Board of Building Standards

CODE COMMITTEE MEETING
AGENDA

DATE: JUNE 24, 2021
TIME: 1:00 PM
LOCATION: VIDEOCONFERENCE
DIAL-IN # 1 614-721-2972 CONFERENCE ID: 333 902 414#
Videoconference Link

Staff & Guest "Sign-In"

Call to Order

Approval of Minutes

MIN-1 March 25, April 1, April 22 & May 7 Code Committee Meeting Minutes

Petitions

No items for consideration.

Recommendations of the Residential Construction Advisory Committee

No items for consideration.

Old Business

OB-1 Code Development Status Update
OB-2 2017 ICC/ANSI A 117.1 Standard for New Construction
OB-3 2020 NEC Reconsideration

1. Article 210.8(F) and the proposed NFPA TIAs (1529, 1589, and 1593) addressing GFCI protection for dwelling outdoor outlets and variable speed HVAC units.
2. Article 705 – Utility scale, on-site power generation

OB-4 Energy Codes Background Discussion

New Business

Adjourn

File Attachments for Item:

MIN-1 March 25, April 1, April 22 & May 7 Code Committee Meeting Minutes

OHIO BOARD OF BUILDING STANDARDS
CODE COMMITTEE MINUTES
MARCH 25, 2021

The Code Committee met on March 25, 2021 via teleconference with the following members present: Mr. Denk, Ms. Cromwell, Mr. Johnson, Mr. Miller, Mr. Pavlis, Mr. Samuelson, Mr. Stanbery, and Mr. Tyler. Board Chairman, Tim Galvin, was also present.

The following staff members were present: Regina Hanshaw, Rob Johnson, Debbie Ohler, and Jay Richards.

Guests present: Eric Lacey and Charles Huber

CALL TO ORDER

The meeting was called to order by Mr. Denk at 12:04 P.M. and then again at 3:06 P.M. after breaking for one hour to support Ms. Cromwell who represented the BBS while serving on the Department of Commerce Diversity, Equity, and Inclusion panel discussion for Women's History Month.

APPROVAL OF MINUTES

Mr. Miller moved approval of the February 25, 2021 and the March 10, 2021 minutes. Mr. Johnson seconded the motion. The motion passed unanimously.

PETITIONS

No items for consideration

RECOMMENDATIONS OF THE RESIDENTIAL CONSTRUCTION ADVISORY COMMITTEE

No items for consideration

OLD BUSINESS

- Discussion regarding the potential adoption of the 2017 edition of the ICC/ANSI A117.1 remained tabled.
- Discussion regarding the 2021 IBC 918/IFC 510 was tabled and will be brought up again when IBC Chapter 9 is revisited.

NEW BUSINESS

Staff presented changes to Chapters 10, 12, and 14 of the 2021 International Building Code. Staff explained that a draft of the Ohio Building Code language would be put into rule form for the committee to review and approve at a later date, prior to starting the stakeholder phase of the rule development process. No action was taken.

ADJOURN

The meeting was temporarily adjourned at 1:57 P.M. and then adjourned again at 4:10 P.M. Mr. Samuelson made the final motion to adjourn. Ms. Cromwell seconded the motion. The motion passed unanimously.

OHIO BOARD OF BUILDING STANDARDS
CODE COMMITTEE MINUTES
APRIL 1, 2021

The Code Committee met on April 1, 2021 via teleconference with the following members present: Mr. Denk, Ms. Cromwell, Mr. Johnson, Mr. Miller, Mr. Pavlis, Mr. Samuelson, Mr. Stanbery, and Mr. Tyler. Board Chairman, Tim Galvin, was also present.

The following staff members were present: Regina Hanshaw, Rob Johnson, Debbie Ohler, and Jay Richards.

Guests present: Tim McClintock and Tom Moore

CALL TO ORDER

The meeting was called to order by Mr. Denk at 1:07 P.M.

OLD BUSINESS

- Petition 20-01 (2020 NEC) - Mr. McClintock and Mr. Moore presented a summary of the 2020 NFPA significant changes to the committee as a refresher. A few members of the committee had some concern about the cost impact of a few of the changes and wanted to consult with others before discussing the issue at the next committee meeting. No action was taken.
- Discussion regarding the potential adoption of the 2017 edition of the ICC/ANSI A117.1 remained tabled.
- Discussion regarding the 2021 IBC 918/IFC 510 remained tabled and will be brought up again when other IBC Chapter 9 issues are revisited.

NEW BUSINESS

Staff presented changes to Chapter 15 and Chapter 16 (through Section 1607) of the 2021 International Building Code. Staff explained that a draft of the Ohio Building Code language would be put into rule form for the committee to review and approve at a later date, prior to starting the stakeholder phase of the rule development process. No action was taken.

ADJOURN

Mr. Pavlis made the motion to adjourn and Mr. Miller seconded the motion. The meeting was adjourned at 1:57 P.M. The motion passed unanimously.

OHIO BOARD OF BUILDING STANDARDS
CODE COMMITTEE MINUTES
APRIL 22, 2021

The Code Committee met on April 22, 2021 via teleconference with the following members present: Mr. Denk, Ms. Cromwell, Mr. Johnson, Mr. Miller, Mr. Pavlis, Mr. Stanbery, Mr. Tyler, and Mr. Yankie. Board Chairman, Tim Galvin, was also present.

The following staff members were present: Regina Hanshaw, Rob Johnson, Debbie Ohler, and Jay Richards.

Guests present: Tim McClintock of NEMA, Tom Moore of the Ohio Electrical Safety Coalition and IEBW, Larry Ayer of the NEC Correlating Committee, David Smith of Eaton, Matt Hittinger and David Hittinger of the Independent Electrical Contractors of Indiana, Nick DeAngelo, Rachel Carl of AGC, and Ashley Bryant

CALL TO ORDER

The meeting was called to order by Mr. Denk at 1:04 P.M.

OLD BUSINESS

- Petition 20-01 (2020 NEC) – All of the guests provided testimony in support of the Board adopting the 2020 NEC without amendments as soon as possible. Mr. Stanbery made the motion to adopt the 2020 NEC without amendments. Mr. Johnson seconded the motion. The motion passed unanimously. The committee discussed whether to adopt the NEC with the rest of the code for a target effective date of 2023 or whether to move forward with adoption now. Mr. Tyler, Mr. Stanbery, and Mr. Johnson stated their support of adopting as soon as possible. Mr. Miller made the motion to recommend that staff start the rule development process for adoption of the 2020 NEC as soon as possible by scheduling a stakeholder meeting. Mr. Johnson seconded the motion. The motion passed unanimously.
- Discussion regarding the potential adoption of the 2017 edition of the ICC/ANSI A117.1 remained tabled.
- Discussion regarding the 2021 IBC 918/IFC 510 remained tabled and will be brought up again when other IBC Chapter 9 issues are revisited.

NEW BUSINESS

Staff presented changes to Chapters 16-22 of the 2021 International Building Code. Staff explained that a draft of the Ohio Building Code language would be put into rule form for the committee to review and approve at a later date, prior to starting the stakeholder phase of the rule development process. No action was taken.

ADJOURN

Mr. Miller made the motion to adjourn and Mr. Yankie seconded the motion. The meeting was adjourned at 3:26 P.M. The motion passed unanimously.

OHIO BOARD OF BUILDING STANDARDS
CODE COMMITTEE MINUTES
MAY 7, 2021

The Code Committee met on May 7, 2021 via teleconference with the following members present: Mr. Denk, Ms. Cromwell, Mr. Johnson, Mr. Miller, Mr. Pavlis, Mr. Samuelson, Mr. Tyler, and Mr. Yankie. Board Chairman, Tim Galvin, was also present.

The following staff members were present: Regina Hanshaw, Rob Johnson, Debbie Ohler, and Jay Richards.

Guests present: Jim Smith of the American Wood Council

CALL TO ORDER

The meeting was called to order by Mr. Denk at 9:03 A.M

OLD BUSINESS

- Discussion regarding the potential adoption of the 2017 edition of the ICC/ANSI A117.1 remained tabled. Ms. Hanshaw mentioned that the Ohio AIA is working on a cost impact report to present to the committee at a later date.
- Discussion regarding the 2021 IBC 918/IFC 510 remained tabled and will be brought up again when other IBC Chapter 9 issues are revisited.

NEW BUSINESS

Staff presented changes to Chapters 23-33 of the 2021 International Building Code. Staff explained that a draft of the Ohio Building Code language would be put into rule form for the committee to review and approve at a later date, prior to starting the stakeholder phase of the rule development process. No action was taken.

Ms. Cromwell mentioned that the City of Cincinnati is requiring special inspections that are not required in the OBC Chapter 17 and do not seem to be officially adopted as ordinance. Ms. Cromwell will invite the building official to attend a future committee meeting.

ADJOURN

Mr. Pavlis made the motion to adjourn and Mr. Miller seconded the motion. The motion passed unanimously. The meeting was adjourned at 11:30 A.M.

File Attachments for Item:

OB-2 2017 ICC/ANSI A 117.1 Standard for New Construction

AIA Ohio

A117.1 Task Force

May 2021

Re: A brief study of the cost implications of adoption of the 2017 ICC/ANSI A117.1 accessibility standard for new construction by the Ohio Board of Building Standards

Participants: Terry Welker, FAIA, Chair
Bruce Sekanick, FAIA
Melinda Scalfaro, AIA
Robert Siebenaller, AIA
Doug Gallow, AIA
Karen Planet, AIA

The Ohio Board of Building Standards is currently reviewing the 2021 IBC for planned tentative adoption on or about January 2023. As part of the review Steve Regoli prepared a summary of the major differences between 2017 ICC/ANSI A117.1 Standard and the 2009 edition which we still currently reference. The Board is not considering adopting the 2017 standard for all buildings (new and existing) but is exploring the option to adopt the 2017 edition for new buildings only where the additional requirements would have the least impact on design and cost. The Board's Code Committee suggested reaching out to AIA Ohio and ODPCA for input as well any information they could provide on the expected cost impact these requirements would have for new construction versus the current standard.

The task force began with the "ICC/ANSI A117.1 Comparison Between the 2009 and 2017 Editions" Chart. Several meetings and lengthy discussions generated an expanded spread sheet with comments and associated costs where applicable. We first ranked the IMPACT of each change from VERY LOW, LOW, MODERATE, HIGH or VERY HIGH. We found that none of the changes were ranked as VERY HIGH and only one item was ranked as HIGH.

Since we are exploring the implications of a standard, rather than a prescriptive code, we've learned that costs are very relative to particular building projects and overall costs can vary widely with the size scope of the project. We also learned that some Use Groups will be affected more than others for some of the proposed changes.

Under the topic of Accessible Building Blocks the impacts were LOW or VERY LOW. The biggest costs are attributed to the incremental of cost of increased sizes of wheelchair spaces and turning spaces. However, this may not necessarily lead to larger buildings. Over the course of time, we anticipate these to be easily integrated in new buildings.

Under the topic of Accessible Route all items were graded as LOW or VERY LOW except for the item about curb ramps which we graded as MODERATE. Most of these impacts were minimal in costs because most of the time building programs call for designing well above the minimal standards. As architects we were pleased to see the expanded guidance for curb ramps even though there is a moderate cost associated with this change. Health care and residential facilities in particular would be impacted by this change. Site design and grading has been easily ignored, misunderstood or inadequately detailed by architects and engineers because the standard was inadequate. Designing facilities to these new or supplemental requirements will have significant positive design rewards.

On the related topic of General Site & Building, parking spaces and routes through parking lots will have an effect on design but it's difficult to universally attribute costs because of the wide variance in possible site conditions.

Under the topic of Special Rooms & Spaces, one item stood out: enhanced acoustics for classrooms. The Use Group most obviously affected by this is Education, but it could also apply to B Use classrooms in colleges and universities. Until these design approaches are more commonly used and standardized in the design world, architects and engineers will have a burden of proof to demonstrate compliance when seeking construction approvals. Increased finish costs and HVAC duct sizes (or alternative HVAC systems) are anticipated. It's important to recognize that this standard is already integrated into the LEED requirements which are already required by the Ohio Facilities Construction Commission. Because of the existing requirements by the OFCC, many communities are already benefitting from these proposed improvements to the code.

The Task Force has studied this new standard as it relates to new buildings only. It is important to recognize however that this new A117.1 anticipates adoption with existing buildings in mind. There is potential for some confusion. The sections where existing building provisions have been included are Sections 304.3.1.2, 304.3.2.2, 305.3.2, 403.5.1 Exception 2, 403.5.2.2, 403.5.3.2 and 403.5.4.2 among others.

In general, many of the changes are simply good clarifications. Where there are cost impacts we regard these as marginal and reasonable. A helpful document for consideration is the ICC's Significant Changes to the ICC A117.1 Accessibility Standard.

Respectfully submitted,

T. Welker

Terry Welker, FAIA, Task Force Chair

AIA Ohio

AIA Ohio A117.1 2009-2017 Comparision Task Group

Steve Regoli ICC/ANSI A117.1 Comparision Between the 2009 and 2017 Editions

		Element	Current 2009 A117.1 Requirement	A117.1-2017 Requirements		Impact	Impact Notations	Estimated Cost	Building Type	OAC Impact
				Existing Buildings	New Buildings					
Building Blocks	1	Wheelchair Space (305.3.1)	48" x 30"	48" x 30"	52" x 30"	Very low	The 4 " increase is relatively minor for new buildings has little to no impact on design	The cost for the increased area per wheel chair space is estimated at between $124 and $190.	General	Architect
Building Blocks	2	Wheelchair Turning Space - Circular (304.3.1.1)	60" w/25" overlap	60" w/25" overlap	67" w/10" overlap	Low	This change provides for better accessibility, however, it can make compliance slightly more dificult. Think about the cummulative effect of the route. Could be affected by Use Group Classification. Single use restrooms could be affected. This could affect small rooms in buildings and is not limited to just restrooms	The cost increase per accessible stall is estimated to be between $874 and $1,342.	General	Owner-Architect
Building Blocks	3	Wheelchair Turning Space - T-shaped (304.3.2.1)	60" x 60" w 24" x 12" cutouts	60" x 60" w/24" x 12" cutouts	3 options: 60" x 64" with different sized cutouts	Very low	The cutouts provide more flexibility for compliance and the increase of the T-shaped turning area is minimal.	No increase projected	General	Architect
Building Blocks	4	Turning Space Overlap in T-shaped space	Not specifically diagrammed			Very low	No impact	No increase projected	General	Architect
Building Blocks	5	Operable Parts (308.3)(309.1)		Added Exceptions to general requirements		Very low	This item refers to fuel dispensers on existing curbs and general operable features of devices or equipment. (Fans, panels, etc.) There is no impact and changes provide additional flexibility for the Owner and Architect.	No increase projected	General	Owner-Architect
	6	Accessible Route: 90 degree truns	36" to 36" corridor	36" to 36" corridor		Low	This item might have a cost impact when the chamfered corners are required to narrow corridors. The other options provide for more flexibility. Most architects design to a higher standard.	Minimal cost. At each intersection where chamfered corners might be needed, add $200 - $400.	General use buildings or structures	Architect
	7	Accessible Route: 180 degree turns	2 options: 42" to 48" to 42" < 48" sep. or 36" to 60" to 36">48" sep.	2 options: 42" to 48" to 42" < 48" sep. or 36" to 60" to 36">48" sep.	3 options: 42" to 48" to 42" < 52" sep.; 36" to 60" to 36" < 52" sep.; 43" to 43" w> 52" sep.	Very low	There is more flexibility added to the requirements. Changes are not anticipated to have any real costs that would impact the over all budget of a project.	No increased costs anticipated.	General use buildings or structures	Architect

Accessible Route	8	Passing Space	36" corridors, comply w/ T-shaped turn and arms extend 48"	36" corridors, comply w/ T-shaped turn and arms extend 48"	36" corridors, comply w/ T-shaped turn and arms extend 52" w/chamfered corners.	Low	The revision provided alternative for design compliance. While this could have a small impact when utilizing chamfered corners, most designs would have minimal to no effect on the overall project. Most architects design to a higher standard	A minimal cost of $200 - $400 could be applied to this item per occurance. The impact however is negligible.	General use buildings or structures	Architect
	9	Manuevering Clearances at doors	Maneuvering clearance includes full opening width of door and cannot include knee or toe clearances	Maneuvering clearance includes full opening width of door and required latch-side and hinge-side clearances.		Very low	This appears to be a clarification to the overall intent. Many designs already exceed this requirement. Based on a review of the changes, the approach clearance for doorways with doors appears to be changed to 52" as well.	There appears to be a minimal cost of $200 - $400 for each occurance due to the change in the area of the approach.	General use buildings or structures	Architect
	10	Maneuvering Clearances at doorways w/o doors	Approach: front 48", side 42"	Approach: front 48", side 42"	Aproach: front 52", side 42"	Low	This is a minor change, but it does have an impact on design and a minor impact on construction.	A minimal cost of $200 - $400 could be applied to this item for each occurance.	General use buildings or structures	Architect
	11	Maneuvering Clearances at recessed doorways	Pull 60", Push 48" w/ conditions	Pull 60", Push 48" w/ conditions	Pull 60", Push 52" w/ conditions	Low	Again, a minor change with a low impact.	It is anticpated to have an impact of only a few hundred dollars per occurance. A minimal cost of $200 - $400 could be applied to this item for each occurance.	General use buildings or structures	Architect
	12	Two doors in a series	48" plus door swing providing 60" turning radius	48" plus door swing providing 60" turning radius	48" plus door swing providing; Diagrams use T-shaped Turning	Very low	This provides clarity to the existing requirements.	No Impact.	General use buildings or structures	Architect
	13	Clear width of an accessible route	Reduced to 32" for 24" spaced 48"	Reduced to 32" for 24" spaced 48"	Reduced to 32" for 24" spaced 52"	Very low	A minor change that will have only a very limited cost implication.	No cost impact is anticipated.	General use buildings or structures	Architect
	14	Curb ramps		Greatly expanded: blended, perpendicular, parallel; grade break, cross slope, counter slope, clear space at bottom 48" x 48"		Moderate	This is listed as moderate because there will be an impact due to some of the new requirements that require larger areas for the ramps. At the same time, this section provides clarity to the curb ramp requirements. Small sites with toographic grading problems could cost much more.	This is difficult to apply a cost to as each condition is different. There could be added costs of as low as a few hundred dollars to more than a $1,000 per occurance depending on the condition. Because of the variations in application, this is listed as moderate.	Varies by use and occupancy. These requirements are more likely to impact smaller projects that often only meet but not exceed requirements.	Architect
	15	Platform Lifts	36" x 48"	36" x 48"; 36 x 60"	36" x 52"; 36 x 60"	Very low	This will have a minimal effect on a very limited number of buildings. The impact is extremely low.	No cost impact is anticipated.	General use. Limited application.	Architect

General Site & Building	16	Parking Spaces		Wide sidewalk and narrow sidewalk parallel, angled parking, parking meter, electric vehicle charging station requirements.		Moderate	This requirement will require added space considerations for new construction. The change however responds to changing technology as well as needed clarifications.	There will be cost impacts, however these will be based on building use and size. General costs implications are anticipated to be low.Site size determines cost. One space = $1000	General use.	Architect
	17	Passenger loading zone access aisle	Loading zomes to be marked 60" wide	Loading zone to be marked 60" wide	Loading zone to be marked 67" wide	Very low	Increase in parking areas will result in some minor design changes. Overall impact however is low.	No to very low cost increase	General use.	Architect
	18	Windows		One operable window operating force requirements		Low	Depending on the building use, this could have a minor impact on design and costs.	Cost implications are minimal, hower there could be some instances where costs of up to $500 could be incurred.		Architect-Contractor
	19	Assessible routes through parking		Routes through parking facility must be physically separated from vehicular traffic except at drive aisle crossing		Moderate	This element could add to additional site development costs to a project. The scope of this depends on the size of the project. Increased site sizes possible.	The cost will vary with project size, but this will have some impact on overall project costs.		Owner-Architect
Plumbing	20	Drinking fountains		Added requirements for children fountain height, water flow		Very low	No Impact	Minor impact item		Architect
	21	Bottle filling stations		Requirements for clear floor space, controls		Very low	No Impact, provides clarity.	Minimal impact to overall project costs.		Architect
	22	Toilet stalls		Added alternate compartments; toe clearances increased to 12" x 8"		Very low	No Impact, provides clarity.	Minimal impact to overall project costs.		Architect
	23	Grab bars in roll-in shower compartments		Detailed plan and elevation dimensions for grab bars		Very low	Clarity added for compliance with minimal impact on costs	No projected increase		Architect
Comm. Elements	24	Signs		Nonglare finish and character contrast requirements added		Very low	Added requirement to existing regulations. No impact in cost for compliance	No projected increase		Architect-Contractor
	25	Visual relay service booth		Requirements for seating, privacy, lighting, finish, color		High	Adding an interpreter style booth will have equipment and space impacts. This section defines the requirements if provided. There is no specific information on requirements as to where and when these faciities should be provided.	Equipment Costs: $6,000-$10,000. Space Costs: $8,000 - $16,000, if required. The impact of this is offset by the potential limited application of the interpreter booth.		Owner-Architect
	26	Detectable warning surfaces		Greatly expanded requirements; accompany changes to curb ramps, islands, rail crossings.		Very low	More claifications for design.	No projected increase		Architect
	27	Assembly wheelchair space	48" or 60" depth	48" or 60" depth	52" or 60" depth	Very low	Cumulative effect possible.	No projected increase		Architect
	28	Assembly wheelchair space overlap		New dimensioned diagrams		Very low	No Impact	No projected increase		Architect
	29	Companion seating seat alignment	12"/36"	New diagrams 12"/36"	New diagrams 12"/4"/36" 12"/12"/36"	Very low	No Impact	No projected increase		Architect
	30	Horizontal dispersion	Dispersed to provide viewing options	Dispersed, but for stage or field, includes entire seating area		Very low	Limited impact to specific use.	There may be a small increase in some areas, although other requirements already make some of these items necessary.		Owner-Architect

Special Rooms & Spaces	31	Sign language interpreter station		Requirement for area, location, illumination, backdrop		Low	New for some uses. This is similar to the Visual Relay Service Booth. The requirements of for interpreter stations if provided. No specific requirements are noted for location and quantity.	$500 per occurance	Owner-Architect
	32	Transportation facilities	60" x 96" boarding/alighting area	60" x 96" boarding/alighting area	60" x 100" boarding/alighting area	Very low	limited impact to specific use.	The cost of this incerease for new construction is negligable.	Architect
	33	Enhanced accoustics for classrooms		Sound requirements for classrooms <20,000 SF performance and prescription methods for reveberatin time; ambient sound limits.		Moderate	Increased finish costs for walls and ceilings. Increased design costs for acoustic analysis. Increased HVAC duct sizes. Already incorporated into LEED Silver standard for OSFC. Good designers often incorporate this. Ambient noise is a new requirement.	$2000-$3000 per classroom.	Architect
Furnishing & Equipment	34	Sales and service counters and windows		Added diagrams and requirements for parallel and forward approach counters		Very low	No Impact.	No projected increase	Architect
	35	Charging stations		New requirements for clear floor space and height and reach ranges		Very low	New rules for airports. Could increase SF if stations are required adjacent to machines and out of aisles.	No projected increase	Architect
	36	Gaming machines and tables		New requirement for clear floor space for transfer or wheel chair use.		Very low	Could increase SF if stations are required adjacent to machines and out of aisles.	No projected increase	Owner-Architect
Recreational Facilities*	37	Golf facilities		New requirements for teeing grounds, putting greens, practce greens, teeing stations, teeing stations at driving ranges, and weather shelters.		Very low	This is a very limited and specific group of requirements and will have minimal impact in general.	No specific cost increase projected	Owner-Architect
	38	Miniature golf club reach range area	36" x 48"within 36"	36" x 48"within 36"	36" x 52"within 36"	Very low	No or limited Impact	No projected increase	Architect
	39	Play area accessible routes		New exceptions to accessible route requirements		Very low	No or limited Impact	No projected increase	Architect
	40	Pool/hot tub/spa clear deck space	36" x 48" forward 12"	36" x 48" forward 12"	36" x 52" forward 12"	Very low	No or limited Impact	No projected increase	Architect
Dwelling Units & Sleeping Units*	41	Bed height	At least one with open frame	At least one 17" - 23" above floor to top of matress		Very low	This is a limited item for residential structures and has minimal impact on a majority of applications	No cost impact due to requirement	Owner-Architect
	42	Wheelchair charging station		Clear floor area required for bed but also serves as charging area.		Very low	Provides additional requirement but also clarifies requirements. Very liminted building type impact indicated.	No significant projected costs. Limited building type application.	Architect
	43	Type B unit accessible route		New exceptions to clear width requirements added.		Very low	Clarity items. No impact to cost or design	No projected cost increase	Architect
	44	Type B ramps, elevators, platform lifts		New exceptions to requirements added.		Very low	Clarity items. No impact to cost or design	No projected cost increase	Architect
	45	Type B refrigerator approach	Centerline of clear floor space offset 24" from centerline of appliance	Centerline of clear floor space offset 24" from centerline of appliance for forward and 15" for parallel.		Very low	This provides clarity for the approach of appliances and will only have a limited impact on cost and design	No projected cost increase	Architect

Standard pricing for facilites are indicated at $150/SF - $230/SF. These prices vary significantly based on use and construction type. Prices can range based on construction type, use, and finishes between $40/SF and $500/SF (or more).

* The chapters addressing Recreational Facilities (forrmerly chapter 11) and Dwelling Units & Sleeping Units (formerly Chapter 10) traded places in the 2017 edition of the standard and the chapters, consequently, were entirely renumbered. Recreational Facilities are now addressed in Chapter 10 and Dwelling Units & Sleeping Units are now dealt with in Chapter 11 of the 2017 edition of the standard.

File Attachments for Item:

OB-3 2020 NEC Reconsideration -

NFPA 70®-2020 Edition
National Electrical Code®
TIA Log No.: 1593
Reference: Section 210.8(F)
Comment Closing Date: July 19, 2021
Submitter: Dean Hunter, Minnesota Department of Labor & Industry

1. Revise 210.8(F) to read as follows:

210.8 Ground-Fault Circuit-Interrupter Protection for Personnel. ...

(F) Outdoor Outlets. All outdoor outlets for dwellings, other than those covered in 210.8 (A)(3), Exception to (3), that are supplied by single-phase branch circuits rated 150 volts to ground or less, 50 amperes or less, shall have ground-fault circuit-interrupter protection for personnel. This requirement shall become effective on January 1, 2023 for mini-split-type heating/ventilating/air-conditioning (HVAC) equipment and other HVAC units employing power conversion equipment as a means to control compressor speed.

Informational Note: *Power conversion equipment* is the term used to describe the components used in HVAC equipment that is commonly referred to as a variable speed drive. The use of power conversion equipment to control compressor speed differs from multistage compressor speed control.

Exception: Ground-fault circuit-interrupter protection shall not be required on lighting outlets other than those covered in 210.8(C).

Substantiation: This expansion of GFCI protection in the 2020 NEC, for the purpose of covering exterior outlets through 250-volts at dwelling units, is a necessary enhancement for electrical safety. Code Making Panel 2 supported the expansion of GFCI protection to cover these outdoor outlets based on the electrocution of a young boy who came into contact with the energized enclosure of an outdoor HVAC unit.

