Medium Office Buildings, Achieving 50% Energy Savings Towards a Net Zero Energy Building, 2011; [online] Available at: https://www.ashrae.org/standards-research--technology/advanced-energy-design-guides

Building Envelope Technology and Code Research

- U.S. Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Office, Windows and Building Envelope Research and Development: Roadmap for Emerging Technologies; February 2014; [online] Available at: https://energy.gov/sites/prod/files/2014/02/f8/BTO_windows_and_envelope_report_3.pdf
- Pacific Northwest National Laboratory, Commercial Building Energy Code Compliance Literature Review; PNNL-25218; February 2016; [online] Available at: http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-25218.pdf
- Pacific Northwest National Laboratory, Roadmap for the Future of Commercial Energy Codes; PNNL-24009; January 2015; [online] Available at: http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-24009.pdf
- American Council for an Energy-Efficient Economy, Energy Codes for Ultra-Low Energy Buildings: A Critical Pathway to Zero Net Energy Buildings; Report A1403; December 2014; [online] Available at: http://kms.energyefficiencycentre.org/sites/default/files/a1403.pdf
- International Energy Agency, Technology Roadmap: Energy Efficient Building Envelopes, 2013; [online] Available at: http://www.iea.org/publications/freepublications/publication/TechnologyRoadmapEnergyEfficientBuildingEnvelopes.pdf
- Michelson, McCowan, Chase, Commercial Building Codes: Finding the Path to Improved Compliance; [online] Available at: http://www.ers-inc.com/wp-content/uploads/2017/02/Commercial-Code-Paths-to-Improved-Compliance.pdf

- McCowan, Epstein, Barry, Leahy, Ranger, Todd, Commercial Construction: Time to Overhaul Energy Code Compliance and Enforcement Approaches; [online] Available at: http://aceee.org/files/proceedings/2014/data/papers/8-533.pdf
- Sawyer, Roof Coatings Manufacturers Association, Internal Roof Coatings Conference, DOE's Building Envelope R&D Program; [online] Available at: https://roofcoatings.org/wp-content/uploads/2014/07/05-Sawyer-Department-of-Energy.pdf
- Karney, Emerging Technologies Building Technologies Office, Windows R&D at the DOE Building Technologies Office; [online] Available at: https://c.ymcdn.com/sites/www.nibs.org/resource/resmgr/Conference/BETEC_RKarney.pdf
- Hun, Oak Ridge National Laboratory, U.S. Department of Energy, Energy Exchange, Building Envelopes 101; [online] Available at: http://www.2017energyexchange.com/wp-content/tracks/track1/T1S1_Hun.pdf
- Code of Federal Regulations, Title 10 – Energy ,Volume: 3; [online] Available at: https://www.gpo.gov/fdsys/pkg/CFR-2001-title10-vol3/xml/CFR-2001-title10-vol3-sec435-105.xml