The purpose of this TIA is not to eliminate the GFCI protection for *all* HVAC outdoor equipment, but to extend the date of enforcement for the circuit supplying the HVAC units employing power conversion equipment.

Emergency Nature: The proposed TIA intends to correct a circumstance in which the revised NFPA Standard has resulted in an adverse impact on a product or method that was inadvertently overlooked in the total revision process or was without adequate technical (safety) justification of the action.

In the state of Minnesota, we began enforcing Section 210.8(F) on April 5, 2021 and we have already documented many cases of operational tripping occurrences which have been difficult for inspectors and electricians to resolve. The only solution at this time is for the AHJ to approve a temporary allowance for the installation of a circuit breaker without GFCI protection so that these HVAC units can operate.

The language in this TIA is in direct alignment with the once-proposed TIA 1529 that was supported by Code Making Panel 2 for Technical and Emergency Nature. The Correlating Committee also agreed that no correlating issues existed with this language; however, the TIA narrowly failed ballot with regards to the Emergency Nature. Recently, proposed TIA 1564, which included "all HVAC equipment" failed ballot, but had multiple voting member comments supporting the language in TIA 1529. Also, TIA 1564 language contains substantiation to support reasons for delaying the date to address the operational GFCI tripping.

As we enter into the peak cooling season in Minnesota and in other states where the 2020 NEC has been adopted, it is expected that this issue will continue to grow and be problematic for the enforcement and installation community. Delaying the implementation date allows for the affected stakeholders to reach a solution to the operational tripping occurrences and provides AHJs with the ability to permit installations of cooling equipment that is essential to the health and safety of residents in warm climates.

Anyone may submit a comment by the closing date indicated above. Please identify the TIA number and forward to the Secretary, Standards Council. SUBMIT A COMMENT

Description of change:
Delete or modify section 210.8(F) concerning new requirements for GFCI protection on outdoor electrical circuits that are supplied by single-phase branch circuits rated 150 volts to ground or less, 50 amperes or less.

Proposed text change:

(1) Delete this section in its entirety; or if deleting in entirety is not acceptable to the committee, then
(2) Revise 210.8 (F) as follows: (F) Outdoor Outlets. All outdoor general-purpose receptacles ~~outlets~~ for other than dwellings units, ~~other than those covered in 210.8 (A) (3), Exception to (3),~~ that are supplied by single-phase branch circuits rated 150 volts to ground or less, 50 amperes or less, shall have ground-fault circuit-interrupter protection for personnel.

Justification:
As of 4/1/2021, 9 of 22 states that have either adopted the 2020 NEC or are in process of adopting have deleted/modified section 210.8(F) so that it does not apply to HVAC equipment. These include OR, WA, TX, ND, SD, MA, IA, UT, and NC.

The substantiation used by MA when they deleted section 210.8(F) noted "This addition in the 2020 NEC has not been substantiated. The loss experience supporting this addition to the NEC was based on untrained and unqualified work on an air-conditioning condenser that ended up energized and a thereby caused a boy who jumped a fence and contacted the housing to become electrocuted. GFCI protection saves countless lives and certainly has its place. However, it is a fool's errand to imply to the public that improper work can be rendered essentially safe by waving the GFCI magic wand. For example, contact between two circuit conductors will never trip a GFCI. CMP 2 came within one vote of rejecting this; Massachusetts needs to set it aside and await proper support."

TX adopted the 2020 NEC in November 2020, however, the Texas Department of Licensing and Regulation issued an emergency injunction against enforcing these Section 210.8(F) requirements on 5/19/2021 (https://www.tdlr.texas.gov/pressrelease/2021-05-20%20NEC%20delay.pdf), while the TDLR has begun work on non-emergency rulemaking to implement this change on a permanent basis. This came about after a rash of nuisance trips of new Heating, Ventilating and Air-Conditioning (HVAC) equipment in new homes over the last month. These nuisance trips are manufacturer generic as both multiple HVAC manufacturers equipment AND multiple GFCI manufacturers product were involved.

Reference documents from each of these states are accessible through the links below.

The industry has experienced many nuisance trips of GFCI breakers operating with inverter-driven HVAC equipment. 100% of all inverter-driven HVAC products that we are aware of when paired with a GFCI breaker have had nuisance tripping. In addition, we have heard claims from the Leading Builders of America (LBA) of single-stage and two-stage HVAC products with nuisance tripping when paired with GFCI breakers.

A Temporary Interim Amendment (TIA) request has been submitted to NFPA requesting a delay in the effective date of this requirement (as it relates to inverter-driven HVAC equipment) to allow the industry to (1) update certification requirements in UL943 and UL/CSA 60335-2-40 to address leakage current testing requirements at higher frequencies and (2) to allow manufacturers to make revisions to their equipment (both GFCI breakers and HVAC equipment manufacturers) to comply with new requirements. Another TIA request has been submitted to NFPA by the National Association of Home Builders (NAHB) on 5/14/2021 requesting a delay in implementation of these requirements for all HVAC equipment due to the nuisance tripping incidents experienced with single-stage and 2-stage equipment.

A CDC report published in 2020 states, "During 2004–2018, an average of 702 heat-related deaths occurred in the United States annually."[1] This CDC report noting 10,527 heat-related deaths in a 15-year period (702/year), or 6,220 deaths where heat was the primary factor (414/year). That CDC report states the following on p732, "Past studies have demonstrated a relationship between ambient temperatures and mortality (8). **In particular, extreme heat exposure can exacerbate certain chronic medical conditions, including hypertension and heart disease (4,5). In addition, medications that are typically used to treat these chronic medical conditions such as beta-blockers, diuretics, and calcium-channel blockers, can interfere with thermoregulation and result in a reduced ability to respond to heat stress (5)**." [Emphasis added]. (NOTE: The numbers in parenthesis are reference numbers in the CDC document). Health related concerns are obviously significant with hundreds of deaths recorded each year reported by the CDC associated due to heat exposure (lack of cooling). It is not infeasible to assume these statistics could worsen if GFCI circuit breakers cause nuisance tripping, causing loss of air conditioning, during the heat of summer.

Daikin/Goodman recommendation is to delete section 201.8(F) in its entirety when your state adopts the 2020 NEC (as has been done or proposed by MA, IA, NC, SD, and UT). If deleting in entirety is not acceptable to the committee, then the recommendation is to modify the requirement as proposed above (text taken from OR amendment).

[1] *Heat-Related Deaths – United States, 2004-2018,* Centers For Disease Control and Prevention, Morbidity and Mortality Weekly Report, Vol. 69, No. 24, June 19, 2020. Page 732
https://www.cdc.gov/mmwr/volumes/69/wr/pdfs/mm6924a1-H.pdf

Reference documents:

IA: Section 210.8(F) was deleted in an amendment after adoption
https://dps.iowa.gov/divisions/electrical-examining-board/electrical-code-updates

MA: GFCI protection was removed for outdoor, non-receptacle outlets during the adoption process.
https://www.mass.gov/doc/527-cmr-12-massachusetts-electrical-code-amendments/download

NC (Proposed): Section 210.8(F) is proposed to be deleted when the 2020 edition is adopted later this year.
https://www.ncosfm.gov/media/2068/open

ND: An exception is provided for mini-split & A/C units with DC invertors. The installer is required to fill out a form including information describing what the contractor has done to the resolve the issue.
https://www.ndseb.com/

OR: Section 210.8(F) was modified to only apply to outdoor receptacles for other than dwelling units.
https://www.oregon.gov/bcd/codes-stand/Documents/21oesc-table1-E-2021April.pdf

SD: Section 210.8(F) was not adopted with the 2020 NEC.
https://dlr.sd.gov/electrical/documents/adopted_code_2020.pdf

TX: An emergency rule delayed the requirements of Section 210.8(F) effective May 20, 2021.
https://www.tdlr.texas.gov/electricians/elec.htm
https://www.tdlr.texas.gov/Agendas/Commagendas/agenda051821.htm

UT (Proposed): Section 210.8(F) is proposed to be deleted when the 2020 edition goes into effect.
https://www.utah.gov/pmn/files/668869.pdf

WA: The state is delaying enforcement of Section 210.8(F) until January 1, 2023.
https://lni.wa.gov/licensing-permits/_docs/Elc2011.pdf

ONE ENERGY
AN INDUSTRIAL POWER COMPANY
12385 TOWNSHIP ROAD 215, FINDLAY, OH 45840
877.298.5853 | www.oneenergy.com

May 17, 2021

TO: Ohio Board of Building Standards

FROM: One Energy Enterprises LLC and its affiliates (One Energy)
Jereme Kent, CEO

RE: Request for Clarification of ManagedHV™ Role Under Building Code

Introduction

The purpose of this letter is to explain the scope of a ManagedHV project and to confirm that ManagedHV, as described, falls outside the scope of the Ohio Building Code and the Ohio Electric Code. This letter follows informal dialogue with Board of Building Standards Staff.

Description of Projects

One Energy intends to build privately owned, high voltage, on-site electric distribution systems for large industrial facilities. Specifically, our distribution systems generally operate at 4,160V, 12,470V, or 34,500V. The systems exist entirely outside of the build / industrial facility structural footprint. The systems may include a substation to enable the customer to take sub transmission or transmission service from the local regulated utility at voltages of 34,500V up to 345,000V.

An example of a ManagedHV system would include the following:

- A 138,000V to 34,500V 30MVA substation (with the utility providing 138,000V service)
- A 34,5000V underground electric distribution loop around the edge of the property that is controlled with two switchgears with 15 junction boxes installed for expansion, each junction box also has a manual disconnect
- On 6 of those junction boxes, there are individual taps that each include a padmount switchgear with a protective relay and a padmount 3,000KVA transformer located outside the building.

In this case, the building contractor would effectively takeover at the low side of the transformer. They would run 480V cable into the building to a switchgear which would be the primary protective device for the building.

While the characteristics of each ManagedHV project is highly customized and varies, they all share the following characteristics:

1. They are not owned by an investor owned utility (AEP, First Energy, etc).
2. They operate at voltages above 4,000 volts.
3. They operate entirely outside the building footprint.
4. They operate upstream (grid side) of the primary overcurrent protective device for the building.
5. They operate downstream of the point of common coupling with the serving utility.

An example of a plan view and a one-line drawing for a ManagedHV project is attached.

Discussion of Regulation

The National Electric Code (NFPA 70) 2020, as published contains the following:

Section 90.2(B) states: *Not Covered. This Code does not cover the following:*

Section 90.2(B) (5) Installations under the exclusive control of an electric utility where such installations

a) Consist of service drops or service laterals, and associated metering, or
b) Are on property owned or leased by the electric utility for the purpose of communications, metering, generation, control, transformation, transmission, energy storage, or distribution of electric energy, or
c) Are located in legally established easements or rights-of-way, or
d) Are located by other written agreements either designated by or recognized by public service commissions, utility commissions, or other regulatory agencies having jurisdiction for such installations. These written agreements shall be limited to installations for the purpose of communications, metering, generation, control, transformation, transmission, energy storage, or distribution of electric energy where legally established easements or rights-of-way cannot be obtained. These installations shall be limited to federal lands, Native American reservations through the U.S. Department of the Interior Bureau of Indian Affairs, military bases, lands controlled by port authorities and state agencies and departments, and lands owned by railroads.

Informational Note to (4) and (5): Examples of utilities may include those entities that are typically designated or recognized by governmental law or regulation by public service/utility commissions and that install, operate, and maintain electric supply (such as generation, transmission, or distribution systems) or communications systems (such as telephone, CATV, Internet, satellite, or data services). Utilities may be subject to compliance with codes and standards covering their regulated activities as adopted under governmental law or regulation. Additional information can be found through consultation with the appropriate governmental bodies, such as state regulatory commissions, the Federal Energy Regulatory Commission, and the Federal Communications Commission.

16 U.S. Code § 796 (22) (A) Defines an electric utility as follows: The term "electric utility" means a person or Federal or State agency (including an entity described in section 824(f) of this title) that sells electric energy.[1]

OAC 4104:1-27-01 Electrical: Section 2701 States:

2701.1 Scope. This chapter governs the electrical components, equipment and systems <u>used in buildings and structures covered by this code</u>. Electrical components, equipment and systems shall be designed and constructed in accordance with the provisions of NFPA 70. [Emphasis added]

OAC 4101:1-1-01 Administration Section 101.2 Scope States:

101.2 Scope. The provisions of the "Ohio Building Code", the "Ohio Mechanical Code", and the "Ohio Plumbing Code" shall apply to the construction, alteration, movement, enlargement, replacement, repair,

[1] The US Code reference is used to broadly illustrate that the phrase "electric utility" as used (but not defined) in the National Electric Code is, at the federal level, a broad construct designed to capture all systems that are moving and selling energy as opposed to just Investor Owned Utilities.

equipment, use and occupancy, location, maintenance, removal and demolition of every building or structure or any appurtenances connected or attached to such buildings or structures. [Emphasis added]

Paragraph 225.61 of the National Electric Code refers to the National Electric Safety Code for voltages above 22,000V.

Discussion

It is One Energy's opinion that NFPA 70, both as published, and as modified and adopted in Ohio never intended to cover the installation of high-voltage electric distribution systems that operate entirely outside of a building. In classic terms, this work would all have been "utility work". In recent years, there has been a privatization of systems like ManagedHV where companies like One Energy are assuming scope that would have traditionally been done by an electric utility.

The scope of a ManagedHV system includes unique risks and technical concepts that are not (and were never intended to be) addressed by NFPA 70 or the building code. There are unique risks associated with operating a substation or high voltage distribution system that must be addressed by the owner of the system. As a practical matter, those risks are addressed in the National Electric Safety Code[2]. It is unlikely that a building or electrical inspector is experienced in the inspection of 35kV class, high-voltage, dead front, terminations, for example.

In addition, the building code and electric code in Ohio were not intended to create a conflict in authority with utilities as regulated by the PUCO. Functionally, for any high voltage interconnection, a customer is required to demonstrate compliance with the PUCO Controlled Utilities interconnection standards. Documents like First Energy's "Requirements For Transmission Connected Facilities"[3], which are published under a requirement from PUCO, serve as the primary design guide to ensure that the customer owned facility safely operates with the transmission system.

Request

One Energy requests that the Board of Building Standards either confirm that One Energy's position is correct and/or clarify at what point the Building Code and the National Electric Code take over.

Specifically, it is One Energy's opinion that an electrical system that meets all the following requirements is not subject to the Ohio Building Code or the National Electric Code:

1. The system operates at greater than 4,000 volts, phase to phase.
2. The system exists entirely outside of a building or accessory structure.
3. The system's primary purpose is to distribute or collect electric energy.
4. The system interconnects to the utility point of common coupling in accordance with a standard published by the utility or agency with oversight authority over the utility.

---

[2] **NESC 2017 Abstract:** This Code covers basic provisions for safeguarding of persons from hazards arising from the installation, operation, or maintenance of (1) conductors and equipment in electric supply stations, and (2) overhead and underground electric supply and communication lines. It also includes work rules for the construction, maintenance, and operation of electric supply and communication lines and equipment. The Code is applicable to the systems and equipment operated by utilities, or similar systems and equipment, of an industrial establishment or complex under the control of qualified persons. This Code consists of the introduction, definitions, grounding rules, list of referenced and bibliographic documents, and Parts 1, 2, 3, and 4 of the 2017 Edition of the National Electrical Safety Code.

[3] https://www.firstenergycorp.com/content/dam/feconnect/files/wholesale/Requirements-for-Transmission-Connected-Facilities-10-03-2016.pdf and https://www.aep.com/assets/docs/requiredpostings/TransmissionStudies/Requirements/AEP_Interconnection_Requirements_Rev2.pdf

5. The system operates upstream of the primary overcurrent protection device(s) for the building or accessory structure.

Based on One Energy's position, in the case of the example ManagedHV system described above, the National Electric Code's authority would begin at the low side of the pad mount transformer mounted outside of the building.

Enclosures:

Sample ManagedHV one line drawing.

Sample ManagedHV plan view drawing.

Closing:

Thank you for your time and assistance clarifying the applicable regulation and oversight of our ManagedHV projects. Please do not hesitate to contact me if there is any additional information that I can provide to help the Board of Building Standards reach a conclusion on this issue.

Very Respectfully,

Jereme Kent
Chief Executive Office
c. 419.905.5274
jeremekent@oneenergyllc.com

About One Energy:

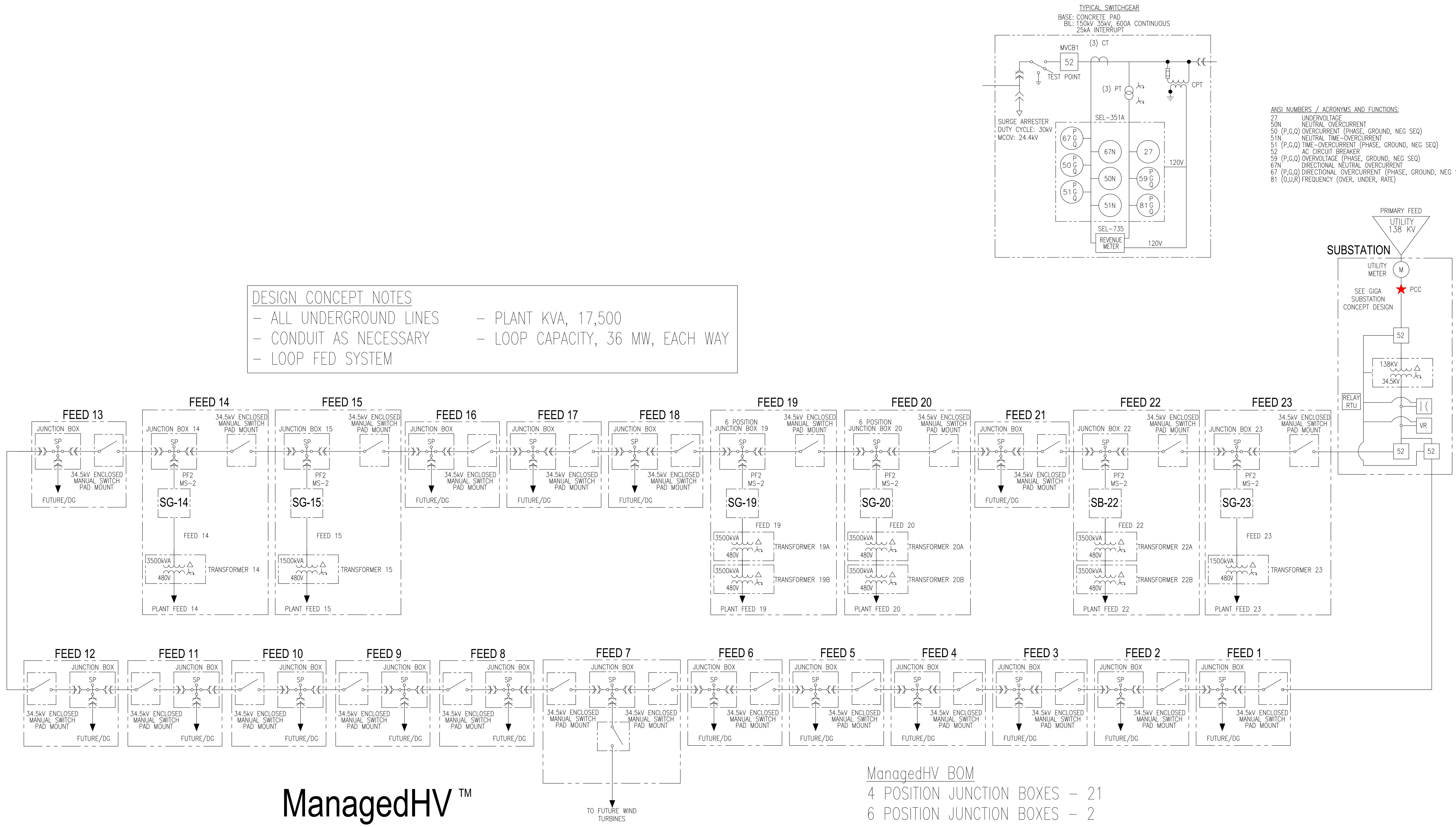
One Energy is an industrial power company and the largest installer of on-site wind energy in North America. Recognizing that energy consumers are fed up with the failings of legacy utilities, One Energy developed modern energy services to control cost and risk, such as *Wind for Industry*® and ManagedHV™. One Energy is building the customer-centric grid of the future.

The One Energy family of companies includes One Energy Enterprises (OEE), One Energy Solutions (OES), and One Energy Capital Corporation (OECC). For more information, visit www.oneenergy.com.

One Energy Enterprises LLC
Sample ManagedHV Drawing Set

One Line
Substation Schematic & One Line
Substation Layout
Project Layout

34.5kV

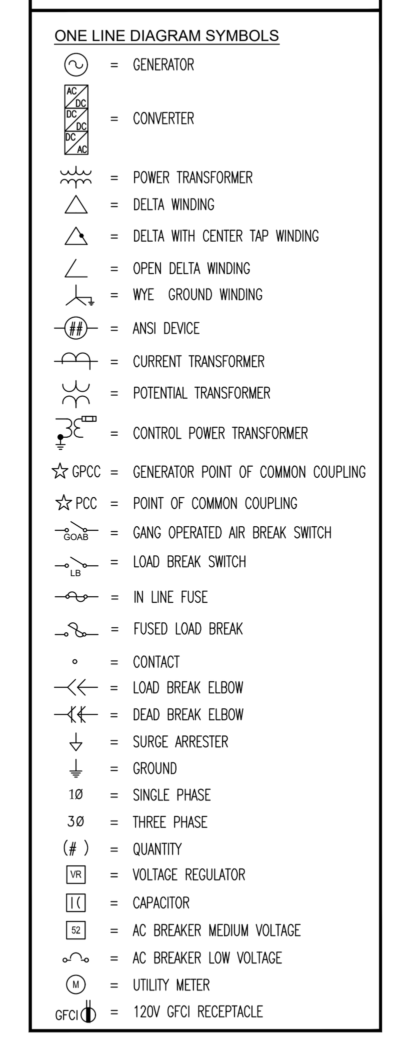


DESIGN CONCEPT NOTES
- ALL UNDERGROUND LINES
- CONDUIT AS NECESSARY
- LOOP FED SYSTEM
- PLANT KVA, 17,500
- LOOP CAPACITY, 36 MW, EACH WAY

ANSI NUMBERS / ACRONYMS AND FUNCTIONS:

27	UNDERVOLTAGE
50N	NEUTRAL OVERCURRENT
50 (P,G,Q)	OVERCURRENT (PHASE, GROUND, NEG SEQ)
51N	NEUTRAL TIME-OVERCURRENT
51 (P,G,Q)	TIME-OVERCURRENT (PHASE, GROUND, NEG SEQ)
52	AC CIRCUIT BREAKER
59 (P,G,Q)	OVERVOLTAGE (PHASE, GROUND, NEG SEQ)
67N	DIRECTIONAL NEUTRAL OVERCURRENT
67 (P,G,Q)	DIRECTIONAL OVERCURRENT (PHASE, GROUND, NEG SEQ)
81 (O,U,R)	FREQUENCY (OVER, UNDER, RATE)

LEGEND OF SYMBOLS



ManagedHV ™

ManagedHV BOM
4 POSITION JUNCTION BOXES – 21
6 POSITION JUNCTION BOXES – 2
MANUAL SWITCHES – 25
SWITCH GEARS – 5
3500 KVA TRANSFORMERS – 7
1500 KVA TRANSFORMERS – 2
COLLECTION LINE LENGTH – 8950 LF.

BEFORE YOU DIG CALL
811
CONTRACTOR SHALL BE RESPONSIBLE FOR LOCATING EXISTING UTILITIES PRIOR TO CONSTRUCTION.

ONE ENERGY SOLUTIONS LLC
12385 TOWNSHIP ROAD 215
FINDLAY, OHIO 45840
877-298-5853

PROJECT: [redacted]

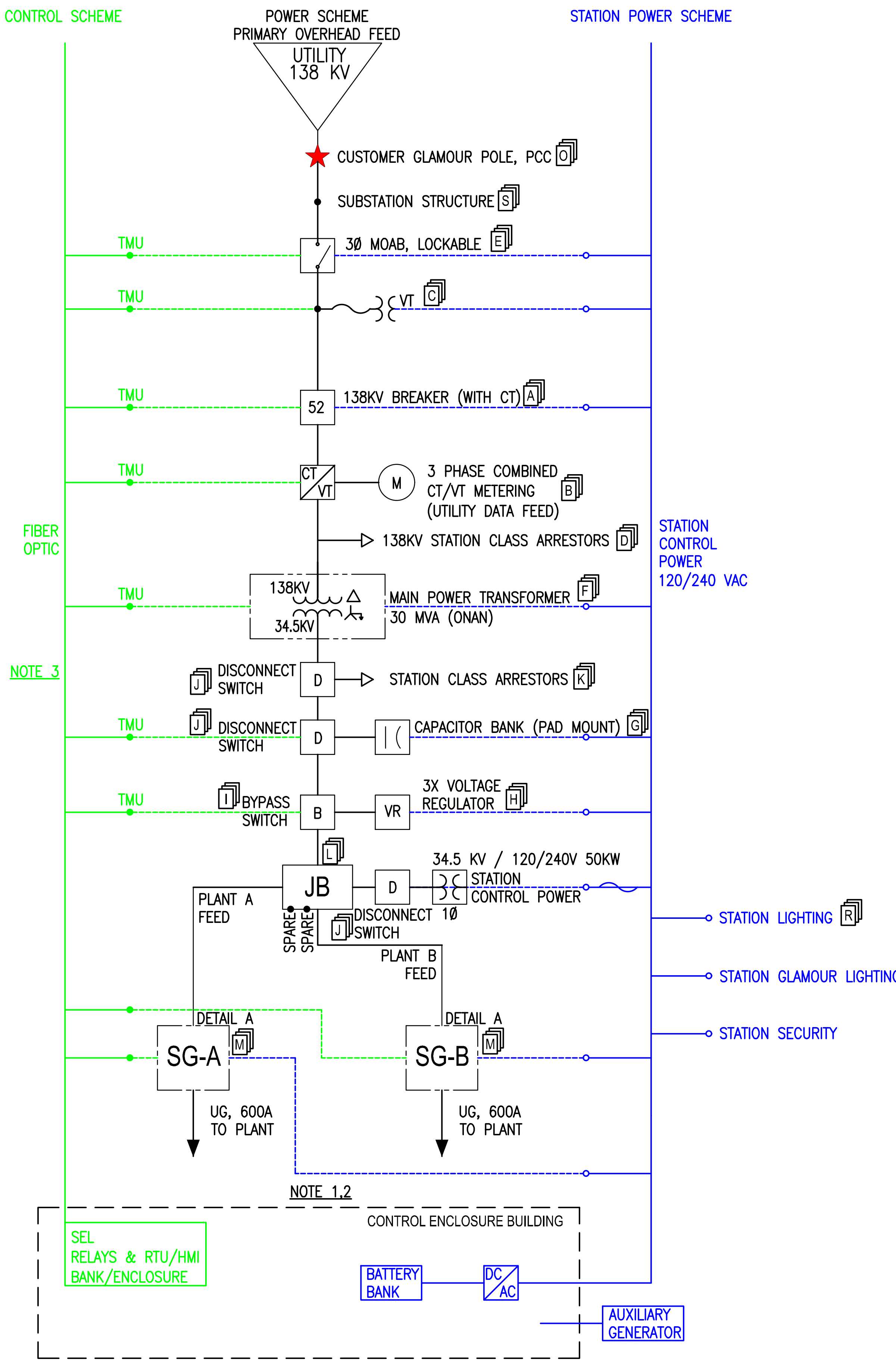
ISSUE:
REV: A 20210512
REV: B
REV: C
REV: D

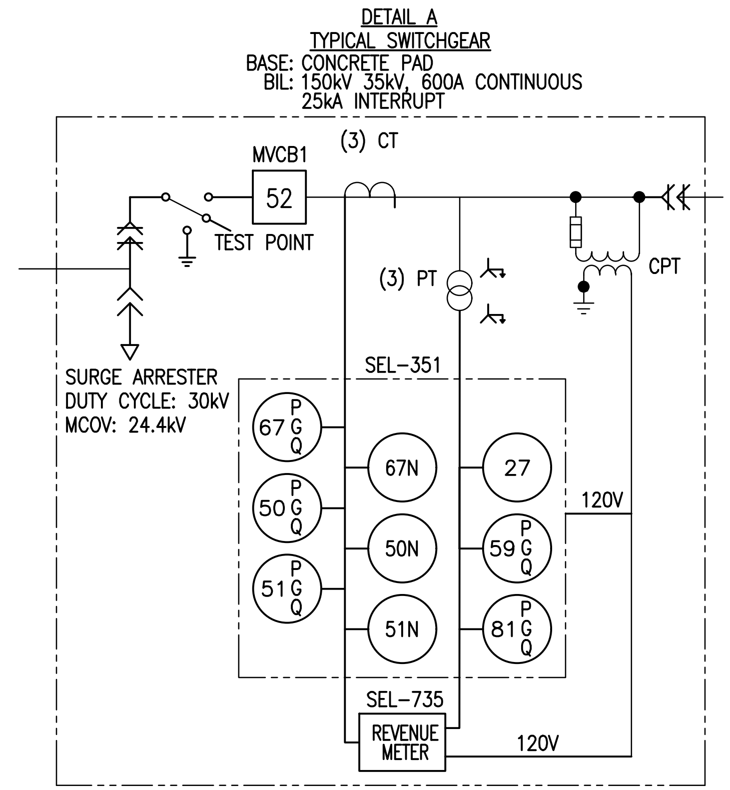
THIS DRAWING IS NOT TO SCALE
"D" SIZE PRINT 24" X 36"

DESIGN CONCEPT
NOT FOR
CONSTRUCTION

SITE DISTRIBUTION
ONE LINE
DIAGRAM

SHEET: 1 OF 1
REV: A





KEY

SPECIFICATIONS A

NOTE 1

ALL LOADS CONNECTED YnYn
ALL GENERATION CONNECTED DYn

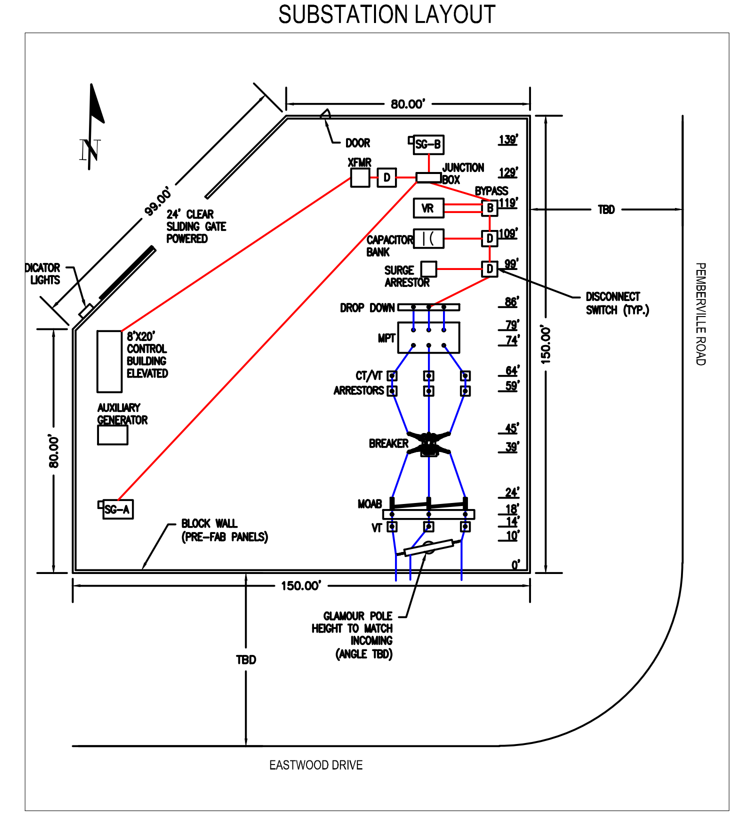
NOTE 2

ALL BEHIND THE METER GENERATION SIZED TO COMPLY WITH NET METERING STANDARD

NOTE 3

CONTROL SCHEME DESIGNED WITH FIBER OPTIC STATION COMMUNICATION. COORDINATED TO TRIP SG-A OR SG-B FOR PLANT SIDE FAULT.
POWER QUALITY ISSUES (EX, LOW FREQUENCY) TO TRIP AT SG-A – SG-B FIRST. MIN CONTROL ELEMENTS: 67,50,51,27,59,81

SUBSTATION LAYOUT



BEFORE YOU DIG CALL

811

CONTRACTOR SHALL BE RESPONSIBLE FOR LOCATING EXISTING UTILITIES PRIOR TO CONSTRUCTION.

ONE ENERGY SOLUTIONS LLC
12385 TOWNSHIP ROAD 215
FINDLAY, OHIO 45840
877-298-5853

PROJECT:

[redacted]

ISSUE:
REV: A 20210513
REV: B
REV: C
REV: D

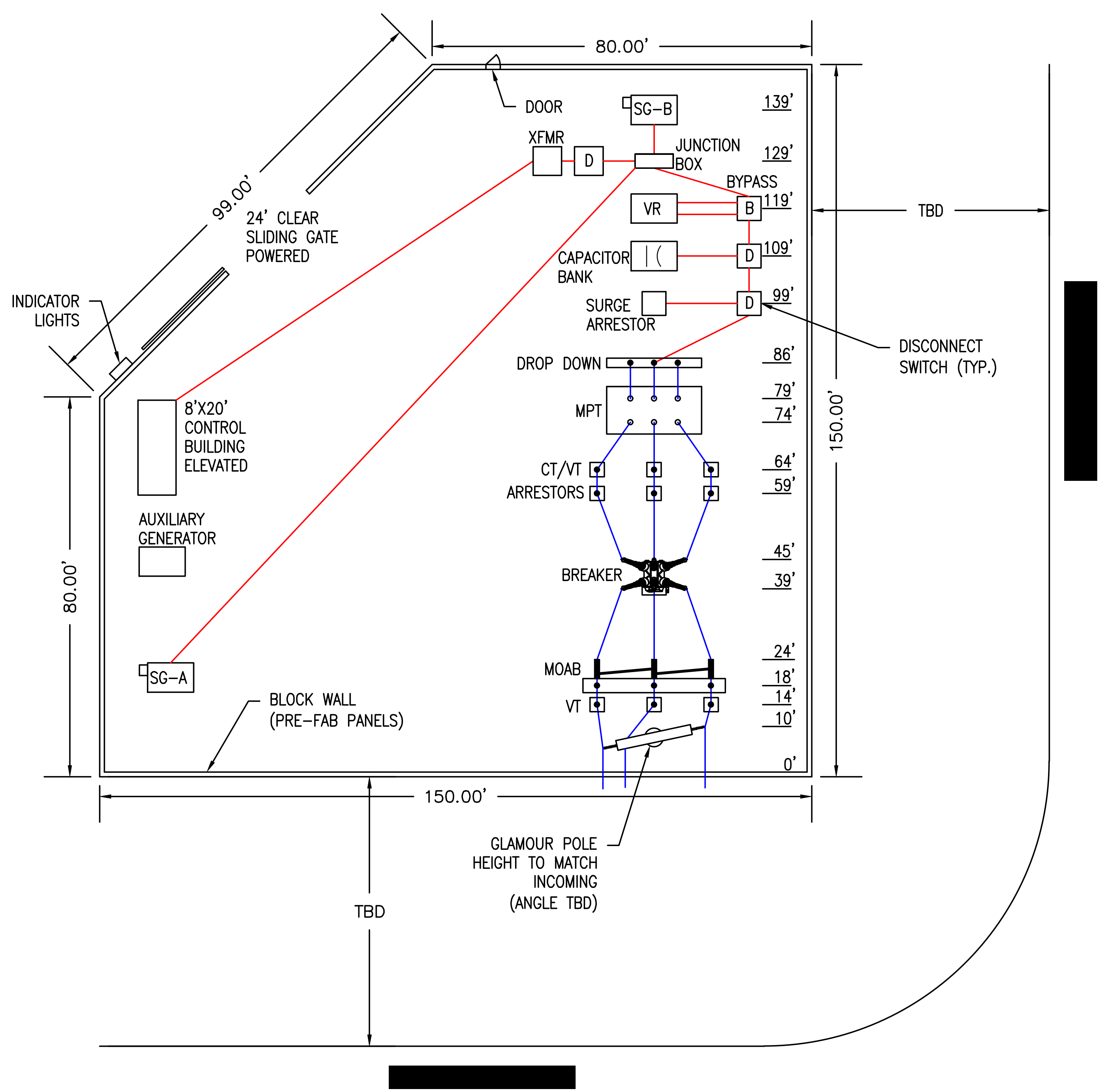
THIS DRAWING IS NOT TO SCALE
"B" SIZE PRINT 11" X 17"

DEISGN CONCEPT
NOT FOR
CONSTRUCTION

SUBSTATION CONCEPT

SHEET: 1 OF 1
REV: A

KEY
ABOVE GROUND
BELOW GROUND



0 30 60 Feet

BEFORE YOU DIG CALL
811
CONTRACTOR SHALL BE RESPONSIBLE FOR LOCATING EXISTING UTILITIES PRIOR TO CONSTRUCTION.

ONE ENERGY SOLUTIONS LLC
12385 TOWNSHIP ROAD 215
FINDLAY, OHIO 45840
877-298-5853

PROJECT:
[redacted]

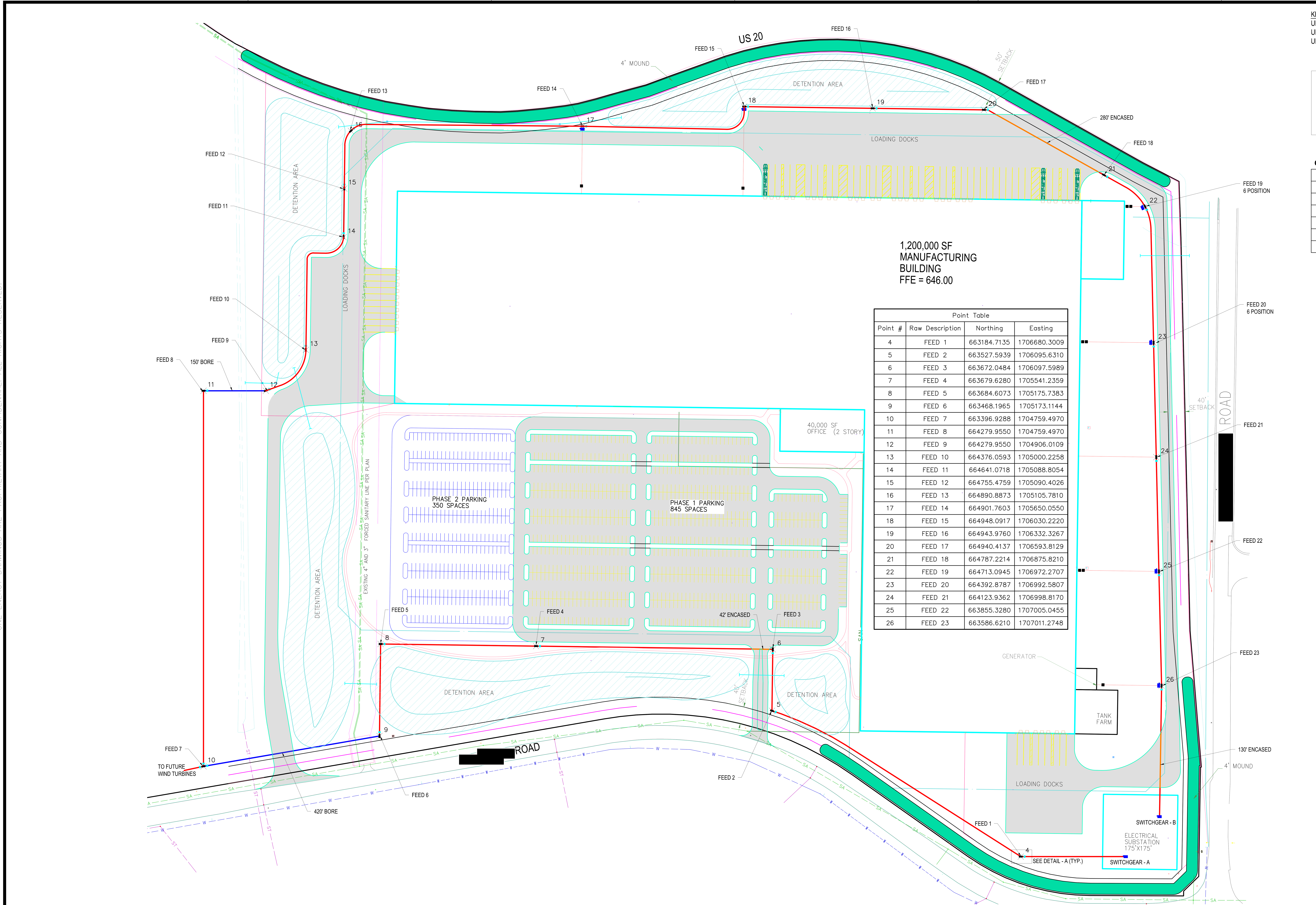
ISSUE:
REV: A 20210513
REV: B
REV: C
REV: D

THIS DRAWING IS NOT TO SCALE
"B" SIZE PRINT 11" X 17"

DEISGN CONCEPT
NOT FOR
CONSTRUCTION

SUBSTATION LAYOUT CONCEPT

SHEET: 1 OF 1
REV: A



Point Table			
Point #	Raw Description	Northing	Easting
4	FEED 1	663184.7135	1706680.3009
5	FEED 2	663527.5939	1706095.6310
6	FEED 3	663672.0484	1706097.5989
7	FEED 4	663679.6280	1705541.2359
8	FEED 5	663684.6073	1705175.7383
9	FEED 6	663468.1965	1705173.1144
10	FEED 7	663396.9288	1704759.4970
11	FEED 8	664279.9550	1704759.4970
12	FEED 9	664279.9550	1704906.0109
13	FEED 10	664376.0593	1705000.2258
14	FEED 11	664641.0718	1705088.8054
15	FEED 12	664755.4759	1705090.4026
16	FEED 13	664890.8873	1705105.7810
17	FEED 14	664901.7603	1705650.0550
18	FEED 15	664948.0917	1706030.2220
19	FEED 16	664943.9760	1706332.3267
20	FEED 17	664940.4137	1706593.8129
21	FEED 18	664787.2214	1706875.8210
22	FEED 19	664713.0945	1706972.2707
23	FEED 20	664392.8787	1706992.5807
24	FEED 21	664123.9362	1706998.8170
25	FEED 22	663855.3280	1707005.0455
26	FEED 23	663586.6210	1707011.2748

QUANTITY	EQUIPMENT
21 EA.	4 POSITION JUNCTION BOXES
2 EA.	6 POSITION JUNCTION BOXES
25 EA.	MANUAL SWITCHES
7 EA.	3500KVA TRANSFORMERS
2 EA.	1500KVA TRANSFORMERS
5 EA.	SWITCHGEARS
8950 LF.	MANAGED HV LOOP

BEFORE YOU DIG CALL
811
CONTRACTOR SHALL BE RESPONSIBLE FOR LOCATING EXISTING UTILITIES PRIOR TO CONSTRUCTION.

PROJECT:
[redacted]

ISSUE:
REV: A 20210514
REV: B
REV: C
REV: D

THIS DRAWING IS NOT TO SCALE
"D" SIZE PRINT 24" X 36"

DESIGN CONCEPT
NOT FOR
CONSTRUCTION

SITE DISTRIBUTION SITE LAYOUT

SHEET: 1 OF 1
REV: A

File Attachments for Item:

OB-4 Energy Codes Background Discussion

Significant changes 2010-2013 ASHRAE 90.1 Commercial Provisions

(Sources: ASHRAE 90.1-2013 and PNNL-SA-107200)

Building Envelope

- Modifies daylighting and several other definitions
- Limits the size of vestibules and adds specific vestibule requirements for large spaces [5.4.3.4]
- Increased stringency requirements for roofs, walls, below grade walls, slab-on-grade floors [Tables 5.5-4 and 5.5-5]
- Lowers fenestration U-factors about 18% [Tables 5.5-4 and 5.5-5]
- Limits skylight area to 3%, except to 6% if daylighting criteria are met [5.5.4.2.2]

Mechanical

- Increased equipment efficiencies for air conditioners, condensing units, heat pumps, water-chillers, boilers, cooling towers, refrigerators, and freezers [6.4.1 & Tables 6.8.1]
- Reduces occupancy threshold for demand-controlled ventilation from 40 people/1000 sq ft to 25 people/1000 sq ft [6.4.3.8]
- Adds vestibule heating controls [6.4.3.9]
- Adds direct digital control (DDC) and graphical display requirements [6.4.3.10 & Table 6.4.3.10.1]
- Adds control requirements for preheat coils [6.5.2.5]
- Adds requirements for fan efficiency and controls [6.5.3]
- Adds requirements for boiler turndown ratio and efficiency [6.5.4.1]
- Reduces system size and outdoor air thresholds for energy recovery [6.5.6]
- Adds requirements for walk-in coolers, freezers and refrigerated display cases [6.4.5 & 6.5.11]
- Adds requirements for Computer room HVAC systems and introduces the Power usage Effectiveness (PUE) [6.6]

Service Water Heating

- Increases efficiency of water-heating equipment 7.5.3 & Table 7.8]

Power

- Increases the spaces where and reduces the threshold for when plug receptacle shutoff control is required [8.4.2]
- Requires electrical energy monitoring and reporting for total electrical, HVAC systems, lighting, and receptacles [8.4.3]
- Requires separate electrical energy monitoring for buildings with tenants [8.4.3.1]
- Adds specific control requirements for guestroom switched receptacles [9.4.1.3]

Lighting

- Requires the use of certain lighting controls in more space types [9.4.1]
- Increases and clarifies requirements for daylighting and daylighting controls [9.4.1.1]
- Updates and reduces the interior and exterior lighting power densities [Table 9.5.1]
- Adds specific requirements for guest room and task lighting controls [9.4.1.3]
- Adds functional testing requirements for occupant sensors, automatic time switches, and daylight controls [9.4.3]

Other Equipment

- Adds requirements for the efficiency of general-purpose motors having power rating greater than 200 hp, but no more than 500 hp [10.4.1]
- Adds power limitations for elevator cab lighting [10.4.3.1]

- Requires escalators and moving walks to slow to minimum permitted speed when not conveying passengers [10.4.4]
- Requires whole-building energy monitoring and reporting [10.4.5.1]

Energy Cost Budget Method (ECB)

- Allows credit for on-site renewable energy but limits the credit to 5% of the calculated energy cost budget [11.4.3.1]

Appendix C (Envelope tradeoff)

- Completely revamps the methodology for the building envelope trade-off option allowed in Section 5.6

Performance Rating Method (Appendix G)- an above code program

- Numerous clarifications are added for modeling

Significant changes 2013-2016 ASHRAE 90.1 Commercial Provisions

[Sources: ASHRAE 90.1-2016 and PNNL-SA-127543]

- Standard reformatted for ease of use
- New Climate maps (to align with ASHRAE 169) [5.1.4.1]
    - 16 Ohio counties will change from Zone 5A to Zone 4A [Annex 1]
- Adds a new path to demonstrate compliance – Performance Rating Method [4.2.1.1 (c) and Appendix G]

Building Envelope

- Air Leakage Verification requirements added [5.4.3.1.3 and 5.9.2.2]
    - Whole building pressurization test for air leakage
    - Continuous air barrier installation inspection and verification during construction
- Increased testing requirements for air leakage of overhead coiling doors [A7.1]
- Increased stringency requirements for fenestration and opaque doors [Table 5.5-4, Table 5.5-5, and 5.5.3.6]
- Clarified topics such as building orientation [5.5.4.5], default assumptions for the effective R-value of air spaces [A9.4.2], and calculation procedures for insulating metal building walls [A3.2.2, Table A3.2.3, A9.4.6]

Mechanical

- Increased equipment efficiencies for chillers, heat pumps, computer room AC, Dedicated Outdoor Air Systems (DOAS), Rooftop AC, Cooling Towers, and Variable Refrigerant Flow
- Clarified that control must be "configured to" meet the requirements, not just be "capable of" meeting the requirements [throughout]
- New HVAC set point and fan control requirements for hotel and motels with greater than 50 guest rooms [6.4.3.3.5]
- Adds HVAC control requirements for cooled vestibules [6.4.3.9]
- Large, electric-driven chilled-water plants are required to be monitored for electric energy use and efficiency [6.4.3.11]
- Air-cooled DX cooling units with economizers are required to have a Fault Detection and Diagnostics (FDD) monitoring system to determine that the air economizer is working properly [6.4.3.12]
- Adds control requirements for return and relief fans [6.5.3.2.4]
- Adds control requirements for parallel-flow fan-powered VAV air terminals [6.5.3.4]
- Dedicated outdoor air systems (DOAS) now include both efficiency and rating requirements for compliance [6.5.3.7]
- Adds pump flow control requirements for chilled and hot water hydronic piping distribution systems [6.5.4.2]
- Adds new requirements for the selection of chilled-water cooling coils [6.5.4.7]
- Prescribes motor fan speed controls for heat-rejection devices [6.5.5.2]
- Adds new requirements for transfer air delivered to a space having mechanical exhaust [6.5.7]

Service Water Heating

- Adds a new requirement for insulation of the first 8 ft of branch piping connections to recirculated, heat traced, or impedance heated service hot-water piping systems [7.4.3]

Power

- Limits the combined voltage drop of feeder conductors and branch circuits to 5% [8.4.1]
- Increased three-phase transformer efficiencies [Table 8.4.4]

Lighting

- Interior and exterior lighting power allowance have been modified (reduced) to reflect new lighting levels in the IES lighting handbook and to recognize LED technology [9.2.2.3 and 9.4.2]
- Lighting control requirements have been modified to add additional controls in some space types and options to others to allow easier application of advanced controls [9.4.1]
  - Reduce exterior lighting power by 50% (previously was 30%) during periods of inactivity or after business hours [9.4.1.4]
  - Certain outdoor parking areas required to reduce power by 50% during periods of inactivity [9.4.1.4]
- Adds a requirement that 75% of permanently installed dwelling unit lighting fixtures use high efficacy lamps [9.4.4]

Other Equipment

- Updates electric motor terminology, adds exceptions, and adds efficiency tables consistent with federal regulations [10.4.1]
- Elevator efficiency specifications are required to be provided on design documents, including both usage category and energy efficiency class. While a minimum threshold is not listed, the first step is taken toward including minimum elevator efficiency requirements in a future standard [10.4.3.4]

Energy Cost Budget Method (ECB)

No significant changes

Performance Rating Method (Appendix G)

- Appendix G now can be used as a path for compliance with the standard. Previously, Appendix G was used only to rate beyond-code performance of buildings
- The proposed design requires computation of a new metric, Performance Cost Index (PCI), and demonstration that it is less than that shown in Table 4.2.1.1, based on building type and climate zone
- The baseline design is now fixed at a certain level of performance, the stringency or baseline of which is expected not to change with subsequent versions of the standard. In this way, a building of any era can be rated using the same method
- Other modifications to Appendix G include changes to elevator, motor, and refrigeration baselines; changes to the baseline for existing building projects; and changes to specific opaque assemblies for the baseline envelope model. Modeling rule changes were made to heat pump auxiliary heat, economizer shutoff, lighting controls, humidification systems, cooling towers, and the simulation of preheat coils

ASHRAE 90.1-2019

The 2019 edition includes various modifications and clarifications to improve internal consistency and to standardize the structure and language of the document.

Significant changes to requirements include the following

Administration and Enforcement

- New commissioning requirements in accordance with ASHRAE/IES Standard 202 [4.2.5 and Appendix H]

Building Envelope

- Combined categories of “nonmetal framed” and “metal framed” products for vertical fenestration [Tables 5.5-0 through 5.5-8]
- Upgraded minimum criteria for SHGC and U-factor across all climate zones [Tables 5.5-0 through 5.5-8]
- Revised air leakage section to clarify compliance [5.4.3 and 5.9]
- Refined exceptions related to vestibules, added new option and associated criteria for using air curtains [5.4.3.3]

Mechanical

- New requirements to allow the option of using ASHRAE Standard 90.4 instead of ASHRAE Standard 90.1 in computer rooms that have an IT equipment load larger than 10 kW [6.6.1]
- Added pump definitions [3.2], requirements [10.4.7], and efficiency tables [10.8.6] to the standard for the first time
- New equipment efficiency requirement tables and changes to existing tables [Tables 6.8.1-1 to 6.8.1-20]
- Replaced fan efficiency grade (FEG) efficiency metric with fan energy index (FEI) [6.5.3.1.3]
- New requirements for reporting fan power for ceiling fans and updated requirements for fan motor selections to increase design options for load-matching variable-speed fan applications [6.5.3.1.2]
- New energy recovery requirements for high-rise residential building [3.2 and 6.5.6]
- New requirement for condenser heat recovery for acute care inpatient hospitals [6.5.6.3]

Lighting

- Modified lighting power allowances for Space-by-Space Method and the Building Area Method [Tables 9.6.1 and 9.5.1]
- New simplified method for lighting for contractors and designers of renovated office buildings and retail buildings up to 25,000 ft2 (2300 m2). [9.3 and Table 9.3.1-1]
- Updated lighting control requirements for parking garages to account for the use of LEDs [9.4.1.2]
- Updated daylight responsive requirements, added definition for “continuous dimming” based on NEMA LSD-64-2014 [3.2 and 9.4.1.1]
- Clarified side-lighting requirements and associated exceptions [9.4.1.1]

Energy Cost Budget (ECB) Method (Section 11)

- Numerous changes to ensure continuity
- Set baseline for on-site electricity generation systems [11.4.3.1 and 11.4.3.2]

Performance Rating Method (Appendix G)

- Clarified Appendix G rules and corresponding baseline efficiency requirement when combining multiple thermal zones into a single thermal block
- New explicit heating and cooling COPs without fan for baseline packaged cooling equipment
- New rules for modeling impact of automatic receptacle controls [Table G3.1 #12]
- Set more specific baseline rules for infiltration modeling
- Clarified how plant and coil sizing should be performed
- Updated building performance factors

Both Compliance Paths

- Clearer, more specific rules for treatment of renewables [G2.4.1]
- New updates to rules for lighting modeling

Significant changes 2012→2015 IECC Commercial Provisions

(Sources: PNNL-SA-107200 and ESL-TR-14-11-02 Texas A&M Energy Systems Laboratory)

Definitions

- Adds or modifies definitions of "Air Curtain", "Alteration", "Approved Agency", "Boiler, Modulating", "Boiler System", "Bubble Point", "Circulating Hot Water System", "Computer Room", "Condensing Unit", "Conditioned Space", "Continuous Insulation", "Daylight Responsive Control", "Daylight Zone", "Fan Efficiency Grade", "Fenestration", "Floor Area, Net", "General Purpose Electric Motor", "Greenhouse", "Hight Speed Door", "Historic Building", "Liner System" , "Low Sloped Roof", "Low-voltage Dry-Type Distribution Transformer", "Occupant Sensor Control", "Opaque Door", "Powered Roof/Wall Ventilator", "Radiant Heating System", "Refrigerant Dew Point", "Refrigerated Warehouse Cooler", "Refrigerated Warehouse Freezer", "Refrigeration System", "Repair", "Reroofing", "Roof Recover", "Roof Replacement", "Rooftop Monitor", "Saturated Condensing Temperature", "Small Electric Motor", "Time-Switch Control", "Variable Refrigerant Flow System", "Walk-in Cooler", "Walk-in Freezer", "Wall, Above-grade", "Wall, Below-Grade", "Water Heater"

Building Envelope

- Adds an exception for greenhouses [C402.1.1]
- Increased stringency for roof insulation installed entirely above roof deck [Table C402.1.3]
- Increased stringency for SHGC of vertical fenestration [C402.4.3]
- Expanded requirements to calculate U-factors of walls with cold-formed steel, aged roof reflectance and provisions for rooms containing fuel burning appliances [C402.5]
- Mandatory skylight threshold reduced from 10K to 2.5K square feet [C402.4.2]

Mechanical

- Improved efficiency requirements for HVAC equipment performance [Table C403.2.3(1)-C403.2.3(10)]
- Added efficiency requirements for air-conditioning units serving computer rooms [Table C403.2.3(9)]
- Elaborated and added provisions for HVAC system controls which include: requirement for zone isolation [C403.2.4.4]; and requirement of economizer fault detection [C403.2.4.7]
- Added specifications for hot water boiler outdoor temperature setback control [C403.2.5]
- Updated provisions for energy recovery ventilation systems whose requirements are now based on the number of hour's ventilations systems operate [C403.2.7]
- Introduced specifications for kitchen exhaust systems [C403.2.8]
- Updated requirements for duct and plenum insulation and sealing [C403.2.9]
- Introduced fan efficiency requirements [C403.2.12.3]
- Added specifications for commercial refrigeration equipment [C403.2.15 and C403.5]
- Updated provisions for air and water economizers, which include added requirements for the efficient operation of these systems [C403.3]
- Updated provisions for complex mechanical systems serving multiple zones, which include updated specifications for fan controls, heat rejection equipment and hot gas bypass limitations [C403.4]

Service Water Heating

- Added performance efficiencies for certain categories of service hot water systems [Table C404.2]
- Revises and clarifies the requirements for insulation of piping [C404.4]

- Added information for implementation of efficient heated water supply piping, heated water circulating and temperature maintenance system, demand recirculation controls, drain water heat recovery systems and energy requirements of portable spas [C404.5]
- Improved specifications for energy consumption of pools and permanent spas [C404.9]
- Added commissioning requirements for hot water systems [C404.11]

Lighting and Power

- Additional provisions for lighting controls, which include the added requirement of occupant sensor controls [C405.2.1]
- New exterior and warehouse lighting control requirements [C405.2.1.2]
- Revised daylighting zone controls [C405.2.3]
- New Hotel/motel sleeping and guest suite lighting controls [C405.2.4 #3]
- Updated lighting power densities for different building area types [Tables C405.4.2]
- Specifies non-tradable components of exterior lighting [C405.5.1]
- Requires a separate meter for each Group R-2 dwelling unit [C405.6]
- Adds federal minimum efficiency requirements for electric transformers [C405.7]
- Adds federal minimum efficiency requirements for electric motors [C405.8]
- Regulates elevator cab luminaires, ventilation fans, and controls [C405.9.1]
- Requires automatic speed control and a variable frequency regenerative drive for escalators [C405.9.2]

Other Equipment

Additional Efficiency Package Options

- Adds new options for more efficient HVAC equipment performance, for reduced lighting power densities, for enhanced digital lighting controls, for dedicated outdoor air systems, and for reduced energy use in service water systems [C406.1]

Total Building Performance

- No significant changes made to this section

Commissioning

- Adds commissioning requirements and documentation submittal requirements for lighting control systems including occupant sensor controls, time control switches, and daylight responsive controls [C408.3.1]

Existing Buildings

- Moved all existing building requirements from Chapter [CE] 1 to a new Chapter [CE] 5
- Historic buildings now partially covered [C501.6]
- Replacement fenestration covered [C401.2.1]
- Requires full upgrade of roofing insulation when re-roofing [C503.1]
- Roof replacement exempt from air barrier requirements [C503.1 Exception 6]

Significant changes 2015-2018 IECC Commercial Provisions

[Sources: IECC 2018 and PNNL-SA-127543]

- Made several editorial changes to eliminate the use of the word "Accessible" (if not associated with the IBC Chapter 11 meaning of "Accessible").
- Clarifies that commissioning is mandatory for all mechanical and hot water heating systems
- Adds additional as-built energy code documentation and owner training requirements for all buildings (typically part of the commissioning documents) …these documents must be submitted to the owner within 90 days of receipt of the Certificate of Occupancy
- Enhanced the section for required energy code inspections

Definitions

- Adds or modifies definitions of "Access (to)", "Air Barrier", "Captive Key Override", "Computer Room", "Demand Recirculation Water System", "Group R", "IEC Design H Motor", "IEC Design N Motor", "Isolation Devices", "Luminaire-level Lighting Controls", "NEMA Design A Motor", "NEMA Design B Motor", "NEMA Design C Motor", "Networked Guestroom Control System", "Ready Access (to)", and "Voltage Drop"

Building Envelope

- Increased stringency requirements for heated slabs [Tables C402.1.3 and C402.1.4]
- Adds maximum U-values for garage door glazing [Table C402.1.4]
- Requires 2 staggered layers of insulation board when continuous roof insulation is installed. Also provides a new exceptions for around roof drains [C402.2.1]
- Clarifies requirements for mass walls and mass floors [C402.2.2 and C402.2.3]
- Restores section on below-grade walls [C402.2.5]
- Adds a section on airspaces [C402.2.7]
- Decreases the SHGC for fenestration in Climates zones 4 and 5 [Table C402.4]
- Raises the allowable skylight area from 5% to 6% with daylight controls [C402.4.1.2]
- Clarified topics such as sliding doors [Table C402.5.2], rooms containing fuel-burning appliances [C402.5.3], loading dock weather seals [C402.5.6]

Mechanical

- Section 403 (Building Mechanical Systems) reorganized for ease of use
- Clarifies that HVAC equipment shall not be oversized [C403.3.1]
- Eliminates outdated federal equipment efficiencies for air conditioners, heat pumps, furnaces, boilers, chillers, cooling towers, and computer room AC [Tables C403.3.2(1) - C403.3.2(10)]
- Clarified that control must be "configured to" meet the requirements, not just be "capable of" meeting the requirements [throughout]
- Clarifies that many controls requirements are "Mandatory" [throughout]
- Adds HVAC control requirements for heated or cooled vestibules [C403.4.1.4]
- Adds pump flow control requirements for chilled and hot water hydronic piping distribution systems [C403.4.3.3.2 and C403.4.4]
- Adds exceptions to economizer requirements [C403.5]
- Adds a section requiring VAV with zone controls for multiple-zone systems [C403.6.1]
- Adds control requirements for parallel-flow fan-powered VAV air terminals [C403.6.7]
- Increases the threshold design airflow rate at which energy recovery is required [Table C403.7.4(2)]
- New HVAC set point and fan control requirements for hotel and motels (Group R-1) with greater than 50 guest rooms [C403.7.6]

- Provides an allowable hp exception for fans less than or equal to 5 hp [C403.8.1]
- Prescribes motor fan speed controls for heat-rejection devices [C403.9]
- Adds federal efficiency requirements for walk-in coolers and freezers to be in effect in 2020 [C403.10.2.1]

Service Water Heating

- Increased federal water heater efficiencies [Table C404.2]

Lighting

- Adds a section for "open plan office areas" and requires occupant sensor controls [C405.2.1.3]
- Adds exceptions for lighting controls for dwelling units [C405.2.4 #3] and patient rooms [C 405.2.4 #2]
- Interior and exterior lighting power allowance have been modified (reduced) to reflect new lighting levels in the IES lighting handbook and to recognize LED technology [Tables C405.3.2(1), C405.3.2(2), and C405.4.2(2)]
- Lighting control requirements have been modified to add additional controls in some space types and options to others to allow easier application of advanced controls [C405.2]
    - Reduce exterior lighting power by 30% during periods of inactivity or after business hours [C405.2.6.3]
- Adds a requirement that 90% of permanently installed dwelling unit lighting fixtures use high efficacy lamps [C405.1]

Power

- Limits the combined voltage drop of feeder conductors and branch circuits to 5% [C405.9]

Other Equipment

- Updates electric motor terminology, adds exceptions, and adds efficiency tables consistent with federal regulations [C405.7]
- Adds an exception to allow a variable voltage drive in lieu of automatic speed control for escalators that are not conveying passengers [C405.8.2]

Additional Efficiency Package Options

- Adds options for enhanced envelope performance as determined by UA analysis [C406.8]
- Adds options for reduced air infiltration as determined by whole building air leakage testing [C406.9]

Total Building Performance

- Limits the amount of credit allowed for on-site renewable energy [C407.3]
- Limits the amount of credit allowed for renewable energy purchased from off-site sources [C407.3]

Commissioning

- Requires that building operations and maintenance documents be provided to the owner
- Requires a completed "Commissioning Compliance Checklist" with the "Preliminary Commissioning Report"

Existing Buildings

- Provides exceptions for Changes in Space Conditioning and for Changes of Occupancy

Significant changes 2018-2021 IECC Commercial Provisions

[Sources: IECC 2021]

- Changes climate zone maps resulting in 15 Ohio counties moving from Climate Zone 5 to Climate Zone 4
- Requires an insulation certificate identifying the installed R-value of insulation when the insulation of the manufacturer is not readily observable upon inspection
- Requires that a Thermal Envelope Certificate be posted in an approved location
- Clarifies and relocates all “Mandatory” and “Prescriptive” labels to a table

Definitions

- Adds or modifies definitions of “Biogas”, “Biomass”, “Data Center”, “Data Center Systems”, “Direct Digital Control”, “Enthalpy Recovery Ratio”, “Embedded Fan”, “Fan Array”, “Fan Energy Index (FEI)”, “Fan Nameplate Electrical Input Power”, “Fan System Electrical Input Power”, “Fault Detection and Diagnostics (FDD) System”, “Information Technology Equipment (ITE)”, “Internal Curtain System”, “Large Diameter Ceiling Fan”, “On-Site Renewable Energy”, “Renewable Energy Resources”, “Testing Unit Enclosure Area”, “Thermal Distribution Efficiency (TDE)”, “Vegetative Roof”, “Visible Transmittance, Annual”, and “Wall, Above-Grade”

Building Envelope

- Increased envelope stringency and clarity for conditioned greenhouses [C402.1.1.1]
- Allows certain electric equipment buildings up to 1200 ft^2 to be exempt from envelope requirements [C402.1.2]
- Recognizes and provides guidance for layered cavity insulation [C402.1.3]
- Increased stringency requirements for attic insulation, above-grade and below-grade walls, and unheated slabs [Tables C402.1.3 and C402.1.4]
- Clarifies U-factor and R-factor insulation requirements at roofs, particularly tapered above-deck insulation [C402.1.4.1 & C402.2.1]
- Adds limit of maximum of 25% glazing area for garage door [Table C402.1.4, note i]
- Increases stringency of U-values and SHGC for fenestration in CZ 4 and CZ 5 [Table C402.4]
- Clarifies skylight requirements [C402.4.2]
- Removes R-values for doors and prescribes maximum U-factors and glazing area for non-swinging doors [C402.4.5]
- Requires either air barrier inspection and commissioning or enclosure testing to verify envelope performance of buildings and provides testing methodologies [C402.5]
- Requires HVAC interlock with operable openings that are greater than 40 ft^2 and provides a few exceptions (separately zoned commercial kitchens, warehouses, and outside vestibule doors) [C402.5.11]

Mechanical

- Exempts data center systems from control and economizer requirements [C403.1]
- Requires that data center systems comply with ASHRAE 90.4 (with a few modifications) [C403.1.2]
- Requires large HVAC systems (serving $\geq$100,000 ft^2) in new buildings to provide a fault detection and diagnostics system [C403.2.3]
- Updates HVAC equipment efficiency tables (some efficiencies to go into effect on January 1, 2023) for air conditioners, heat pumps, furnaces, boilers, chillers, cooling towers, condensers, and computer room AC [Tables C403.3.2(1) - C403.3.2(16)]
- Clarifies heat pump control requirements [C403.4.1.1]

- Clarifies that automatic stop controls are also required for HVAC systems [C403.4.2.3]
- Requires two-position valve for hydronic heat pump systems to be automatic and interlocked [C403.4.3.3.3]
- Adds a Variable Refrigerant Flow (VRF) exception to economizer requirements [C403.5]
- Requires Demand Control Ventilation (DCV) whenever economizers are required [C403.7.1]
- Increases number of enclosed parking garages that will require detection and controls [C403.7.2]
- Prescribes specific enthalpy recovery ratios for dwelling unit energy recovery systems [C403.7.4.1]
- Differentiates control requirements for hotel and motels (Group R-1) based upon occupancy status of rooms and changes time-out time from 30 minutes to 20 minutes [C403.7.6]
- Requires fans and fan arrays to have a Fan Energy Index (FEI) certified IAW AMCA 208 [C403.8.3]
- Prescribes minimum efficiencies of low-capacity residential-type fans [C403.8.5]
- Recognizes Large-diameter ceiling fans [C403.9]
- Adds performance requirements for commercial refrigerators, freezers, walk-in coolers, walk-in refrigerators and refrigeration equipment [C403.11]
- Clarifies insulation requirements for underground ducts [C403.12.1]
- Prescribes control system operation for operable opening interlocks [C403.14]

Service Water Heating

- Increases minimum efficiency for large (1 M Btu/h input) individual water heating equipment to 92% [C404.2.1]

Lighting

- Clarifies what is meant by "general lighting" [C405.1]
- Requires corridor lighting to be reduced to minimum levels (no more than 50% full power) when unoccupied [C405.2.1.1 & C405.2.1.4]
- Adds a section for "warehouse storage areas" and requires occupant sensor controls [C405.2.1.2]
- Clarifies intent of light reduction control requirements [C405.2.3]
- Adds additional control requirements for the secondary side lit daylight zone [C405.2.4.2]
- Adds control requirements for parking lot luminaires [C405.2.7.3]
- Adds control requirements for parking garage lighting [C405.2.8]
- Clarifies lighting power allowance calculations, especially for projects that involve only a portion of a building and for exterior lighting [C405.3.2 & C405.5.2]]
- Interior and exterior lighting power allowance have been modified to reflect new lighting levels in the IES lighting handbook and to recognize LED technology [Tables C405.3.2(1), C405.3.2(2), and C405.4.2(2)]
- Recognizes the high energy use of plant growth lighting and requires 95% of permanent luminaires to have a minimum photon efficiency of 1.6 m mol/J [C405.4]

Power

- Limits the combined voltage drop of customer-owned service conductors, feeder conductors and branch circuits to 5% [C405.10]
- Requires automatic receptacle control of at least 50% of 125V, 15 and 20 amp receptacles in offices, conference rooms, copy/print rooms, breakrooms, classrooms, and modular workstations and 25% of branch circuit feeders for modular furniture not shown on plans [C405.11]
- Requires new buildings with $\geq$ 25,000 ft^2 to be provided with an energy monitoring system [C405.12]

Other Equipment

- Requires that escalators be designed to recover more electrical energy than is consumed when resisting overspeed in the down direction [C405.9.2.1]

Additional Efficiency Requirements [C406]

- Requires at least 10 credits by adding additional energy efficient features to the building. The credits are determined from newly added tables arranged by occupancy classification [C406.1]
- Modifies more efficient HVAC option [C406.2]
- Modifies reduced lighting power option [C406.3]
- Modifies the basic renewable energy option [C406.5]
- Adds options for energy monitoring systems, if not otherwise required [C406.10]
- Adds options for fault detection system, if not otherwise required [C406.11]
- Adds options for efficient kitchen equipment [C406.12]

Total Building Performance

- Provides a new table that outlines the code requirements that must be met when using the Total Building Performance method [Table C407.2]

Commissioning

- Allows an “approved agency” or a qualified commissioning professional to perform the commissioning activities [C408.3.1]

Existing Buildings

- Reorganizes and clarifies requirements
- Clarifies that commissioning is required for new lighting and power systems [C502.3.6]

U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Preliminary Energy Savings Analysis: ANSI/ASHRAE/IES Standard 90.1-2019

April 2021

(This page intentionally left blank)

Acknowledgments

This Report was Prepared for:
U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Building Technologies Office
Energy.gov/eere/buildings

By
Jian Zhang
Michael Rosenberg
Jeromy Lerond
Yulong Xie
Chitra Nambia
Yan Chen
Reid Hart
Mark Halverson
Douglas Maddox
Supriya Goel

Pacific Northwest National Laboratory

Acronyms

AEO	Annual Energy Outlook
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
Btu	British thermal unit(s)
CBECS	Commercial Building Energy Consumption Survey
COP	coefficient of performance
CRAC	computer room air conditioner
DCV	demand controlled ventilation
DDC	direct digital control
DOAS	dedicated outdoor air system
DOE	U.S. Department of Energy
ECB	Energy Cost Budget
ECI	energy cost intensity
ECPA	Energy Conservation and Production Act
ERR	enthalpy recovery ratio
EIA	Energy Information Administration
EPA	U.S. Environmental Protection Agency
ERV	energy recovery ventilator
EUI	energy use intensity
ft^2	square foot(feet)
GWP	Global Warming Potential
HRV	heat recovery ventilator
HVAC	heating, ventilating, and air conditioning
IAM	integrated assessment model
IECC	International Energy Conservation Code
IEER	integrated energy efficiency ratio
IES	Illuminating Engineering Society
IESNA	Illuminating Engineering Society of North America
kft^2	thousand square feet
kWh	thousand Watt-hour
LPD	lighting power density
PBA	principal building activity
PCI	Performance Cost Index
PRM	Performance Rating Method
PNNL	Pacific Northwest National Laboratory
SAT	supply air temperature

SCOP	seasonal coefficient of performance
SC-CO_2	social cost of carbon
SHGC	solar heat gain coefficient
SSPC	Standing Standard Project Committee
SWH	service water heating
U.S.C	United State Code
VAV	variable air volume
VRF	variable-refrigerant-flow
VT	visible transmittance
yr	year(s)

Executive Summary

Title III of the Energy Conservation and Production Act, as amended (ECPA), establishes requirements for DOE to review consensus-based building energy conservation standards. (42 U.S.C. 6831 et seq.) Section 304(b), as amended, of ECPA provides that whenever the ANSI/ASHRAE/IESNA[1] Standard 90.1-1989 (Standard 90.1-1989 or 1989 edition), or any successor to that code, is revised, the Secretary of Energy (Secretary) must make a determination, not later than 12 months after such a revision, whether the revised code would improve energy efficiency in commercial buildings, and must publish a notice of such determination in the *Federal Register*. (42 U.S.C. 6833(b)(2)(A))

Standard 90.1 is developed under ANSI-approved consensus procedures[2], and is under continuous maintenance by a Standing Standard Project Committee (commonly referenced as SSPC 90.1). ASHRAE has an established program for regular publication of addenda, or revisions, including procedures for timely, documented, consensus action on requested changes to the Standard.[3] Standard 90.1-2019 was published in October 2019, triggering the statutorily required DOE review process.

To meet the statutory requirement, DOE conducted an analysis to quantify the expected energy savings associated with Standard 90.1-2019. This report documents the methodology used to conduct the analysis.

Based on the analysis, DOE has preliminarily determined that the 2019 edition of the ANSI/ASHRAE/IES Standard 90.1 would improve overall energy efficiency in buildings subject to the code (compared to the 2016 edition of Standard 90.1).

Methodology

The methodology applied in this analysis is consistent with that utilized for previous DOE building energy codes analyses and determinations, is designed to evaluate the impact of the updated Standard on new construction across the U.S., and is based on a combination of *qualitative* and *quantitative* assessments:

- **Qualitative**: The first phase of analysis was a comparative review of the textual requirements of the Standard, examining specific changes (known as "addenda") made between Standard 90.1-2019 and the previous 2016 edition. ASHRAE publishes changes to Standard 90.1 as individual addenda to the preceding Standard and then bundles them together to form the next published edition. Addenda with direct impact on energy use were identified and their anticipated impact on energy use was determined.
- **Quantitative**: The second phase of analysis examined the impact of addenda having a direct impact on energy use. The quantitative phase uses whole-building energy simulation and relies upon the established DOE methodology for energy analysis, which is based on 16 representative building types across all U.S. climate zones, as defined by Standard 90.1. Energy use intensities (EUIs) by fuel type and by end-use were developed for each building type and weighted by the relative square footage of construction to estimate the difference between the aggregated national energy use under Standard 90.1-2016, which serves as the baseline, and Standard 90.1-2019.

---

[1] ANSI – American National Standards Institute; ASHRAE – American Society of Heating, Refrigerating, and Air-Conditioning Engineers; IES – Illuminating Engineering Society; IES – Illuminating Engineering Society (previously identified as the Illuminating Engineering Society of North America, IESNA)

[2] See https://www.ansi.org/about_ansi/overview/

3 More information on the development of ANSI/ASHRAE/IES Standard 90.1 is available at http://sspc901.ashraepcs.org/index.php

Results

In creating Standard 90.1-2019, ASHRAE published 88 addenda in total, of which:

- 29 are expected to *decrease* energy use (i.e., increased energy savings);
- none are expected to *increase* energy use (i.e., decreased energy savings), and;
- 59 are expected to have *no direct impact* on energy savings (such as administrative or clarifications or changes to alternative compliance paths).[1]

New commercial buildings meeting the requirements of Standard 90.1-2019 that were analyzed in the quantitative analysis exhibit national savings (compared to Standard 90.1-2016) of approximately the following:

- 4.7 percent *site* energy savings;
- 4.3 percent *source* energy savings;
- 4.3 percent *energy cost* savings, and;
- 4.2 percent *carbon emissions*.

The quantitative analysis relies upon prototype buildings reflecting a mix of typical U.S. building types and construction practices. In creating its prototypes, DOE leverages recent U.S. construction data that is mapped to the commercial building types defined by the Energy Information Administration (EIA) and adapted for use by Standard 90.1. In combination with resulting building type weighting factors, the prototypes represent approximately 75 percent of the total square footage of new commercial construction (Lei et al. 2020).

Site and source EUIs, energy cost indices (ECIs), carbon emissions, and SC-CO_2, which vary by building type, are shown in Table ES.1 and Table ES.2 for Standard 90.1-2016 and Standard 90.1-2019, respectively. Percentage savings aggregated at the national level are shown in Figure ES.1 and Table ES.3, and analogous tables aggregated by climate zone are included in Section 4.2.

[1] Addenda characterized as having *no direct impact* on energy savings are detailed in Appendix A:

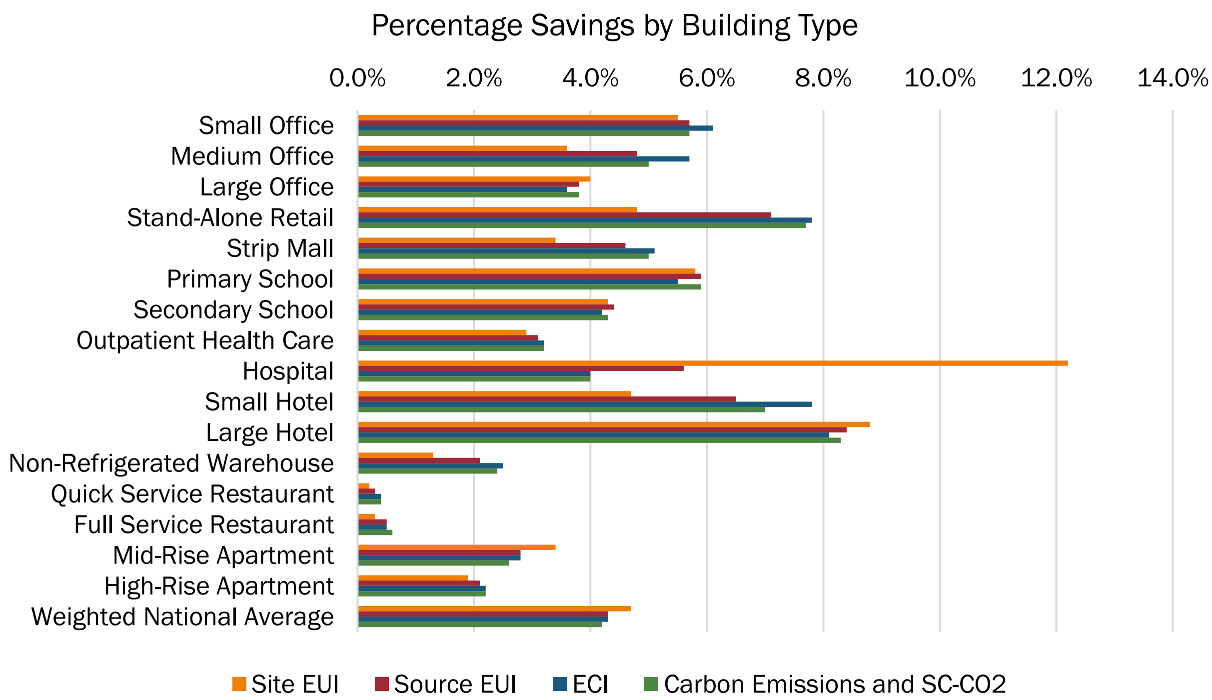


Figure ES.1. Percentage Savings by Building Type from 90.1-2016 to 90.1-2019

Table ES.1. Estimated Energy Use Intensity by Building Type – Standard 90.1-2016

Building Type	Prototype Building	Floor Area Weight (%)	Whole Building Energy Metrics				
			Site EUI (kBtu/ft²-yr)	Source EUI (kBtu/ft²-yr)	ECI ($/ft²-yr)	Carbon Emission (tons/kft²-yr)	$SC\text{-}CO_2$ ($/kft²-yr)
Office	Small Office	3.8%	27.1	77.6	$0.82	5.5	$275
	Medium Office	5.0%	30.8	84.2	$0.88	5.9	$296
	Large Office	3.9%	55.4	156.9	$1.65	11.1	$555
Retail	Stand-Alone Retail	10.9%	48.4	114.4	$1.15	7.8	$389
	Strip Mall	3.7%	52.8	133.8	$1.37	9.2	$462
Education	Primary School	4.8%	43.4	107.4	$1.09	7.4	$369
	Secondary School	10.9%	37.2	94.0	$0.96	6.5	$325
Healthcare	Outpatient Health Care	3.4%	107.6	276.3	$2.84	19.1	$958
	Hospital	4.5%	120.0	276.8	$2.77	18.7	$936
Lodging	Small Hotel	1.6%	54.8	118.0	$1.16	7.8	$392
	Large Hotel	4.2%	83.1	177.1	$1.73	11.7	$586
Warehouse	Non-Refrigerated Warehouse	18.6%	15.7	33.2	$0.32	2.2	$110
Food Service	Quick Service Restaurant	0.3%	493.4	863.7	$7.87	53.7	$2,689
	Full Service Restaurant	1.0%	336.5	649.8	$6.14	41.7	$2,090
Apartment	Mid-Rise Apartment	13.7%	37.8	104.4	$1.09	7.3	$367
	High-Rise Apartment	9.6%	41.3	92.0	$0.91	6.2	$308
National		100%	48.6	116.0	$1.17	7.9	$395

Table ES.2. Estimated Energy Use Intensity by Building Type – Standard 90.1-2019

Building Type	Prototype	Floor Area Weight (%)	Whole Building Energy Metrics				
			Site EUI (kBtu/ft^2-yr)	Source EUI (kBtu/ft^2-yr)	ECI (\$/ft^2-yr)	Carbon Emission (tons/kft^2-yr)	SC-CO_2 (\$/kft^2-yr)
Office	Small Office	3.8%	25.6	73.2	$0.77	5.2	$259
	Medium Office	5.0%	29.7	80.2	$0.83	5.6	$281
	Large Office	3.9%	53.2	151.0	$1.59	10.7	$534
Retail	Stand-Alone Retail	10.9%	46.1	106.3	$1.06	7.2	$359
	Strip Mall	3.7%	51.0	127.6	$1.30	8.8	$440
Education	Primary School	4.8%	40.9	101.1	$1.03	6.9	$348
	Secondary School	10.9%	35.6	89.9	$0.92	6.2	$311
Healthcare	Outpatient Health Care	3.4%	104.5	267.7	$2.75	18.5	$927
	Hospital	4.5%	105.4	261.2	$2.66	17.9	$898
Lodging	Small Hotel	1.6%	52.2	110.3	$1.07	7.3	$364
	Large Hotel	4.2%	75.8	162.2	$1.59	10.7	$538
Warehouse	Non-Refrigerated Warehouse	18.6%	15.5	32.5	$0.32	2.1	$107
Food Service	Quick Service Restaurant	0.3%	492.5	860.9	$7.84	53.5	$2,679
	Full Service Restaurant	1.0%	335.5	646.6	$6.11	41.5	$2,079
Apartment	Mid-Rise Apartment	13.7%	36.5	101.5	$1.06	7.1	$358
	High-Rise Apartment	9.6%	40.5	90.1	$0.89	6.0	$302
National		100%	46.3	111.0	$1.12	7.6	$379

Table ES.3. Estimated Percent Energy Savings between 2016 and 2019 Editions of Standard 90.1 – by Building Type

Building Type	Prototype Building	Floor Area Weight (%)	Savings (%)			
			Site EUI	Source EUI	ECI	Carbon Emissions & SC-CO_2
Office	Small Office	3.8%	5.5%	5.7%	6.1%	5.7%
	Medium Office	5.0%	3.6%	4.8%	5.7%	5.0%
	Large Office	3.9%	4.0%	3.8%	3.6%	3.8%
Retail	Stand-Alone Retail	10.9%	4.8%	7.1%	7.8%	7.7%
	Strip Mall	3.7%	3.4%	4.6%	5.1%	5.0%
Education	Primary School	4.8%	5.8%	5.9%	5.5%	5.9%
	Secondary School	10.9%	4.3%	4.4%	4.2%	4.3%
Healthcare	Outpatient Health Care	3.4%	2.9%	3.1%	3.2%	3.2%
	Hospital*	4.5%	12.2%	5.6%	4.0%	4.0%
Lodging	Small Hotel	1.6%	4.7%	6.5%	7.8%	7.0%
	Large Hotel	4.2%	8.8%	8.4%	8.1%	8.3%
Warehouse	Non-Refrigerated Warehouse	18.6%	1.3%	2.1%	2.5%	2.4%
Food Service	Quick Service Restaurant	0.3%	0.2%	0.3%	0.4%	0.4%
	Full Service Restaurant	1.0%	0.3%	0.5%	0.5%	0.6%
Apartment	Mid-Rise Apartment	13.7%	3.4%	2.8%	2.8%	2.6%
	High-Rise Apartment	9.6%	1.9%	2.1%	2.2%	2.2%
National		100%	4.7%	4.3%	4.3%	4.2%

*See Section 4.2 for discussion of Hospital site EUI savings

Table of Contents

List of Figures

List of Tables

1. Introduction

ANSI/ASHRAE/IES[1] Standard 90.1 is recognized by the U.S. Congress as the national model energy code for commercial buildings under the Energy Conservation and Production Act (ECPA), as amended. (42 U.S.C 6833) With each new edition of Standard 90.1, Section 304(b) of ECPA directs the Secretary of Energy (Secretary) to make a *determination* as to whether the update would improve energy efficiency in commercial buildings. Standard 90.1 is developed under ANSI-approved consensus procedures[2] and is under continuous maintenance by a Standing Standard Project Committee (commonly referenced as SSPC 90.1). ASHRAE has an established program for regular publication of addenda, or revisions, including procedures for timely, documented, consensus action on requested changes to the Standard.[3] Standard 90.1-2019 (ASHRAE 2019), the most recent edition, was published in October 2019, triggering the statutorily required U.S. Department of Energy (DOE) review and determination process. A notice of the determination must be published in the Federal Register not later than 12 months after such revision. (42 U.S.C. 6833 (b)(2)(A)) Within two years of publication of the determination, each State is required to certify that it has reviewed and updated the provisions of its commercial building code regarding energy efficiency with respect to the revised or successor code and to include in its certification, a demonstration that the provisions of its commercial building code, regarding energy efficiency, meet or exceed the revised Standard. (42 U.S.C. 6833(b)(2)(B)(i))

On February 27, 2018, DOE issued an affirmative determination of energy savings for Standard 90.1-2016 (DOE 2017), which concluded that it would achieve greater overall energy efficiency in commercial buildings required to meet the Standard than the previous edition, Standard 90.1-2013 (83 FR 8463). Through this determination, Standard 90.1-2016 became the national model energy code for commercial buildings. Consequently, and consistent with previous determinations, it also then represents the baseline to which future changes are compared, including the current review of Standard 90.1-2019. In performing its determination, DOE recognizes that not all states adopt the national model energy code directly, and many states adopt and update their codes at different rates. Instead of adopting Standard 90.1 directly, many states adopt the International Energy Conservation Code (IECC), which includes the option to comply with Standard 90.1 by reference (ICC 2018). Separately, the DOE Building Energy Codes Program also provides technical assistance supporting states implementing building energy codes, including analysis to quantify state code impacts, tracking the status of state code adoption, and developing a suite of tools to assist states and industry stakeholders in demonstrating compliance with their codes (DOE 2020).

To fulfill its statutory directive, DOE analyzed Standard 90.1-2019 to understand its overall impact on energy efficiency in commercial buildings required to meet the Standard. Section 2 of this report summarizes specific changes (known as 'addenda') made between Standard 90.1-2019 and the previous 2016 edition; Section 3 documents the qualitative and quantitative analysis methodology; Section 4 presents the analysis results. In addition, Appendix A discusses addenda not included in the quantitative analysis. Appendix A also details the modeling strategies for individual addenda included in the quantitative analysis.

---

[1] ANSI – American National Standards Institute; ASHRAE – American Society of Heating, Refrigerating, and Air-Conditioning Engineers; IES – Illuminating Engineering Society; IES – Illuminating Engineering Society (previously identified as the Illuminating Engineering Society of North America, IESNA)

[2] See ANSI Essential Requirements (updated January 2020) at https://share.ansi.org/Shared%20Documents/Standards%20Activities/American%20National%20Standards/Procedures,%20Guides,%20and%20Forms/2020_ANSI_Essential_Requirements.pdf

[3] More information on the development of ANSI/ASHRAE/IES Standard 90.1 is available at http://sspc901.ashraepcs.org/index.php

1.1 Compliance with Standard 90.1

Standard 90.1-2019 includes several paths for compliance in order to provide flexibility to users of the Standard. The prescriptive path, which is widely considered the most traditional, establishes criteria for energy-related characteristics of individual building components, such as minimum insulation levels, maximum lighting power, and controls for heating, ventilating, and air conditioning (HVAC) systems. Some of those requirements are considered “mandatory,” meaning that they must be met even when one of the other optional paths is utilized (e.g., performance path). The other optional paths are further described below.

In addition to the prescriptive path, Standard 90.1 includes two optional whole building performance paths. The first, known as the *Energy Cost Budget* (ECB) method, provides flexibility in allowing a designer to “trade-off” compliance. This effectively allows a designer to not meet a given prescriptive requirement if the impact on energy cost is offset by exceeding other prescriptive requirements, as demonstrated through established energy modeling protocols. A building is deemed in compliance when the annual energy cost of the proposed design is no greater than the annual energy cost of the reference building design (baseline). In addition, Standard 90.1-2019 includes a second performance approach, the *Performance Rating Method* (PRM), often referred to by its location in the Standard, Appendix G. PRM is similar to ECB except that it uses a stable baseline that does not increase in stringency with each new edition of the Standard, target building performance factors which must be achieved on a whole-building basis to demonstrate compliance, and it allows credit for design features not credited in ECB. The qualitative assessment in this analysis includes addenda impacting all three paths, and the quantitative analyzes the prescriptive path only. More details are provided in Section 3.

2. Summary of Addenda Included in Standard 90.1-2019

ASHRAE publishes changes to Standard 90.1 as individual addenda to the preceding Standard and then bundles them together to form the next published edition. In creating the 2019 edition, ASHRAE published 88 addenda in total (listed in Appendix I of Standard 90.1-2019). Table 2.1 shows the number of addenda included in Standard 90.1-2019 grouped into the primary sections of the Standard they impact. When an addendum impacts multiple sections, it is counted only once in this table towards the section that receives the most substantial impacts.

Table 2.1. Number of Addenda affecting Various Sections in Standard 90.1-2019

Section of 90.1-2019	Number of Addenda
5. Building Envelope	9
6. Heating, Ventilating, and Air Conditioning	32
7. Service Water Heating	1
8. Power	0
9. Lighting	10
10. Other Equipment	1
Performance Compliance (including Sections 4.2.1.1, 11 and Appendices C and G)	23
Others	12
Total	88

More broadly, DOE characterized the individual addenda into three categories to help guide the analysis:

1. are clarifications, administrative, or update references to other documents;
2. modify the prescriptive and mandatory design and construction requirements for the building envelope, HVAC, service water heating (SWH), power, lighting, and other equipment sections of the Standard; or
3. modify the performance path options for compliance (e.g., the ECB, building envelope trade-off option, and PRM sections of Standard 90.1).

While DOE reviews all addenda from a given code cycle, performing a qualitative review to characterize the expect impacts of each, category #2 above—changes which affect the mandatory and prescriptive provisions of the code—represents the subset of addenda which ultimately become the primary focal point of the energy savings analysis. This is discussed further in the following section.

3. Methodology

The methodology applied in this analysis is consistent with that utilized for previous DOE building energy codes analyses and determinations, evaluates the expected impact of the updated Standard on new construction, and is based on a combination of qualitative and quantitative assessments.

3.1 Overview

The *qualitative* phase of the analysis made initial assessments as to whether an individual addendum decreased energy use, increased energy use, or did not affect energy use in a direct manner. The *quantitative* phase then used whole-building energy modeling and simulation to quantify the impact of the collection of addenda on overall energy use. The following steps provide a general overview of the process:

Qualitative Analysis:

1. Determine whether each addendum is applicable to the *prescriptive* or *mandatory* requirements of Standard 90.1-2019.

2. Determine whether each addendum that is applicable to the prescriptive path directly impacts energy use.

3. Of the addenda that directly impact energy use, determine whether they increase or decrease energy use.

Quantitative Analysis:

4. Of the addenda that directly impact energy use, determine those that can be reasonably quantified through energy modeling and simulation analysis.

5. Calculate whole-building results and quantify the national impact based on energy use of the addenda in step 4.

Additional detail on each phase of the analysis is provided in Sections 3.2 and 3.3.

3.2 Qualitative Analysis

Expanding upon the steps presented in the previous section, the first and second steps of the qualitative analysis are used to filter out addenda that were deemed to not directly impact energy use (within the context of this analysis). Addenda were excluded if they met either of the following criteria:

1. The addenda are not applicable to the *prescriptive* and *mandatory* requirements of the Standard, meaning they only applied to the performance paths in Standard 90.1: Section 11 (Energy Cost Budget Method), Appendix C (Methodology for Building Envelope Trade-off Option), and Appendix G (Performance Rating Method). The performance paths represent optional alternatives to the prescriptive path, and generally intended to align with the prescriptive path. As the stringency of the prescriptive path is increased, the performance path rules and targets are typically updated to mirror those changes. Therefore, the use of the prescriptive and mandatory requirements effectively represents changes to the entire Standard. Additionally, the purpose of the optional performance paths is to provide design flexibility, which occurs by allowing an almost limitless number of trade-off combinations that comply with the Standard. Analytically, it is not practical or possible to model all these combinations in a manner which can be aggregated to align with the purpose of a national energy savings determination.

2. The addenda affect the prescriptive path but had no impact on energy use, an undetermined impact within the scope of the analysis, or cannot be reasonably quantified through established and accepted methods of energy modeling and simulation analysis. Addenda with no impact include administrative changes or clarifications, changes to rating methods or categorization of equipment (as opposed to required efficiency levels), changes to optional alternatives, exceptions, updates of references to other documents, and text changes that are intended to improve the general usability of Standard 90.1. Addenda with undetermined impact include those related to commissioning and functional testing requirements, and to those whose impact on energy is dependent on site-specific conditions (such as shading from trees or its neighboring buildings). Changes with impacts, which do not become effective within three years from the publication of Standard 90.1-2019 (i.e., until a cutoff date of December 31, 2022), are also considered as having no impact (within the context of this analysis).

The addenda that were considered to not have a direct impact on energy use, as described above, are compiled in Appendix A. The remaining addenda were carried to the next step in the qualitative analysis, which was to make a determination of the anticipated impact on energy use (i.e., whether the addendum will decrease or increase energy use). Section 4.1 presents the results of the qualitative analysis.

3.3 Quantitative Analysis

The quantitative analysis builds on established methods to assess the energy performance of new editions of Standard 90.1. As described in the previous section, whole-building energy models were used to quantify the impact of addenda on energy use. Individual building models were created to represent each unique combination of the mandatory and prescriptive requirements for Standard 90.1-2016 for each of 16 prototype building types in each of 16 climate zones. Each of these 'compliant' models was then duplicated, with the second version amended only to incorporate the new requirements of 90.1-2019. Additional details of the implementation into the prototype building models for each of the 17 addenda are provided in Appendix B:.

The models were simulated using *EnergyPlus Version 9.0* (DOE 2018). Those addenda that were not captured through the quantitative analysis were filtered out and are labeled as such in Table 4.1 in Section 4.1. Addenda were not included in the quantitative analysis when they met one of the following criteria:

1. The addenda impact features are not representative of typical building designs. As explained in Section 3.3.1, the purpose of the prototype models is to represent common design features found in each building type in the United States. Therefore, there are less common features that are not incorporated in the prototypes, such as series energy recovery, swimming pools, exterior lighting (except for uncovered parking, building entrances and exits, and façade lighting that is typically linked with the building), parking garages, and so on. Addenda affecting these features of buildings were not captured via the prototypes in order to preserve representation of the typical building stock.

2. The addenda adopt known standard practices. The systems and their configuration in the prototype models are based on standard practice that has been widely adopted in the United States. When an addendum is to fix a loophole for an uncommon design practice, the uncommon design is not modeled in the prototypes and thus, has no affect within the quantitative analysis.

3. The addenda relate to verification or commissioning. Addenda related to verification, commissioning, and fault-detection generate savings only when there is imperfect operation. Because the models and simulation assume ideal operation, including these addenda would have no impact.

4. The addenda incorporate federal minimum equipment standards. These addenda mirror update to

federal equipment standards and will improve efficiency even in the absence of their replication in Standard 90.1-2019, and therefore, they were left out of the quantitative analysis. Additional discussion is provided in Section 3.3.4.

3.3.1 Building Types and Model Prototypes

The 16 prototype buildings (DOE and PNNL 2020) used in the quantitative analysis largely correspond to a classification scheme established in the 2003 DOE/Energy Information Administration (EIA) Commercial Building Energy Consumption Survey (CBECS) (EIA 2003). CBECS separates the commercial sector into 29 categories and 51 subcategories using the two variables "principal building activity" (PBA) and "detailed principal building activity" (PBAplus, for more specific activities). DOE relied heavily on these classifications in determining the buildings to be represented by the set of prototype building models. By mapping CBECS observations to each prototype building, DOE also used the CBECS building characteristics data to develop prototypes that could best represent the building stock.

The exception to this is multi-family housing buildings that are not included in CBECS but are covered by Standard 90.1 if more than three stories tall. Consequently, DOE developed mid-rise and high-rise multi-family prototype buildings to add to the 14 prototype buildings identified through the review of CBECS (Thornton et al. 2011).

Table 3.1 lists the broad building category, the prototype building, floor area of the prototype building, and its construction weight relative to the other building types. DOE developed three sizes and form factors characteristic of small, medium, and large office buildings to reflect the wide variation in office building design. Similarly, retail, education, healthcare, lodging, food service, and apartments have two representative prototypes each.

The 16 prototype buildings are representative of the characteristics of new construction in the United States. It is not feasible to simulate all building types and possible permutations of building design. Further, data are simply not available to correctly weight each possible permutation in each U.S. climate zone as a fraction of the national building construction mix. Hence, the quantitative analysis focuses on the use of prototype buildings that reflect a representative mix of typical construction practices. Together with the construction weighting factors (described in Section 3.3.3), the 16 prototypes represent approximately 75% of the total square footage of new commercial construction, including multi-family buildings more than three stories tall, consistent with the scope of Standard 90.1 (Lei et al. 2020).

Table 3.1. Commercial Prototype Building Models

Building Type	Prototype Building	Floor Area (ft^2)	Floor Area (%)
Office	Small Office	5,502	3.8%
	Medium Office	53,628	5.0%
	Large Office	498,588	3.9%
Retail	Stand-Alone Retail	24,692	10.9%
	Strip Mall	22,500	3.7%
Education	Primary School	73,959	4.8%
	Secondary School	210,887	10.9%
Healthcare	Outpatient Health Care	40,946	3.4%
	Hospital	241,501	4.5%
Lodging	Small Hotel	43,202	1.6%
	Large Hotel	122,120	4.2%
Warehouse	Non-Refrigerated Warehouse	52,045	18.6%
Food Service	Quick Service Restaurant	2,501	0.3%
	Full Service Restaurant	5,502	1.0%
Apartment	Mid-Rise Apartment	33,741	13.7%
	High-Rise Apartment	84,360	9.6%
Total			100%

3.3.2 Climate Zones

Building models were analyzed in standardized climate zones described in ASHRAE Standard 169-2013 (ASHRAE 2013). Standard 169-2013 includes nine thermal zones and three moisture regimes. The U.S. climate zones and moisture regimes are shown in Figure 1.

For this analysis, a specific climate location (city) was selected as a representative of each of the 16 climate/moisture zones found in the United States. These are also consistent with representative cities approved by the SSPC 90.1 for setting the criteria for 90.1-2019.

The 16 cities used in the current analysis are as follows:

- 1A: Honolulu, Hawaii (very hot, humid)
- 2A: Tampa, Florida (hot, humid)
- 2B: Tucson, Arizona (hot, dry)
- 3A: Atlanta, Georgia (warm, humid)
- 3B: El Paso, Texas (warm, dry)
- 3C: San Diego, California (warm, marine)
- 4A: New York, New York (mixed, humid)
- 4B: Albuquerque, New Mexico (mixed, dry)
- 4C: Seattle, Washington (mixed, marine)
- 5A: Buffalo, NY (cool, humid)
- 5B: Denver, Colorado (cool, dry)
- 5C: Port Angeles, Washington (cool, marine)
- 6A: Rochester, Minnesota (cold, humid)
- 6B: Great Falls, Montana (cold, dry)
- 7: International Falls, Minnesota (very cold)
- 8: Fairbanks, Alaska (subarctic/arctic)

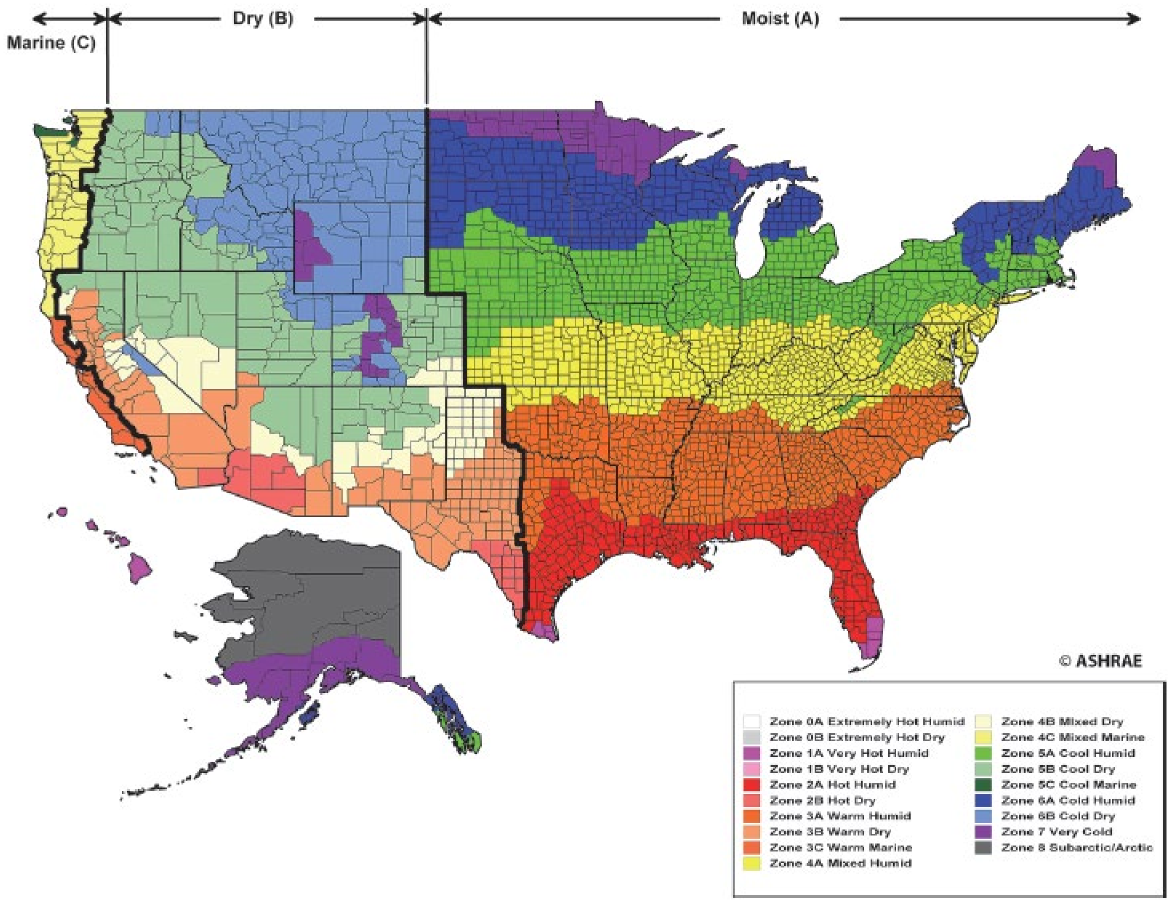


Figure 1. United States Climate Zone Map

3.3.3 Development of Weighting Factors

Weighting factors that allow aggregation of the energy impact from an individual building and climate zone level to the national level were developed from construction data purchased from McGraw Hill. Details of the development are further discussed in a PNNL report (Lei et al. 2020). New construction weights were determined for each building type in each climate zone based on the county-climate zone mapping from ASHRAE Standard 169-2013. Table 3.2 lists the resulting weighting factors by climate and by prototype building used in the analysis. These data are used to develop the relative fractions of new construction floor space represented by prototype building and within the 16 climate zones.

Using the energy use intensity (EUI) statistics from each building simulation and the corresponding relative fractions of new construction floor space, DOE developed floor-space-weighted national EUI statistics by energy type for each building type and standard edition. DOE then summed these energy type-specific EUI estimates to obtain the national site energy EUI by building type and standard edition. DOE also applied national data for average energy prices, average source energy conversion rates to the energy type-specific EUI data, average carbon emission factors, and social cost of carbon (SC-CO_2) to obtain estimates of national source energy EUI, national energy cost intensity (ECI), national carbon emissions, and national SC-CO_2, again by building type and by standard edition.

3.3.4 Treatment of Federal Minimum Equipment Standards

Standard 90.1 contains requirements for specific types of equipment that are regulated by federal efficiency standards for manufacturing and import. Addenda that adopted federal efficiency standards were excluded from the analysis to ensure that savings from energy codes and efficiency standards were not double counted. In the quantitative analysis, this was accomplished by assuming current minimum federal equipment efficiencies (i.e., as published in Standard 90.1-2019 with an effective date no later than December 31, 2022) in both the 2016 and 2019 prototype building models (with offsetting effects), which is consistent with historical DOE determination analyses. Note that the excluded addenda relate to minimum equipment efficiency levels set through the federal appliance and equipment standards rulemaking process, and not revised efficiency levels standards originating in ASHRAE Standard 90.1-2019. If the efficiency improvement is due to a change initiated in Standard 90.1, even those which may subsequently trigger an update in federal regulations, then those addenda are included in the determination savings.

Table 3.2. Relative Construction Volume Weights for 16 Prototype Buildings by Climate Zone (percent)

Building Type	1A	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8	Weights by Bldg Type
Large Office	0.11	0.54	0.07	0.54	0.26	0.23	1.13	0.00	0.24	0.48	0.15	0.00	0.09	0.00	0.01	0.00	3.86
Medium Office	0.14	0.78	0.19	0.73	0.45	0.16	0.95	0.03	0.17	0.88	0.31	0.00	0.17	0.03	0.02	0.00	5.01
Small Office	0.11	0.77	0.15	0.70	0.27	0.05	0.58	0.03	0.09	0.67	0.21	0.00	0.13	0.02	0.02	0.00	3.80
Stand-Alone Retail	0.29	1.79	0.31	1.78	0.85	0.12	1.92	0.08	0.26	2.37	0.54	0.01	0.49	0.06	0.06	0.01	10.94
Strip Mall	0.16	0.63	0.14	0.70	0.42	0.09	0.66	0.02	0.09	0.61	0.12	0.00	0.06	0.01	0.01	0.00	3.71
Primary School	0.13	0.98	0.12	0.94	0.36	0.04	0.88	0.03	0.12	0.77	0.23	0.00	0.16	0.05	0.02	0.00	4.83
Secondary School	0.26	1.86	0.19	2.16	0.77	0.14	1.98	0.07	0.27	2.18	0.51	0.01	0.37	0.09	0.06	0.01	10.92
Hospital	0.09	0.75	0.11	0.63	0.32	0.10	0.92	0.03	0.13	0.95	0.23	0.01	0.20	0.03	0.03	0.00	4.52
Outpatient Health Care	0.05	0.54	0.09	0.53	0.17	0.04	0.62	0.02	0.10	0.80	0.20	0.00	0.18	0.03	0.03	0.00	3.42
Full Service Restaurant	0.03	0.18	0.03	0.17	0.08	0.01	0.16	0.01	0.02	0.19	0.04	0.00	0.03	0.00	0.00	0.00	0.97
Quick Service Restaurant	0.01	0.07	0.01	0.06	0.02	0.00	0.06	0.00	0.00	0.07	0.02	0.00	0.01	0.00	0.00	0.00	0.33
Large Hotel	0.18	0.71	0.10	0.56	0.55	0.09	0.82	0.02	0.13	0.65	0.19	0.00	0.14	0.04	0.02	0.00	4.22
Small Hotel	0.03	0.30	0.02	0.27	0.11	0.02	0.30	0.01	0.03	0.27	0.10	0.00	0.08	0.03	0.02	0.00	1.59
Non-Refrigerated Warehouse	0.53	3.53	0.63	2.77	2.23	0.18	3.69	0.05	0.54	3.14	0.82	0.00	0.37	0.03	0.04	0.00	18.56
High-Rise Apartment	1.44	1.19	0.08	0.57	0.63	0.29	3.26	0.00	0.49	1.36	0.19	0.00	0.11	0.01	0.00	0.00	9.64
Mid-Rise Apartment	0.36	2.24	0.27	1.78	1.18	0.49	3.02	0.03	0.71	2.22	0.73	0.01	0.57	0.05	0.04	0.00	13.69
Weights by Zone	3.94	16.85	2.52	14.89	8.67	2.06	20.94	0.43	3.39	17.60	4.59	0.05	3.17	0.49	0.38	0.03	100.00

3.4 Comments on Methodology

The goal of this analysis was to determine if the 2019 edition of Standard 90.1 is more energy-efficient relative to the 2016 edition. The approach selected to make this determination has certain limitations. These limitations are outlined below.

State Code Adoption: As discussed in the Introduction (Section 1), states adopt and update their energy codes in a variety of different manners. Some states adopt updated model codes as published while others draft state-level amendments to modify the model code. States also adopt codes at varying rates, with some states updating relatively quickly after a new edition is available, while others may remain on older editions for a longer duration. While these variables are not included in the DOE determination analysis, they ultimately affect the impacts of the model codes as applied across adopting states and localities.

Prototype Representation: Not all the addenda impacting energy use can be captured by the quantitative analysis due to the fixed nature of the prototypes, as explained in Section 3.3.1. Thus, the impact resulting from the quantitative analysis can be considered conservative. At the same time, the impact could be considered generous because the addenda that were included impacted all buildings of a given type (i.e., the weighting factors carried the impact to all buildings of a given type in a climate zone even though some of those buildings may not fit the descriptions of the prototype buildings). For example, the analysis assumes all large office buildings have water-cooled chillers—a property of the Large Office prototype. In reality, some have air-cooled, some have packaged equipment, some have variable refrigerant volume systems, etc. If the water-cooled chiller efficiency improved more than the other systems, the analysis overestimates savings. Whereas, if the efficiency improved less than the other systems, the analysis will have underestimated savings.

Combination of Qualitative & Quantitative Analysis: In any high-level analysis there is a need to balance precision, accuracy and practicality. The approach selected here addresses that by performing both a qualitative and quantitative analysis. The quantitative analysis taken together with the qualitative analysis provides a more robust and defensible determination. If the qualitative analysis determines that a large majority of addenda are expected to decrease energy use, and the quantitative analysis also shows a reduction in energy use from addenda impacting representative building designs, then taken together, the determination can be said to be more robust and reliable.

4. Results

4.1 Qualitative Analysis Results

The qualitative analysis concluded that 29 of the 88 addenda had a direct impact on energy use as defined in Section 3.2 — all 29 of the addenda listed decrease energy use in commercial buildings. The 59 remaining changes were determined to have no direct impact on energy use. A graphical summary of the qualitative analysis results is shown in Figure 2.

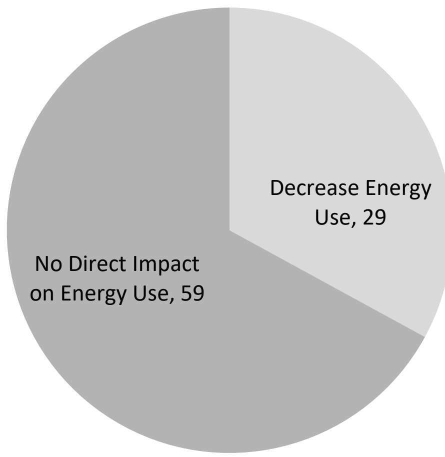


Figure 2. Categorization of Addenda

The 29 addenda with a direct impact are shown in Table 4.1, while the remainder are shown in Appendix A:. Six columns of information are listed for each addendum in Table 4.1:

1. **Addendum**: the letter addendum designation assigned by ASHRAE.
2. **Code Section(s)**: a list of the section numbers in Standard 90.1-2016 that are affected by the addendum.
3. **Description of Change**: a brief description of the change made by the addendum.
4. **Impact on Energy Use**: the anticipated impact of the addendum on energy use.
5. **Included in Quantitative Analysis**: whether the addendum can be included in the forthcoming Quantitative Analysis (see Section 4.2).
6. **Discussion**: how the impact on energy use was determined (and why the addendum was excluded from the quantitative analysis, if applicable).

Addenda characterized as having *no direct impact* on energy savings are detailed in Appendix.

Table 4.1. Addenda Determined to Directly Save Energy by the Qualitative Analysis of Standard 90.1-2019

Addendum	Code Sections	Description of Change	Impact on Energy Use	Included in Quantitative Analysis	Discussion
dn	6.5.6	Modifies exceptions to exhaust air energy recovery requirements.	Decreases Energy Use	No	Excluded from quantitative analysis because series energy recovery is not modeled in the prototypes.
a	6.4.3.4.2, 6.4.3.4.3, 6.5.1.1.4	Changes term "ventilation air" to "outdoor air" in multiple locations. Adds an exception to allow systems intended to operate continuously not to install motorized outdoor air damper. Changes return air dampers to require low leakage ratings.	Decreases Energy Use	Yes	Reduces fan energy by allowing systems intended to operate continuously not to install motorized outdoor air damper (less pressure drop), and reduce cooling energy for systems with air economizers because of lower leakage through return air dampers.
g	3.2, 6.4.3.9	Provides definition of "occupied-standby mode" and adds new ventilation air requirements for zones served in occupied-standby mode.	Decreases Energy Use	Yes	Requires thermostat setback and minimum variable air volume (VAV) damper reset to zero during occupied standby model.
h	6.5.6.1	Clarifies that exhaust air ERVs should be sized to meet both heating and cooling design conditions unless one mode is not exempted by existing exceptions.	Decreases Energy Use	Yes	Reduces HVAC energy by requiring adequately sized ERVs.
j	6.4.3.8	Revises exception to demand control ventilation (DCV) requirements to clarify that the exception only applies to systems with ERV required to meet Section 6.5.6.1.	Decreases Energy Use	No	Reduces HVAC energy by preventing a bad design practice of using ERV rather than DCV in climate zones where ERVs are not required and DCV would save more energy. Excluded from quantitative analysis because typical designs, as represented by the established prototypes, do not use this design practice.
k	3.2, 6.4.3.3.5, 9.4.1.3	Revises definition of "networked guest room control system" and aligns HVAC and lighting time-out periods for guest rooms.	Decreases Energy Use	Yes	Reduces timeout period from 30 to 20 minutes to activate occupancy-based temperature and ventilation setback controls for guestrooms.
t	9.4.2	Expands the exterior lighting power density (LPD) application table to cover additional exterior spaces that are not in the exterior LPD table.	Decreases Energy Use	No	Reduces lighting energy. Excluded from quantitative analysis because the exterior areas added to the table are not modeled in the prototypes.
v	6.5.6.3	Adds heat recovery for space conditioning requirement targeted specifically at in-patient hospitals	Decreases Energy Use	Yes	Requires in-patient hospitals with large chillers to recover rejected heat for use in heating water systems.
ai	Too many to list. See Addendum ai	Restructures commissioning and functional testing requirements in all sections of Standard 90.1 to require verification or testing for smaller and simpler buildings and commissioning for larger and more complex buildings.	Decreases Energy Use	No	Excluded from quantitative analysis because the analysis is based on proper operation of controls in the prototypes and would not show savings for improvements from verification, testing, or commissioning.

Addendum	Code Sections	Description of Change	Impact on Energy Use	Included in Quantitative Analysis	Discussion
am	6.5.6.4	Adds indoor pool dehumidifier energy recovery requirement.	Decreases Energy Use	No	Reduces HVAC energy. Excluded from quantitative analysis because swimming pools are not modeled in the prototypes.
an	3.2, 10.4.6	Implements federal clean water pump requirements.	Decreases Energy Use	No	Reduces pump energy through improved efficiency. Excluded from quantitative analysis because impacted pumps are federally-regulated. (See Section 3.3.4)
ao	3.2, 6.5.3.1.3, 12	Replaces Fan Energy Grade metric with Fan Energy Index metric	Decreases Energy Use	No	Reduces fan energy through improved fan efficiency. Excluded from quantitative analysis because fan power in the prototypes is set based on the total fan power limit in the Standard, which has not been changed.
ap	6.5.3.5	Revises supply air temperature reset controls	Decreases Energy Use	Yes	Revises supply air temperature reset requirements.
au	6.5.2.1,	Eliminates the requirement that zones with direct digital control (DDC) have air flow rates that are no more than 20% of the zone design peak flow rate.	Decreases Energy Use	Yes	Replaces VAV box minimum setpoint of 20% of the design supply air rate with a setpoint determined using Simplified Procedure in ASHRAE Standard 62.1.
aw	3.2, Tables 5.5-0 through 5.5-8, 12	Revises prescriptive fenestration U and SHGC requirements and makes them material neutral.	Decreases Energy Use	Yes	Improves thermal performance of most fenestration components.
ay	6.5.6.1	Provides separate requirements for nontransient dwelling unit exhaust air energy recovery.	Decreases Energy Use	Yes	Requires more dwelling units to have exhaust air energy recovery.
bb	Table 9.6.1	Changes interior LPD requirements for many space types.	Decreases Energy Use	Yes	Reduces lighting energy with lower LPD.
bd	Table 6.8.1-18	Adds new chiller table for heat pump and heat recovery chillers.	Decreases Energy Use	Yes	Establishes new efficiency requirement for equipment including heat recovery chillers.
be	Table 6.8.1-11, Table 6.8.1-19	Revises computer room air conditioner (CRAC) requirements to clarify these are for floor mounted units and adds a new table for ceiling mounted units.	Decreases Energy Use	Yes	Requires higher efficiency CRAC units.
bo	3.2, Tables 6.8.1.5 and F4	Adds definition of Standby Power Mode Consumption. Increases furnace efficiency requirements.	Decreases Energy Use	No	Reduces heating energy through improved furnace efficiency. Excluded from quantitative analysis because the impacted furnaces are federally-regulated. (See Section 3.3.4)
bp	Tables 6.8.1.6 and F5	Adds a new table F-5 to specify DOE covered residential water boiler efficiency requirements and notes that requirements in Table 6.8.1-6 apply only to products used outside the US. Adds standby mode and improved efficiency as of 1/15/2021.	Decreases Energy Use	No	Excluded from quantitative analysis because the impacted boilers are federally-regulated. (See Section 3.3.4)

Addendum	Code Sections	Description of Change	Impact on Energy Use	Included in Quantitative Analysis	Discussion
bq	Table 6.8.1.7	Adds dry cooler efficiency requirements and slightly increases efficiency requirements for evaporative condensers.	Decreases Energy Use	Yes	Requires higher efficiency dry coolers.
br	Table 6.8.1.13 & 12	Combines commercial refrigerator and freezer table with refrigerated casework table into a single table. Increases efficiency requirements.	Decreases Energy Use	No	Excluded from quantitative analysis because the impacted refrigerators and freezers are federally-regulated. (See Section 3.3.4)
cg	Table 9.5.1	Revises LPDs using the Building Area Method.	Decreases Energy Use	Yes	Reduces lighting energy with lower LPD.
cm	6.5.2.1	Makes a similar change to VAV box minimums as Addendum au to 90.1-2016, but in exception 1 to Section 6.5.2.1 where the same 20% requirement still existed.	Decreases Energy Use	Yes	Replaces VAV box minimum setpoint of 20% of the design supply air rate with a setpoint determined using the Simplified Procedure in Standard 62.1. Similar to Addendum au.
cn	6.4.1.1, 6.4.5, Table 6.8.1-20, Table 6.8.1-21, Table 6.8.1-22	Cleans up outdated language regarding walk-in cooler and walk-in freezer requirements, and makes the requirements consistent with current and future federal regulations.	Decreases Energy Use	No	Excluded from quantitative analysis because the impacted walk-in coolers and freezers are federally-regulated. (See Section 3.3.4)
co	12	Adds new normative references and updates existing ones with new effective dates, including several addenda to ASHRAE Standard 62.1-2016, which enable Simplified Ventilation Procedure.	Decreases Energy Use	Yes	Updates to include Addendum f to 62.1-2016, which enables Simplified Ventilation Procedure to be used for VAV box minimum setpoint controls and system ventilation control.
cv	9.4.1.2	Updates the lighting control requirements for parking garages in Section 9.4.1.2.	Decreases Energy Use	No	Reduces lighting energy. Excluded from quantitative analysis because the parking garages are not modeled in the prototypes.
cw	9.4.1.1, Table 9.6.3	Changes the daylight responsive requirements from continuous dimming or stepped control to continuous dimming required for all spaces and adds a definition of continuous dimming.	Decreases Energy Use	Yes	Reduces lighting energy because of more stringent daylighting control requirements.

4.2 Quantitative Analysis Results

The quantitative analysis only includes those addenda that have a direct impact on energy use as described in Section 3.2 and Section 3.3. A graphical summary of the addenda included in the quantitative analysis is shown in Figure 3. The category labeled "Unquantified Energy Impact" includes those addenda that were determined to have a direct impact on energy use but are not be included in the quantitative analysis. Appendix B: describes the implementation of addenda into the prototype models.

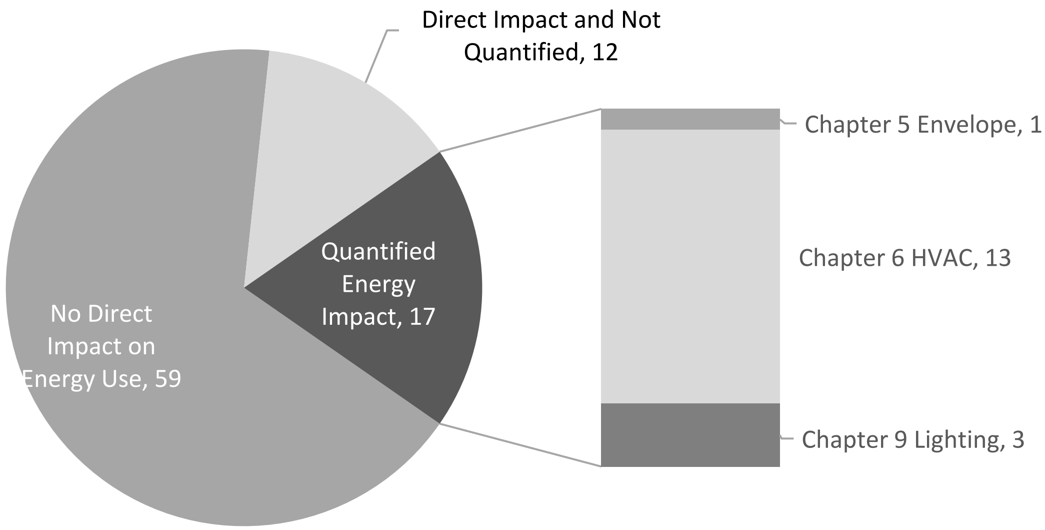


Figure 3. Categorization of Quantified Addenda

Table 4.3 through Table 4.6 show the quantitative analysis results by building type and climate zone for Standard 90.1-2016 and 90.1-2019, respectively. The results were aggregated on a national basis for each Standard, based on the weighting factors discussed in Section 3.3.3. In these tables, site energy refers to the energy consumed at the building site, and source energy (or primary energy) refers to the energy required to generate and deliver energy to the site. To calculate source energy, conversion factors were applied to the electricity and natural gas consumption. The development of these conversion factors is explained below.

The electric energy source conversion factor of 9,957 Btu/kWh was calculated from EIA's Annual Energy Outlook (AEO) 2020 (EIA 2020) Table 2[1] as follows:

- Delivered commercial electricity, 2019: 4.65 quads
- Commercial electricity related losses, 2019: 8.92 quads
- Total commercial electric energy use, 2019: 13.58 quads
- Commercial electric source ratio, U.S. 2019: 2.92
- Source electric energy factor (3413 Btu/kWh site) 9,957 Btu/kWh[2]

[1] Available at https://www.eia.gov/outlooks/aeo/

[2] The final conversion value is calculated using the full seven digit values available in Table 2 of AEO 2020. Other values shown in the text are rounded.

Natural gas EUIs in the prototype buildings were converted to source energy using a factor of 1.088 Btu of source energy per Btu of site natural gas use, based on the 2019 national energy use estimate shown in Table 2 of the AEO 2020 as follows:

- Delivered total natural gas, 2019: 29.39 quads
- Natural gas used in well, field, and pipeline: 2.58 quads
- Total gross natural gas use, 2019: 31.97 quads
- Total natural gas source ratio, U.S. 2019: 1.088 Btu source/Btu site
- Source natural gas energy factor (100,000 Btu/therm site): 108,800 Btu/therm

To calculate the energy cost, DOE relied on national average commercial building energy prices based on EIA statistics for 2019 in Table 3, "Energy Prices by Sector and Source," of the AEO 2020 for commercial sector natural gas and electricity of:

- $0.1052/kWh of electricity
- $7.79 per 1000 cubic feet ($0.752/therm) of natural gas.

DOE recognizes that actual energy costs will vary somewhat by building type within a region, and even more across regions. However, the use of national average figures sufficiently illustrates energy cost savings and the effect on energy efficiency in commercial buildings, as is the purpose of the DOE determination.

Carbon emissions in the quantitative analysis are based on the source energy consumption on a national scale. Carbon emission metrics are provided by the U.S. Environmental Protection Agency (EPA) Greenhouse Gas Equivalencies Calculator[1]. The Greenhouse calculator reports the national marginal carbon emission conversion factor for electricity at 7.07×10^{-4} metric tons carbon dioxide (CO_2)/kWh. For natural gas, the carbon emission conversion factor is 0.0053 metric tons CO_2/therm. Table 4.2 summarizes the carbon emission factors.

Table 4.2. Carbon Emission Factors by Fuel Type

Fuel Source	Carbon Emission Factor
Electricity	7.07×10^{-4} metric tons CO_2/kWh
Natural Gas	0.0053 metric tons CO_2/therm

On January 20, 2021, President Biden issued Executive Order (E.O.) 13990[2], which noted that it is essential that agencies capture the full costs of greenhouse gas emissions as accurately as possible, including by taking global damages into account and that doing so facilitates sound decision-making, recognizes the breadth of climate impacts, and supports the international leadership of the United States on climate issues. To that end, DOE is including estimates of the absolute cost and relative costs savings

---

[1] See the EPA webpage at https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator.

[2] Exec. Order No. 13990, 86 Fed. Reg. 7037 (January 20, 2021) https://www.federalregister.gov/documents/2021/01/25/2021-01765/protecting-public-health-and-the-environment-and-restoring-science-to-tackle-the-climate-crisis

of greenhouse gas emissions associated with the building energy use examined in this analysis.

The principal greenhouse gas emission associated with commercial building energy use, as examined in this analysis, is CO_2. DOE estimates the global social benefits of first year CO_2 emission reductions using the SC-CO_2 estimates presented in the *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990* (IWG 2021). These SC-CO_2 estimates are interim values established under E.O. 13990 for use in benefit-cost analyses until an improved estimate of the impacts of climate change can be developed based on the best available science and economics. These SC-CO_2 estimates are the same as those used in the *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866* (IWG 2016), but are updated to 2020$. An unrounded value of $51.086 (2020$/Metric Ton CO_2) is used in this analysis reflecting a SC-CO_2 present value per metric ton of carbon dioxide emissions avoided in 2020 based on a 3% discount rate and the average global damage estimate from three integrated assessment models (IAMs).

Table 4.7 and Table 4.8 present the estimated percent energy and energy cost savings between the 2016 and 2019 editions of Standard 90.1 by building type and climate zone respectively.

Overall, the analysis indicates that Standard 90.1-2019 will result in increased energy efficiency in commercial buildings. On a weighted national average basis, Standard 90.1-2019 saves 4.7% site energy, 4.3% of source energy, 4.3% of energy cost, and 4.2% of carbon emissions and SC-CO_2. Weighted national average savings results by building type and climate zone are shown in Figure 4 and Figure 5.

Of interest is the large site energy savings found in the Hospital prototype compared to source energy and cost savings. The majority of savings is due to Addendum v which requires acute care hospitals to recover chiller condenser heat to be used to offset space heating. This causes a large reduction in natural gas consumption, and a much smaller increase in electricity consumption required by the heat recovery chiller and pumping system (see Section B.2.5). Since the site-to-source conversion factor for electricity is almost three times that of natural gas and the cost per delivered Btu of electricity is about four times that of natural gas (see Section 4.2), the result is much higher savings for site energy than either of the other two metrics.

Table 4.3. Estimated Energy Use Intensity by Building Type – Standard 90.1-2016

Building Type	Prototype Building	Floor Area Weight (%)	Whole Building Energy Metrics				
			Site EUI (kBtu/ft^2-yr)	Source EUI (kBtu/ft^2-yr)	ECI ($/ft^2-yr)	Carbon Emission (tons/kft^2-yr)	SC-CO_2 ($/kft^2-yr)
Office	Small Office	3.8%	27.1	77.6	$0.82	5.5	$275
	Medium Office	5.0%	30.8	84.2	$0.88	5.9	$296
	Large Office	3.9%	55.4	156.9	$1.65	11.1	$555
Retail	Stand-Alone Retail	10.9%	48.4	114.4	$1.15	7.8	$389
	Strip Mall	3.7%	52.8	133.8	$1.37	9.2	$462
Education	Primary School	4.8%	43.4	107.4	$1.09	7.4	$369
	Secondary School	10.9%	37.2	94.0	$0.96	6.5	$325
Healthcare	Outpatient Health Care	3.4%	107.6	276.3	$2.84	19.1	$958
	Hospital	4.5%	120.0	276.8	$2.77	18.7	$936
Lodging	Small Hotel	1.6%	54.8	118.0	$1.16	7.8	$392
	Large Hotel	4.2%	83.1	177.1	$1.73	11.7	$586
Warehouse	Non-Refrigerated Warehouse	18.6%	15.7	33.2	$0.32	2.2	$110
Food Service	Quick Service Restaurant	0.3%	493.4	863.7	$7.87	53.7	$2,689
	Full Service Restaurant	1.0%	336.5	649.8	$6.14	41.7	$2,090
Apartment	Mid-Rise Apartment	13.7%	37.8	104.4	$1.09	7.3	$367
	High-Rise Apartment	9.6%	41.3	92.0	$0.91	6.2	$308
National		100%	48.6	116.0	$1.17	7.9	$395

Table 4.4. Estimated Energy Use Intensity by Building Type – Standard 90.1-2019

Building Type	Prototype	Floor Area Weight (%)	Whole Building Energy Metrics: Site EUI (kBtu/ft²-yr)	Source EUI (kBtu/ft²-yr)	ECI ($/ft²-yr)	Carbon Emission (tons/kft2-yr)	SC-CO2 ($/kft2-yr)
Office	Small Office	3.8%	25.6	73.2	$0.77	5.2	$259
	Medium Office	5.0%	29.7	80.2	$0.83	5.6	$281
	Large Office	3.9%	53.2	151.0	$1.59	10.7	$534
Retail	Stand-Alone Retail	10.9%	46.1	106.3	$1.06	7.2	$359
	Strip Mall	3.7%	51.0	127.6	$1.30	8.8	$440
Education	Primary School	4.8%	40.9	101.1	$1.03	6.9	$348
	Secondary School	10.9%	35.6	89.9	$0.92	6.2	$311
Healthcare	Outpatient Health Care	3.4%	104.5	267.7	$2.75	18.5	$927
	Hospital	4.5%	105.4	261.2	$2.66	17.9	$898
Lodging	Small Hotel	1.6%	52.2	110.3	$1.07	7.3	$364
	Large Hotel	4.2%	75.8	162.2	$1.59	10.7	$538
Warehouse	Non-Refrigerated Warehouse	18.6%	15.5	32.5	$0.32	2.1	$107
Food Service	Quick Service Restaurant	0.3%	492.5	860.9	$7.84	53.5	$2,679
	Full Service Restaurant	1.0%	335.5	646.6	$6.11	41.5	$2,079
Apartment	Mid-Rise Apartment	13.7%	36.5	101.5	$1.06	7.1	$358
	High-Rise Apartment	9.6%	40.5	90.1	$0.89	6.0	$302
National		100%	46.3	111.0	$1.12	7.6	$379

Table 4.5. Estimated Energy Use Intensity by Climate Zone – Standard 90.1-2016

Climate Zone	Climate Zone Floor Area Weight %	Whole Building Energy Metrics				
		Site EUI kBtu/ft^2-yr	Source EUI kBtu/ft^2-yr	ECI \$/ft^2-yr	Carbon Emission tons/kft^2-yr	SC-CO_2 \$/kft^2-yr
1A	3.9%	46.5	121.0	$1.25	8.4	$421
2A	16.9%	47.0	122.0	$1.26	8.5	$424
2B	2.5%	43.3	112.9	$1.16	7.8	$393
3A	14.9%	47.3	116.2	$1.18	8.0	$399
3B	8.7%	40.8	103.1	$1.06	7.1	$356
3C	2.1%	41.0	105.5	$1.08	7.3	$366
4A	20.9%	48.0	111.8	$1.12	7.6	$379
4B	0.4%	50.6	121.7	$1.23	8.3	$416
4C	3.4%	42.3	100.4	$1.01	6.8	$342
5A	17.6%	54.9	119.9	$1.18	8.0	$399
5B	4.6%	49.7	115.4	$1.15	7.8	$391
5C	0.1%	54.4	126.3	$1.26	8.5	$428
6A	3.2%	64.2	136.7	$1.33	9.0	$453
6B	0.5%	59.1	130.3	$1.28	8.7	$435
7	0.4%	69.9	147.0	$1.43	9.7	$485
8	0.03%	86.6	165.5	$1.56	10.6	$530
National	100%	48.6	116.0	$1.17	7.9	$395

Table 4.6. Estimated Energy Use Intensity by Climate Zone – Standard 90.1-2019

Climate Zone	Climate Zone Floor Area Weight %	Whole Building Energy Metrics Site EUI kBtu/ft²-yr	Source EUI kBtu/ft²-yr	ECI \$/ft²-yr	Carbon Emission tons/kft²-yr	SC-CO_2 \$/kft²-yr
1A	3.9%	44.5	115.9	$1.19	8.0	$403
2A	16.9%	44.5	116.4	$1.20	8.1	$405
2B	2.5%	41.1	107.9	$1.11	7.5	$376
3A	14.9%	44.5	110.1	$1.12	7.6	$379
3B	8.7%	38.8	98.6	$1.01	6.8	$341
3C	2.1%	39.0	101.1	$1.04	7.0	$351
4A	20.9%	46.2	107.7	$1.08	7.3	$365
4B	0.4%	48.3	116.3	$1.18	7.9	$397
4C	3.4%	39.7	95.9	$0.97	6.5	$328
5A	17.6%	53.0	115.3	$1.13	7.7	$384
5B	4.6%	47.2	110.3	$1.11	7.5	$374
5C	0.1%	52.7	122.0	$1.22	8.2	$413
6A	3.2%	61.9	131.5	$1.28	8.7	$435
6B	0.5%	57.2	125.3	$1.23	8.3	$418
7	0.4%	67.4	141.2	$1.37	9.3	$466
8	0.03%	84.1	159.5	$1.50	10.2	$510
National	100%	46.3	111.0	$1.12	7.6	$379

Table 4.7. Estimated Percent Energy Savings between 2016 and 2019 Editions of Standard 90.1 – by Building Type

Building Type	Prototype Building	Floor Area Weight (%)	Savings (%)			
			Site EUI	Source EUI	ECI	Carbon Emissions & SC-CO2
Office	Small Office	3.8%	5.5%	5.7%	6.1%	5.7%
	Medium Office	5.0%	3.6%	4.8%	5.7%	5.0%
	Large Office	3.9%	4.0%	3.8%	3.6%	3.8%
Retail	Stand-Alone Retail	10.9%	4.8%	7.1%	7.8%	7.7%
	Strip Mall	3.7%	3.4%	4.6%	5.1%	5.0%
Education	Primary School	4.8%	5.8%	5.9%	5.5%	5.9%
	Secondary School	10.9%	4.3%	4.4%	4.2%	4.3%
Healthcare	Outpatient Health Care	3.4%	2.9%	3.1%	3.2%	3.2%
	Hospital	4.5%	12.2%	5.6%	4.0%	4.0%
Lodging	Small Hotel	1.6%	4.7%	6.5%	7.8%	7.0%
	Large Hotel	4.2%	8.8%	8.4%	8.1%	8.3%
Warehouse	Non-Refrigerated Warehouse	18.6%	1.3%	2.1%	2.5%	2.4%
Food Service	Quick Service Restaurant	0.3%	0.2%	0.3%	0.4%	0.4%
	Full Service Restaurant	1.0%	0.3%	0.5%	0.5%	0.6%
Apartment	Mid-Rise Apartment	13.7%	3.4%	2.8%	2.8%	2.6%
	High-Rise Apartment	9.6%	1.9%	2.1%	2.2%	2.2%
National		100%	4.7%	4.3%	4.3%	4.2%

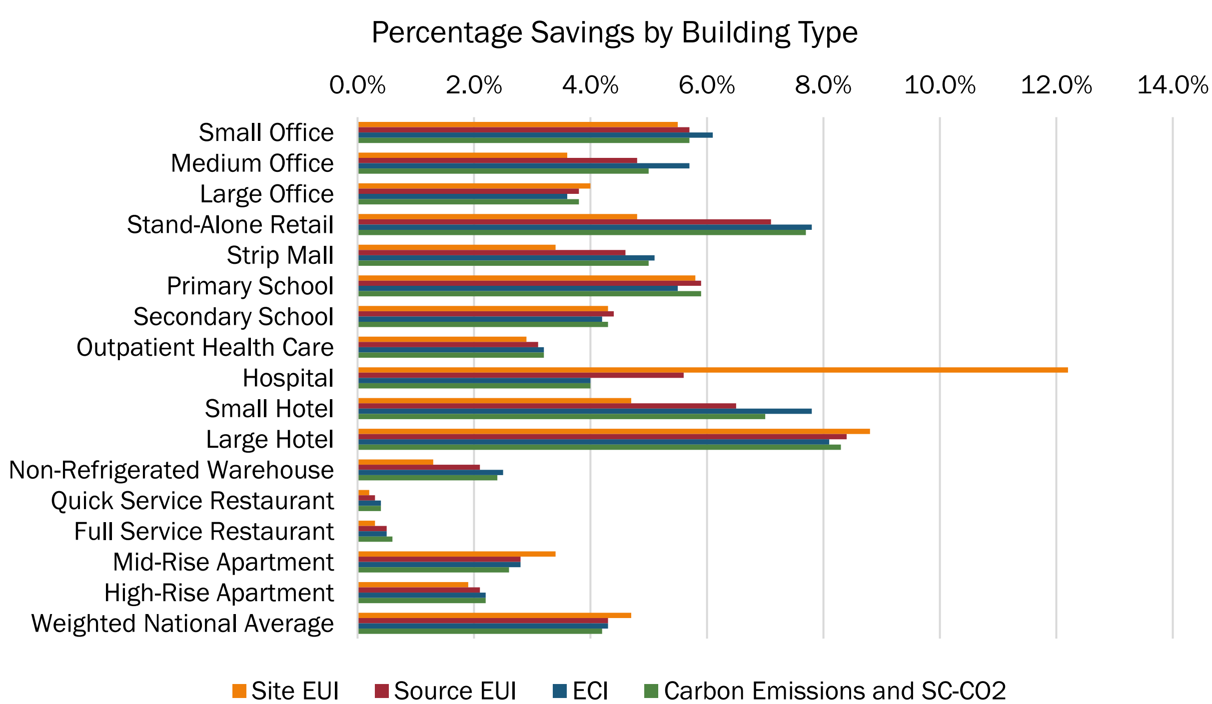


Figure 4. Percentage Savings by Building Type from 90.1-2016 to 90.1-2019

Table 4.8. Estimated Percent Energy Savings between 2016 and 2019 Editions of Standard 90.1 – by Climate Zone

		Savings (%)			
Climate Zone	Climate Zone Floor Area Weight %	Site EUI	Source EUI	ECI	Carbon Emissions & SC-CO2
1A	3.9%	4.3%	4.2%	4.8%	4.2%
2A	16.9%	5.3%	4.6%	4.8%	4.5%
2B	2.5%	5.1%	4.4%	4.3%	4.3%
3A	14.9%	5.9%	5.2%	5.1%	5.1%
3B	8.7%	4.9%	4.4%	4.7%	4.2%
3C	2.1%	4.9%	4.2%	3.7%	4.0%
4A	20.9%	3.8%	3.7%	3.6%	3.7%
4B	0.4%	4.5%	4.4%	4.1%	4.4%
4C	3.4%	6.1%	4.5%	4.0%	4.2%
5A	17.6%	3.5%	3.8%	4.2%	3.9%
5B	4.6%	5.0%	4.4%	3.5%	4.3%
5C	0.1%	3.1%	3.4%	3.2%	3.5%
6A	3.2%	3.6%	3.8%	3.8%	3.9%
6B	0.5%	3.2%	3.8%	3.9%	3.9%
7	0.4%	3.6%	3.9%	4.2%	4.0%
8	0.03%	2.9%	3.6%	3.8%	3.9%
National	100%	4.7%	4.3%	4.3%	4.2%

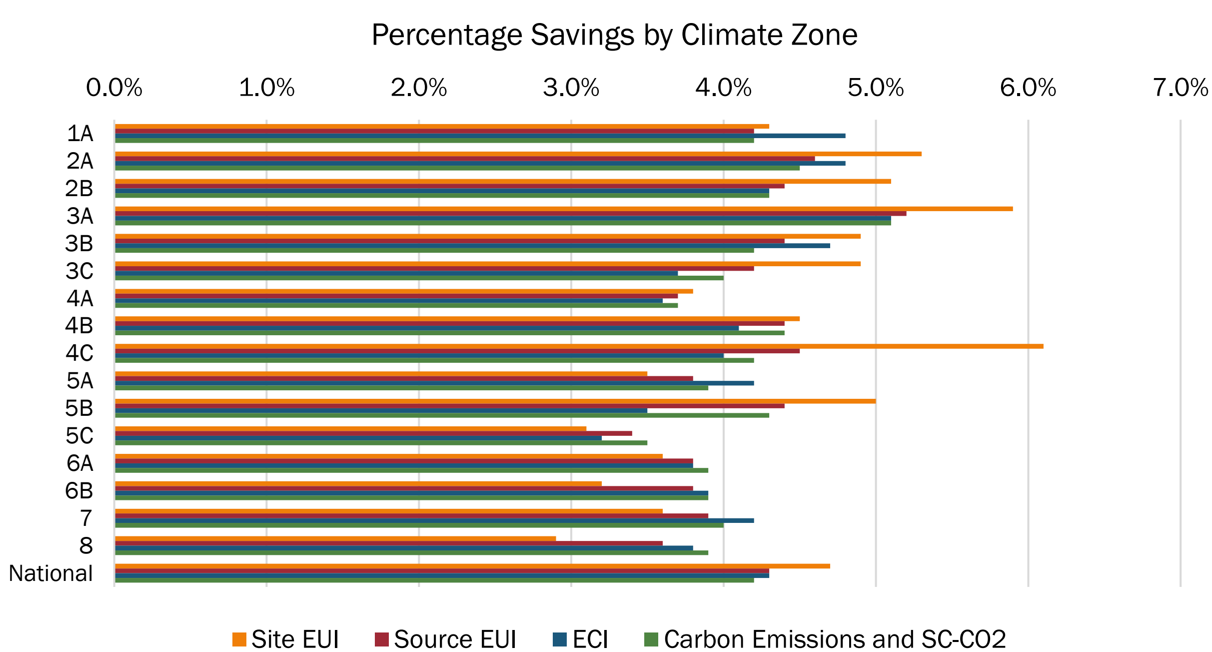


Figure 5. Percentage Savings by Climate Zone from 90.1-2016 to 90.1-2019

80

5. References

42 U.S.C. 6833. Chapter 42, U.S. Code, Section 6833. Available at http://www.gpo.gov/fdsys/pkg/USCODE-2011-title42/pdf/USCODE-2011-title42-chap81-subchapII.pdf.

42 U.S.C. 6831. Chapter 42, U.S. Code, Section 6831. Available at http://www.gpo.gov/fdsys/pkg/USCODE-2011-title42/pdf/USCODE-2011-title42-chap81-subchapII.pdf.

83 FR 8463. 2018. Federal Register Volume 83, Number 39 (February 27, 2018). Page 8463 – 8465. U.S. Government Publishing Office, Washington, D.C. Available at https://www.regulations.gov/document?D=EERE-2017-BT-DET-0046-0008.

ASHRAE. 2013. *ANSI/ASHRAE Standard 169-2013. Climatic Data for Building Design Standards*. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, Georgia.

ASHRAE. 2016. *ANSI/ASHRAE/IES 90.1-2016, Energy Standard for Buildings Except Low-Rise Residential Buildings.* ASHRAE, Atlanta, GA.

ASHRAE. 2019. *ANSI/ASHRAE/IES 90.1-2019, Energy Standard for Buildings Except Low-Rise Residential Buildings.* ASHRAE, Atlanta, GA

BECP – U.S. Department of Energy, Building Energy Codes Program. 2020. *Status of State Energy Code Adoption*. Accessed February 14, 2020 at http://www.energycodes.gov/adoption/states.

DOE. 2018. EnergyPlus Energy Simulation Software, Version 9.0.1. U.S. Department of Energy, Washington, D.C. Accessed August 29, 2019 at https://energyplus.net/downloads.

DOE. 2017. *Energy Savings Analysis: ANSI/ASHRAE/IES Standard 90.1-2016*. Prepared by Athalye, R.A, M.A. Halverson, M.I. Rosenberg, B. Liu, J. Zhang, R. Hart, V.V. Mendon, S. Goel, Y. Chen, Y. Xie, and M. Zhao, Richland, WA, Pacific Northwest National Laboratory. https://www.energycodes.gov/sites/default/files/documents/02202018_Standard_90.1-2016_Determination_TSD.pdf.

DOE and PNNL. 2020. *Commercial Prototype Building Models*, Richland, WA, Pacific Northwest National Laboratory. Available at https://www.energycodes.gov/development/commercial/prototype_models.

EIA –U.S. Energy Information Administration. 2003. *Commercial Buildings Energy Consumption Survey 2003*. Energy Information Administration of U.S. Department of Energy, Washington, D.C. Available at http://www.eia.doe.gov/emeu/cbecs/contents.html.

EIA – U.S. Energy Information Administration. 2020. *Annual Energy Outlook 2020*. Energy Information Administration of U.S. Department of Energy, Washington, D.C. Available at https:/./www.eia.gov/outlooks/aeo/.

ICC – International Code Council. 2018. 2018 International Energy Conservation Code®. Washington D.C.

IWG - Interagency Working Group on Social Cost of Carbon. 2016. *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866.* United States Government. Available at https://www.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf.

IWG - Interagency Working Group on Social Cost of Carbon. 2021. *Social Cost of Carbon, Methane, and Nitrous Oxide. Interim Estimates under Executive Order 13990*. United States Government. Available at https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf.

Lei, X, JB Butzbaugh, Y Chen, J Zhang, and MI Rosenberg. 2020. *Development of National New Construction Weighting Factors for the Commercial Building Prototype Analyses (2003-2018)*. PNNL-29787. Pacific Northwest National Laboratory, Richland, WA. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23269.pdf.

Thornton B.A., M.I. Rosenberg, E.E. Richman, W. Wang, Y. Xie, J. Zhang, H. Cho, VV Mendon, R.A. Athalye, and B. Liu. 2011. *Achieving the 30% Goal: Energy and Cost Savings Analysis of ASHRAE Standard 90.1-2010*. PNNL-20405. Richland, WA: Pacific Northwest National Laboratory. https://www.energycodes.gov/sites/default/files/documents/BECP_Energy_Cost_Savings_STD2010_May2011_v00.pdf.

Appendix A: Addenda Not Quantified in Energy Savings Analysis

Addendum	Sections Affected	Description of Change	Discussion
bg	9.3	Adds a simplified building method for interior lighting in offices, schools, and retail buildings, and exterior lighting.	Changed provisions are an alternative to the existing requirements.
b	5.5.3.1.1	Updates reference to ANSI/CRRC S100 "Standard Test Methods for Determining Radiative Properties of Materials."	References update only.
c	3.2	Adds rooftop monitors to the definition of fixed and operable vertical fenestration.	Clarification only.
d	Table G3.1 1c	Modifies text to make it consistent with other portions of Appendix G for projects undergoing phased permitting.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
e	Table G3.1 11f	Adds direction that service water heater (SWH) piping losses shall not be modeled.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
f	G3.1.2.1	Modifies text to require that the capacity used for selecting the system efficiency is based on the size of the actual zone instead of the size of the zones as combined into a single thermal block.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
l	Table G3.1.2.9	Adds requirements for fan break horsepower for two systems.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
m	Table G3.1 5b	Lowers baseline building performance air leakage and sets an air leakage value to be used in conjunction with the air barrier verification path.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
n	3.2	Removes 10 unused definitions and changes the definition of "unitary cooling equipment" to "unitary air conditioners."	Clarification only.
o	3.2, 4.2.2.3, 5.5.1, 5.5.2, 5.7, 5.8, 6.7, 7.7, 8.7, 9.7, 10.7,	Revises the submittals section of the envelope and power chapters for consistency across the Standard.	Administrative provisions only.

Addendum	Sections Affected	Description of Change	Discussion
	11.7, G1.3		
p	Table 6.8.1-14	Revises the rating conditions for indoor pool dehumidifiers.	Clarification to rating condition.
q	5.4.3, 5.5, 5.8.3	Clarifies and restructures air leakage requirements for the building envelope.	Clarification only.
r	G3.1.2.6	Specifies air economizer control types for Appendix G.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
s	4.2.1.1, 11.4.3, G2.4.1	Modifies the Performance Cost Index (PCI) equation to implement a 5% limitation on renewable energy usage and clarifies what types of renewable energy systems are eligible.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
x	4.2	Clarifies compliance paths for new construction, additions, and alterations.	Clarification only.
y	G3.1.2.2	Provides explicit guidance on how to conduct sizing runs for Appendix G.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
z	11.5, G3.1.2	Modifies the formulas in Section 11 and G3.1.2.1 for removing fan energy from baseline packaged heating and cooling efficiency ratings to cap the system capacity equations in Section 11 to levels allowed in Section 6 and provide a fixed baseline efficiency rating for Appendix G.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
ab	3.2	Modifies definition of “door”, “entrance door”, “fenestration”, and “sectional garage door.”	Clarification only.
ac	3.2	Clarifies use of defined terms to include the term with different tense or plurality.	Clarification only.
ad	5, 6, 7, 8, 9, 10, 11, G	Clarifies the requirements for showing compliance using the methods in Sections 5-10, or Section 11, or Appendix G.	Clarification only.
ae	3.2, 6.4.3.6	Clarifies humidification and dehumidification control requirements.	Clarification only.

Addendum	Sections Affected	Description of Change	Discussion
ag	Table G3.1 12	Accounts for the inclusion of automatic receptacle controls in a proposed building design for spaces that are not required to have them.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
ah	9.1.4	Updates the language and terminology of the lighting wattage section to clarify application in modern lighting systems and equipment. Also adds a section specifically to address using DC power over Cat6 structured cable for connection of LED lighting to a remote power supply.	Clarification only.
aj	3.2, 6.4.3, 6.5.1, 6.5.2, 6.5.4	Adds new definition “process application” and uses it throughout the Standard in place of “process load.”	Clarification only.
ak	Tables G3.4-1 to G3.4-8	Defines solar heat gain coefficient (SHGC) baseline for buildings in zones where there is no prescriptive maximum SHGC.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
al	Table G3.1 4, Table G3.1 7, G3.1.2.4	Modifies requirements in Appendix G to ensure that the intent of G3.1.1(c) (separate HVAC systems for unusual loads or schedules) is met.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
aq	9.2.2.3, 9.4.1.3, 9.4.4, 9.6.2,	Clarifies lighting control requirements for applications not covered in Section 9.6.2.	Clarification only.
ar	G3.1.2.9, Table G3.1 12, Table G3.5.5, Table G3.5.6, Table G3.6, Table G3.9, Table G3.9.3	Cleans up the modeling requirements for pumps in Appendix G to address unresolved comments to Addendum di to Standard 90.1-2016.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
as	New appendix I	Adds informative appendix Additional Guidance for Verification, Testing, and Commissioning	Change applies to informative appendix and does not change normative requirements.
at	11.5, G1.2.2,	Adds an exception for energy used to refuel or recharge offsite vehicles.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
az	Table G3.1 17	Clarifies how to deal with refrigeration equipment rated under AHRI 1200 in Appendix G.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.

Addendum	Sections Affected	Description of Change	Discussion
ba	Table G3.1 11	Establishes a methodology for determining the baseline flow rates on projects where service water-heating is demonstrated to be reduced by water conservation measures that reduce the physical volume of service water required, such as with low-flow showerheads.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
bf	5.4.3.4, 10.4.5, App E	Allows self-closing doors with air curtains as an alternative to vestibules for particular climate zones and building heights.	Changed provisions are alternative to the existing and unchanged ones.
bh	5.4.3.2, Table 5.8.3.2	Corrects omissions from Addendum q.	Clarification only.
bi	11.4.1.4, 12, C3.1.4, G2.4.4	Updates reference to Standard 140 and makes clarifications regarding application of Standard 140.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
bj	6.5.5.1	Adds equipment covered by Tables 6.8.1-9 through 6.8.1-16 to the list of exceptions from heat rejection requirements.	Clarification only.
bk	3.2, 11.4.3.2, G2.4.2	Defines onsite electricity generation systems and clarifies that systems using the performance path must use the same electricity generation systems in the baseline as in the proposed design, except for onsite renewable generation systems.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
bl	Table 6.8.1.1	Updates efficiency requirements for Table 6.8.1-1 Electrically Operated Unitary Air Conditioners and Condensing Units.	Change will not be effective within three years from the publication of Standard 90.1-2019.
bm	6.4.1.1, Tables 6.8.1.2 and 6.8.1.17	Removes water, evaporatively, and ground cooled heat pumps from Table 6.8.1.2 and establishes their efficiency requirements in new table 6.8.1.18. Updates efficiency requirements for all heat pumps.	Change will not be effective within three years from the publication of Standard 90.1-2019.
bn	3.2, Tables 6.8.1.4, F1, and F3.	Adds new definitions for CEER, CCOPc, and Off-mode power consumption. Updates efficiency for PTAC, PTHP, SPVAC, SPVHP, and room air conditioners. Updates federally regulated equipment efficiency in Appendix F.	Change will not be effective within three years from the publication of Standard 90.1-2019.
bs	Tables 7.8 and F-2	Updates water heater requirements in Tables F2 and 7.8 to align with new federal requirements.	Change aligns with recent federal rulemaking that impacts the categorizations and performance rating method of service water heaters but not (intended) the stringency of the requirements.
bt	Table 4.2.1.1	Updates Building Performance Factors used to show compliance with Appendix G.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.

Addendum	Sections Affected	Description of Change	Discussion
bu	G3.1.1, G3.1.3.2, G3.1.3.3, G3.1.3.6, G3.1.3.10, G3.1.3.11, G3.1.3.12, Tables 4.2.1.1, G3.1.1-1, G3.4-1, G3.4-2, G3.4-3, G3.4-4, G3.4-5, G3.4-6, G3.4-7, G3.4-8.	Changes references from spaces to zones, corrects a conflict on heating source, clarifies when separate baseline systems are required, removes redundant footnote in Tables 4.2.1.1, G3.1.1-1, G3.4-1, corrects errors in subsection title headings.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
bv	3.2, 6.2.1, 6.6.1, 6.6.6.1, 6.6.1.2, 6.6.1.3, 8.2.1, 8.6.1	Deletes computer room alternative compliance option in Standard 90.1 and instead allows an alternative path of complying with ASHRAE Standard 90.4 for electrical and mechanical components in computer rooms greater than 10 kW.	Changed provisions are alternative to the existing and unchanged ones.
bx	A6.1, Table A6.3.1-1	Adds F-factors for heated slabs that are uninsulated or insulated only under slab.	Additional factors for condition combinations not currently covered and do not change requirements.
bz	3.2, C1.4, C2.7, C3.1.2, C3.3, C3.5.5.1, C3.5.8	Modifies Appendix C Envelope Tradeoff.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
ca	Table A3.2.3	Adds U-factors to Table A3.2.3 for use of continuous insulation on metal building walls with double layer cavity insulation	Clarification only.
cc	A9.4.6	Clarifies the limitations of the calculation procedures in A9.4.6.	Clarification only.
ce	6.5.3.1.2	Removes one of three criteria for fan motor selections.	Changed provisions are alternative to the existing and unchanged ones.
cf	6.4.5	Adds vacuum insulating glazing to the list of options for reach-in doors in walk-in coolers and freezers.	Changed provisions are alternative to the existing and unchanged ones.
ch	3.2, 9.4.1.1	Addresses two areas of uncertainty in the definitions of daylighted zones.	Clarification only.

Addendum	Sections Affected	Description of Change	Discussion
ci	Table 4.2.1.1	Updates the Building Performance Factors that are used for compliance with Appendix G.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
cj	Table 11.5.1, Table G3.1, Table G3.7	Makes three specific changes to the lighting provisions of the Energy Cost Budget Method and the specific changes to the lighting provisions of Appendix G.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
cl	3.2, 11.4.1, 11.4.1.1, 11.4.1.2, 11.4.2, 11.4.5, 11.5.2, 11.7, Table 11.5.1, Table 11.5.2-1, Table 11.5.2-3, Table 11.5.2-5	Makes changes throughout Section 11 to better align with Appendix G providing greater consistency between the two sections.	Change applies to an alternative compliance path and does not affect the prescriptive or mandatory requirements.
cq	6.4.1.3 (new)	Adds requirements for large-diameter ceiling fans to be rated in accordance with certain test methods.	Requires fans to be rated, but includes no minimum efficiency requirement.
cs	Appendix E	Makes many edits and updates to Informative References.	References update only.
ct	12	Updates the revision date for Acceptance Test Code for open circuit cooling towers.	References update only.
cu	6.4.1.4, 6.4.7 (new)	Adds 6.4.7 to require that liquid to liquid heat exchangers that fall under the scope of AHRI 400 be rated in accordance with AHRI 400. Deletes Table 6.8.1-8 which included the same rating requirement.	References update only.
cy	9.4.1	Clarifies language in an exception to the sidelighting requirements and adds natural objects to the exception.	Primarily a clarification.

Appendix B: Modeling of Individual Addenda

This appendix details the modeling of the 17 addenda to Standard 90.1-2016 simulated for the quantitative analysis. They are a subset of the addenda listed in Table 4.1 and marked as "Included in Quantitative Analysis". In the cases where individual addenda modify the same section of Standard 90.1, these addenda are discussed together. The procedures for implementing the addenda into the Standard 90.1-2016 and 90.1-2019 prototype models include identifying the changes to the prototypes required by each addendum, developing model inputs to simulate those changes, applying those changes to the prototype models, running the simulations, and extracting and post-processing the results. This section explains the addenda and their impact on energy savings, the modeling strategies, and the development of the simulation inputs for EnergyPlus. The terms "baseline" and "advanced" are used in some cases to describe the modeling of the addenda. The baseline case is Standard 90.1-2016 and the advanced case is Standard 90.1-2019. In some instances, a new addendum to Standard 90.1-2016 identifies the need for a change to baseline 2016 models. There are generally two reasons why a baseline change was necessary: (1) in the course of modeling an addendum, an opportunity to increase the accuracy of the simulation was identified and (2) to add additional detail to the models so that the impact of a particular addendum could be captured. For example, prior to the simulation of the 2019 Standard, ventilation in the Mid-rise and High-rise Apartment prototypes was changed from through the space air conditioning systems to through an exhaust-driven ventilator. This allows the accurate simulation of Addendum *ay*, which requires residential systems to have heat recovery.

B.1 Building Envelope Addenda

B.1.1 Addendum *aw*: Fenestration U and SHGC

Addendum Description. Addendum *aw* revises the prescriptive U-factor and solar heat gain coefficient (SHGC) requirements in Tables 5.5-0 through 5.5-8 for vertical fenestrations and skylights. It also modifies the vertical fenestration categories from "Nonmetal," "Metal fixed," "Metal operable," and "Metal entrance door" to "Fixed," "Operable," and "Entrance Door." The adjusted categorization is independent of frame material type, provides increased consistency with the International Energy Conservation Code (IECC), and helps facilitate alignment of 90.1 and IECC criteria. The revised SHGC values for operable and vertical fenestrations are slightly lower than those for fixed ones, which is to acknowledge the fact that operable windows have a larger frame-to-glass ratio and therefore lower SHGC values with the same glazing type. The addendum generally reduces U-factor for fixed metal framed windows; however; it also increases the U-factor for non-metal framed windows. Since the predominant framing is metal in commercial construction, the average U-factor is reduced, in turn reducing heat loss and gain for commercial buildings, which provides an overall reduction in both annual and peak heating and cooling loads. SHGC is slightly reduced overall, contributing further to a reduction in cooling load and energy use.

Modeling Strategy. All the prototypes have vertical fenestration (i.e., windows), and four (Stand-alone Retail, Primary School, Secondary School, and Non-refrigerated Warehouse) have skylights, which are all modeled using U-factor and SHGC inputs to WindowMaterial:SimpleGlazingSystem objects in EnergyPlus. To capture the window requirements with different categorizations introduced by this addendum, weighting factors of different window categories as shown in Table B.1 were used to calculate weighted U-factor and SHGC values for each prototype based on recent market data from Ducker.[1] The weighting factors are slightly updated from those used in the previous analyses (Thornton et al. 2011). Although the required minimum ratio of visible transmittance (VT) to SHGC (VT/SHGC) is not changed

[1] Detailed market data from https://www.ducker.com/ were processed by the SSPC90.1 Envelope Subcommittee.

by the addendum, the new SHGC values result in different VT inputs in the prototypes.

Table B.1. Weighting Factors of Different Windows Categorized in 90.1-2016 and 90.1-2019

	Vertical fenestration categories in 90.1-2016			Vertical fenestration categories in 90.1-2019	
Building Prototype	Nonmetal	Metal - Fixed	Metal - Operable	Fixed	Operable
Small Office	2.5%	95.7%	1.8%	96.9%	3.1%
Medium Office	2.5%	95.7%	1.8%	96.9%	3.1%
Large Office	2.5%	95.7%	1.8%	96.9%	3.1%
Stand-alone Retail	2.6%	96.2%	1.2%	97.8%	2.2%
Strip Mall	2.6%	96.2%	1.2%	97.8%	2.2%
Primary School	7.5%	86.6%	5.8%	89.8%	10.2%
Secondary School	7.5%	86.6%	5.8%	89.8%	10.2%
Outpatient Healthcare	3.1%	94.6%	2.3%	95.9%	4.1%
Hospital	3.1%	94.6%	2.3%	95.9%	4.1%
Small Hotel	5.8%	89.7%	4.5%	92.0%	8.0%
Large Hotel	5.8%	89.7%	4.5%	92.0%	8.0%
Non-Refrigerated Warehouse	2.4%	96.1%	1.5%	97.4%	2.6%
Quick Service Restaurant	2.6%	96.2%	1.2%	97.8%	2.2%
Full Service Restaurant	2.6%	96.2%	1.2%	97.8%	2.2%
Mid-Rise Apartment	17.3%	68.7%	14.0%	75.4%	24.6%
High-Rise Apartment	17.3%	68.7%	14.0%	75.4%	24.6%

B.2 Heating, Refrigerating, and Air-Conditioning Addenda

B.2.1 Addendum *a*: Outdoor and Return Dampers

Addendum Description. Addendum *a* makes a few clarification changes such as modifying the term "ventilation air" to "outdoor air." It also improves energy efficiency by requiring return dampers to meet Table 6.4.3.4.3, which means a lower leakage rate from return air to supply air than Standard 90.1-2016. This improves economizer operation by increasing the outside air entering the system during economizer mode, as leaky return air dampers result in mixing of some return air back into the mixed air, even when dampers are fully closed. In addition, an exception is added to Section 6.4.3.4.2. Without this exception, a system with continuous ventilation intake needs to have an outdoor air damper, which creates a pressure drop. With the exception, such a system without the outdoor air damper would have lower pressure drop and therefore less fan energy consumption.

Modeling Strategy. When air-side economizers are modeled in single-zone unitary systems in the baseline prototypes, their maximum fraction of outdoor over design supply air is modeled to be 70% based on field measurements for unitary systems (Davis et al. 2002), which limits the maximum outdoor air flow during economizer operation. With the lower leakage damper required by the addendum, the improvement in the economizer option is modeled as an increase in the maximum outdoor air fraction from 70% to 75%, which is approximated based on the relationship between damper leakage rates and opening positions of sample products. The savings were only captured for single-zone systems with economizers. In some systems, the design outdoor air flow fraction is already higher than 70% due to zone exhaust or ventilation needs; therefore, the impacts of the addendum on these systems are not modeled. Similarly, for multiple-zone variable air volume (VAV) systems, the modeled maximum outdoor air fraction is already 100%; therefore, the impacts on these are not captured.

Although the added exception to Section 6.4.3.4.2 could theoretically result in a pressure drop reduction for fans with continuous operation, the Fan Power Limitation calculation method is used in the prototypes to calculate the fan pressure drop, which only allows pressure adjustments for devices listed in Table 6.5.3.1-2 Fan Power Limitation Pressure Drop Adjustment. Because the outdoor air dampers are not in the table, the energy savings impacts were not captured.

B.2.2 Addendum *g*: Occupied Standby Controls

Addendum Description. Standard 90.1-2016 Section 9.4.1.1 (see Table 9.6.1) already requires occupancy sensors for lighting control in certain spaces, but the available occupancy status is not required to control heating, ventilating, and air conditioning (HVAC) systems except for hotel/motel guest rooms (see Section 6.3.3.3.5). Standard 62.1-2016, referenced by Standard 90.1-2019, introduced a new definition for occupied-standby mode: when a zone is scheduled to be occupied and an occupant sensor indicates zero population within the zone. It now allows outside air ventilation to be shut off in occupied-standby mode for many occupancy categories including office and conference/meeting spaces (see Note H in Table 6.2.2.1 Minimum Ventilation Rates in Breathing Zone in Standard 62.1-2016). Addendum *g* requires zones that already have occupancy sensors and qualify for the occupied-standby mode to automatically enter an occupied standby mode, during which the zones should have a heating and cooling thermostat setback of 1°F and should completely shut off HVAC supply air within the deadband.

Addendum *g* provides energy savings for VAV systems by significantly reducing deadband airflow and thereby reducing fan, cooling, and reheat energy during the occupied-standby mode. Before this addendum, the full minimum amount of air was delivered to empty zones during the occupied-standby mode, resulting in excessive reheat to maintain temperature. Energy is saved by reducing reheat, primary air cooling, and fan use for unneeded airflow. Single-zone, dedicated outdoor air systems (DOAS) and other HVAC systems experience similar savings through shut off of airflow to temporarily unoccupied spaces unless there is a demand for thermal conditioning.

Modeling Strategy. Each thermal zone in the prototypes is mapped to an occupancy category defined in Table 6.2.2.1 in Standard 62.1-2016 and a space type defined in Table 9.6.1 in Standard 90.1-2019. The two were crossed checked to identify the zones that are required to have occupancy sensors for lighting control and their occupancy category qualifies for occupied-standby mode. They include enclosed office, conference/meeting, corridor, and lobby spaces. Because lobby and corridor spaces are not expected to be often in occupied-standby mode, the savings to these were ignored. For prototypes without detailed space type zoning such as the three office prototypes, selected zones were designated to represent the collective impacts on the prototypes.

The occupancy schedules of the impacted zones were adjusted to have a few hours of occupied-standby mode per day as baseline enhancements based on occupancy profile data from literature and engineering judgment. In the advanced models, the thermostat schedules were set to have the setback of 1°F during the standby hours. During occupied-standby mode, the single-zone HVAC systems were modeled with the supply air flow cycling with thermal load and not providing ventilation. For multiple-zone VAV systems, standby mode was modeled with the minimum VAV box damper position and the zone ventilation set to zero that results in system outdoor air flow reduction through the Ventilation Rate Procedure. The impacted prototypes include Small Office, Medium Office, Large Office, Primary School, Secondary School, Outpatient Healthcare, Small Hotel, Mid-Rise Apartment, and High-Rise Apartment.

B.2.3 Addenda *h and ay*: ERV Sizing and Residential Energy Recovery

Addendum Description. Standard 90.1-2016 already has requirements for exhaust air energy recovery for ventilation systems based on the design supply fan airflow rate and the ratio of outdoor airflow rate to fan supply airflow rate at design conditions. Dwelling units are subject to the criteria in Table 6.5.6.1-2 Exhaust Air Energy Recovery Requirements for Ventilation Systems Operating Greater than or Equal to 8000 Hours per Year. There has been confusion as to whether heating or cooling design should be used for sizing an energy recovery ventilator (ERV).

Addendum *h* clarifies that the ERV equipment should meet the greater enthalpy recovery ratio (ERR) of either heating or cooling, unless one mode is specifically excluded for the climate zone by exception. This addendum is primarily a clarification.

Addendum *ay* provides new requirements for the nontransient dwelling unit (apartment) ERV that are distinct from other commercial buildings. Dwelling unit energy recovery uses different equipment than general commercial spaces and has a different cost effectiveness, so the addenda resulted in the ERV being required in more climate zones than under the commercial requirements. Based on the SSPC 90.1 analysis, climate zone 3C is completely exempt, while the energy recovery device selection is based on heating only in climate zones 4 through 8 and cooling only in climate zones 0 through 2. Climate zones 3A and 3B must meet both heating and cooling requirements. Smaller apartments—less than 500 square feet—are exempt in climate zones 0 through 3 and 4C and 5C.

The ERV provides energy savings by pre-heating or pre-cooling incoming outside air for ventilation using the heat energy in the exhaust air stream. Pre-treatment of the outside air reduces the energy use by the heating and cooling systems. While there is some increase in fan energy use, this is partially offset by reduced exhaust fan operation for ventilation. Overall, in the climate zones where it is required, exhaust air energy recovery will save more heating and cooling energy than the fan energy increase. The addendum specifies an enthalpy recovery ratio of at least 50% at cooling design conditions and at least 60% at heating design conditions. There are several exceptions to these requirements. The addendum increases the number of climate zones and situations where exhaust air energy recovery is required in apartments, dormitories, and residential institutions.

Modeling Strategy. All apartment units modeled in the Mid-Rise Apartment and High-Rise Apartment prototypes meet the definition of nontransient dwelling unit and their sizes are all above 500 square feet. Continuous ventilation of 55 cubic feet per minute (cfm) is provided to each dwelling unit. To better represent the typical design practice, the prototypes were recently modified from supplying ventilation airflow through the unitary air conditioner in the Mid-Rise Apartment and the water source heat pump for the High-Rise Apartment to having a local exhaust-driven ventilator in each unit. In the enhanced models, space conditioning systems cycle with thermal loads. The ventilator fan airflow rate (i.e., the outdoor airflow rate) is 55 cfm. Without an ERV, the fan power of the ventilator is estimated to be 44 Watts per unit, which is modeled with fan efficiency and pressure drop inputs in the simulation model. When an ERV is installed, an additional pressure drop is approximated to result in added fan power of 51 Watts based on a review of residential heat/energy recovery ventilator products.

The baseline prototypes, as shown in Table B.2, are required to have heat recovery ventilators (HRV) or ERVs in colder and dry climate zones. Addendum *ay* now requires all dwelling units to have ERVs except for climate zone 3C, and it also has different minimum ERRs for heating and cooling, as summarized in Table B.2.

EnergyPlus requires inputs in terms of heat recovery effectiveness. In order to convert the ERR values at local design conditions to effectiveness, representative data from equipment manufacturers with both ERR and effectiveness were reviewed. Both Addenda *h* and *ay* specify ERR at the local design condition rather than at an Air Conditioning, Heating, and Refrigeration Institute (AHRI) standard rating condition. Some adjustment factors from rated ERR to that at the local design conditions were derived from the product review, and these were used to calculate climate-specific heat recovery effectiveness inputs as shown in Table B.3.

Table B.2. The Modeled ERVs in the Mid-Rise and High-Rise Apartments for 90.1-2016 and 90.1-2019

Climate zones	90.1-2016 Table 6.5.6.1-2	90.1-2019 Section 6.5.6.1.1		
			Enthalpy recovery ratio (ERR)	
	Required	Required	Cooling	Heating
0A	No	Yes	50%	No minimum
0B	No	Yes	50%	No minimum
1A	No	Yes	50%	No minimum
1B	No	Yes	50%	No minimum
2A	No	Yes	50%	No minimum
2B	No	Yes	50%	No minimum
3A	No	Yes	50%	60%
3B	No	Yes	50%	60%
3C	NR	Exempt	NA	NA
4A	Yes	Yes	No minimum	60%
4B	No	Yes	No minimum	60%
4C	No	Yes	No minimum	60%
5A	Yes	Yes	No minimum	60%
5B	No	Yes	No minimum	60%
5C	No	Yes	No minimum	60%
6A	Yes	Yes	No minimum	60%
6B	Yes*	Yes	No minimum	60%
7	Yes*	Yes	No minimum	60%
8	Yes*	Yes	No minimum	60%

* Even though cooling energy recovery is exempted, the installed HRV for heating will save sensible cooling energy.

Table B.3 Heat Recovery Effectiveness for Standard 90.1-2016 and 90.1-2019 Based on Required Design EER for Mid-Rise and High-Rise Apartment Prototypes

	90.1-2016		90.1-2019			
Climate zones	4A, 5A, 6A	6B, 7, 8	0, 1, 2A, 3A	2B	3B	4 thru 8
Design condition used for sizing ERR	Cooling	Heating	Cooling	Cooling	Cooling	Heating
Required ERR at local design conditions	50%	50%	50%	50%	50%	60%
Sensible Eff. at 100% Heating Air Flow	0.67	0.50	0.67	0.63	0.62	0.60
Latent Eff. at 100% Heating Air Flow	0.45	0.00	0.45	0.38	0.35	0.00
Sensible Eff. at 75% Heating Air Flow	0.70	0.53	0.70	0.67	0.66	0.62
Latent Eff. at 75% Heating Air Flow	0.50	0.00	0.50	0.43	0.40	0.00
Sensible Eff. at 100% Cooling Air Flow	0.66	0.50	0.66	0.62	0.61	0.60
Latent Eff. at 100% Cooling Air Flow	0.41	0.00	0.41	0.33	0.31	0.00
Sensible Eff. at 75% Cooling Air Flow	0.69	0.52	0.69	0.66	0.64	0.62
Latent Eff. at 75% Cooling Air Flow	0.45	0.00	0.45	0.38	0.35	0.00

B.2.4 Addendum *k*: Hotel/Motel HVAC Guest Room Controls

Addendum Description. Standard 90.1-2016 already requires hotel/motel guest rooms to have automatic setback thermostat setpoint and shut off ventilation for rooms that are either rented and unoccupied, or unrented and unoccupied. Addendum *k* clarifies the language by calling out the two modes with the same intent, and the clarification does not have quantifiable energy impacts. The addendum saves a little bit more energy by reducing the time-out period for unoccupied indication from 30 minutes to 20 minutes. Consequently, there will be 10 minutes more per cycle with reduced ventilation and setback heating and cooling, reducing energy use.

Modeling Strategy. The baseline Small Hotel and Large Hotel prototypes were already modeled to meet the control requirements through thermostat and ventilation schedules. The schedules in their advanced models were slightly adjusted to capture the added savings from the reduced time-out period.

B.2.5 Addenda *v* and *bd*: Heat Recovery Chiller and Its Efficiency

Addendum Description. Addendum *v* adds a new code section that requires acute inpatient hospital mechanical systems to include heat recovery for space conditioning in all climate zones except 6B, 5C, 7 and 8. The requirement is limited to hospitals that include spaces that are used on a 24-hour basis and have an installed total design chilled water capacity at design conditions that exceed 300 tons (1,100 kW). The cooling capacity of the heat recovery system is required to be 7% of the total design chilled water capacity at peak design conditions.

Addendum *bd* adds new minimum performance requirements for air- and water-cooled heat pump chillers. The new requirements are split between two categories: cooling-only performance and heating operation. While cooling-only requirements have been defined as being the same as defined in Table

6.8.1-3 less 5% (to take into account the impact of additional hardware needed for heat recovery), the heating performance of these machines is described by three new metrics defined in AHRI Standard 550/590: heating coefficient of performance (COP_H), heat recovery coefficient of performance (COP_{HR}) and simultaneous heating and cooling coefficient of performance (COP_{SHC}).

Modeling Strategy. The only prototype that is targeted by the language in Addendum *v* is the Hospital. As per the addendum description, since the total design chilled water capacity at design conditions exceeds 300 tons in all climate zones, heat recovery chillers were modeled in all Hospital models except in 6B, 5C, 7 and 8.

Different configurations can be employed with a heat recovery chiller, such configurations include "preferential loading" or "sidestream." In the "preferential loading" configuration, the chiller is in parallel with the other chillers, whereas in the "sidestream" configuration, the heat recovery chiller is placed in series, ahead of the other chillers; it pre-cools some of the water returning from the cooling coils. This configuration is typically preferred and hence was chosen for modeling the impact of Addendum *v*.

Heat recovery chillers can have a single or a double condenser bundle. The former allows the chiller to transfer the condenser heat to a hot water loop, whereas the latter allows the chiller to transfer heat to both a hot and a condenser water loop. By having the ability to reject heat to a condenser loop, the chiller heat transferred to the hot water loop can be modulated to not operate above a specific inlet water temperature and/or controlled to meet a setpoint. A double-bundled chiller was modeled to estimate the impact of Addendum *v*.

In EnergyPlus, most chiller objects have heat recovery capabilities whether it is through the condenser bundle or through a dedicated heat recovery bundle (double-bundled chiller). To model such a configuration, that is a "sidestream" double-bundled chiller, heat is recovered from the chiller through a dedicated heat recovery loop which is transferred to the hot water loop using an ideal water heater with (with 100% efficiency, acting as an ideal fluid-to-fluid heat exchanger). The second bundle of the chiller is connected to the condenser water loop.

To benefit from heat recovery, a hot water loop setpoint reset strategy was implemented: 140°F at 20°F outdoor air dry-bulb temperature moving linearly to 120°F at 50°F outdoor air dry-bulb temperature. A reset strategy was also implemented for the chilled water loop: 44°F at 70°F outdoor air dry-bulb moving linearly to 48°F at 55°F outdoor air dry-bulb. Ideally, the heat recovery chiller operation would be controlled based on the desired water temperature leaving the heat recovery bundle, but this strategy is not currently available in EnergyPlus. As a solution, the heat recovery chiller was simulated to provide a maximum water temperature of 120°F and controlled based on the return water temperature and hot water loop load relative to the chiller heat recovery output to minimize excess heat rejection. This control strategy was implemented in an EnergyPlus energy management system (EMS) program.

B.2.6 Addendum *ap*: SAT Reset

Addendum Description. HVAC systems with simultaneous heating and cooling (typically multiple-zone VAV systems) were previously required to provide supply air temperature (SAT) reset except in climate zones 0A through 3A. In these climate zones, several approaches can successfully dehumidify the outside air while still providing SAT reset and reducing reheat energy use. Addendum *ap* extends the requirement for SAT reset to the warm and humid climate zones where it was previously excepted. The dehumidification requirements of addendum *ap* can be met with either a separate outside air cooling coil or alternative approaches including bypassing return air around the cooling coil, a dedicated outside air system, or series heat recovery.

Units smaller than 3000 cfm are excepted from SAT reset in climate zones 0A, 1A and 3A, with units smaller than 10,000 cfm excepted in 2A. There are also requirements that the system is designed to allow simultaneous SAT reset and dehumidification with one of the strategies discussed above.

Supply air temperature reset saves significant heating energy in VAV reheat systems that require minimum airflow for ventilation. That savings is higher in northern climate zones than in climate zones 0A through 3A, which were previously excepted because outside air dehumidification—typically performed with a low dewpoint on the supply air—is required much of the year. Dehumidification can be achieved more efficiently by separately dehumidifying the outside air, as it reduces the total volume of air that must be cooled, significantly reducing cooling energy use in all the warm and humid climate zones and allowing SAT reset that reduces reheat energy use.

Modeling Strategy. Seven prototypes have multiple-zone VAV systems, and only Hospital and Outpatient Healthcare include a few air handling units (AHUs) with active dehumidification control modeled with a zone humidistat that triggers the central cooling coils to reduce the setpoint, increasing latent cooling during dehumidification. These AHUs are not modeled with SAT reset for all climates because its interaction with the dehumidification controls and the energy use cannot be captured using the prototype models without significant custom modeling and testing. All other VAV systems are modeled with SAT reset except for 0A, 1A, 2A, and 3A, which meet the current SAT reset requirements and exceptions in Standard 90.1-2016.

To capture the savings to the AHUs without active dehumidification control, the sample HVAC system designs in the Informative Note in Addendum *ap* were not used. It was found that simply adding outdoor-air-temperature-based SAT reset controls to the VAV AHUs in Climate Zones 0A, 1A, 2A, and 3A was sufficient to estimate savings and did not cause much increase to the indoor humidity level.

B.2.7 Addenda *au*, *cm*, and *co*: DDC VAV Minimum Damper and Simplified Ventilation Procedure

Addendum Description. Addendum *co* reflects the periodic update of Standard 90.1 normative references. It updates many references with new effective dates and adds some new references. One of them (i.e., the Addendum *f* to Standard 62.1-2016, Ventilation for Acceptable Indoor Air Quality), in particular, creates a “Simplified Procedure” to determine system ventilation efficiency. Addenda *au* and *cm* take advantage of the changes in Standard 62.1 to reduce the minimum airflow required in VAV boxes and outdoor air intake of the AHUs; hence, these reduce energy used to condition outdoor air intake and reheat of cooled primary air.

Addenda *au* and *cm* refer to this new minimum primary airflow rate to replace the provision in Standard 90.1 that allows VAV box minimum setpoints to be 20% of the design supply air rate. Outdoor air rates for zones with moderate occupancy density, such as offices, are generally much lower than 20% of the design supply air rate, but designers often need a higher percentage or an oversized VAV box when they follow the system ventilation efficiency specified in Standard 62.1 and its Normative Appendix A Multiple-zone System Ventilation Efficiency. With these addenda, Appendix A in Standard 62.1 becomes an alternative to the Simplified Procedure, by which designers no longer need to calculate what minimum rates are required using the multiple spaces equations in Appendix A. They now can set the minimum primary airflow to be 1.5 times the ventilation zone airflow. The system ventilation efficiency from the Simplified Procedure is generally higher than that calculated using Appendix A, which means the outdoor air intake through the AHU is less. Moreover, using percentages to determine minimums is problematic because VAV boxes are almost always oversized due to conservative load assumptions for occupants, lights, plug loads, etc. It is not unusual for boxes to be sized three or more times larger than they need to be, as was found in ASHRAE RP-1515 “Thermal and air quality acceptability in buildings that reduce energy by reducing minimum airflow from overhead diffusers.” (Arens et al. 2015) RP-1515 showed that even if the minimums were set to 20% instead of 30%, excess minimum air would have been supplied due to the oversized cooling maximum box sizing, wasting fan energy, reheat energy, and cooling energy.

In summary, Addenda *au* and *cm* save energy by 1) reducing outdoor air intake at the central system; and 2) reducing the actual airflow minimums in VAV boxes using the cfm-based approach rather than percentage-based minimums previously used in 90.1. When the minimum airflow in VAV boxes is reduced, less air volume needs to be reheated, saving both cooling and heating energy.

Modeling Strategy. There are 7 prototype buildings with multiple-zone VAV systems (i.e., Medium Office, Large Office, Primary School, Secondary School, Outpatient Healthcare, and Hospital). Section 2.2.6 in the PNNL report *Enhancements to ASHRAE Standard 90.1 Prototype Building Models* (Goel et al. 2014) describes the modeling strategy used in the baseline prototypes to calculate system ventilation efficiency using Appendix A of Standard 62.1-2013. Where the efficiency is lower than 0.6, VAV box minimums of the critical zones are adjusted from 20% to be higher values to reach a target efficiency of 0.6. Then, the design outdoor air intake is determined using this efficiency and can be dynamically reset during the operation using the dynamic efficiency reflecting the zone loads at each time step. For VAV systems serving low occupancy density zones, the VAV box minimums remain at 20%.

In the advanced prototypes, the VAV box minimum, system ventilation efficiency, and design and operation outdoor air intake are based on different calculations as required by Addenda *au* and *cm* and the referenced Addendum *f* to Standard 62.1-2016. The VAV box minimum ($V_{pz\text{-}min}$) is changed to

$$V_{pz\text{-}min} = V_{oz} \times 1.5$$

Where,

$V_{pz\text{-}min}$ is minimum primary airflow, and

V_{oz} is ventilation zone airflow.

The Simplified Procedure allows the system ventilation efficiency and the corresponding outdoor air intake flow to be determined in accordance with the following equations

$$E_v = 0.88 * D + 0.22 \text{ for } D<0.60$$

$$E_v = 0.75 \text{ for } D \geq 0.60$$

$$V_{ot} = V_{ou} / Ev$$

Where,

E_v is the system ventilation efficiency, and

D is the occupancy diversity ratio,

V_{ot} is the design outdoor air intake flow

V_{ou} is the uncorrected outdoor air intake.

To simplify the calculation, we assumed D always to be greater than 0.6 for all VAV systems in the prototypes. The change in E_v from 0.6 to 0.75 results in a significant reduction in the design outdoor air intake flow. Although both editions require Multiple-Zone VAV System Ventilation Optimization Control, also known as dynamic ventilation reset, in Section 6.5.3.3 of Standard 90.1, the design outdoor air intake flow serves a maximum outdoor air, which leads to energy reduction. The dynamic ventilation reset can be modeled using native EnergyPlus controls, which are able to follow the Normative Appendix A Multiple-zone System Ventilation Efficiency in Standard 62.1-2016 during the operational hours.

PNNL consulted with the SSPC 90.1 Mechanical Subcommittee experts and clarified that Appendix A is intended to be used during building operation for 90.1-2019. The reduced design outdoor air intake flow V_{ot} calculated with the Simplified Procedure should be used as the maximum outside airflow for the dynamic ventilation reset, except for economizer mode, and the maximum is implemented in the prototypes through an EMS program.

B.2.8 Addendum *be*: CRAC Unit Efficiencies

Addendum Description. Addendum *be* clarifies that the computer room air conditioners listed in Table 6.8.1-11 are floor mounted computer room units. Efficiency requirements were modified to align with current industry levels. The addendum also adds a new Table 6.8.1-19 that covers small ceiling-mounted computer room units.

Modeling Strategy. Computer rooms and IT closets were added to the Large Office prototype as part of an enhancement in 2014 (Goel et al. 2014). Computer room air conditioning (CRAC) units were modeled as water source heat pumps (WSHP) to simulate a water-cooled air conditioner during its debut into the prototypes, and the modeled efficiency was based on Standard 90.1-2010 efficiency requirements. Seasonal coefficient of performance (SCOP) was converted to coefficient of performance (COP) inputs along with performance curves that correspond to the WSHP configurations used in EnergyPlus.

The CRAC unit efficiency requirements were introduced in 90.1-2010 and were updated in 2013 and 2016; however, these interim changes were not included in the prior analysis because there was pending federal rulemaking. The analysis of Addendum *be* includes the change to the 90.1-2019 efficiencies. The baseline and improved COP for the CRAC units in the basement computer rooms and IT closets is based on typical equipment sizes used in data centers, even though the EnergyPlus model thermal zoning grouped areas that would be served by multiple CRAC units into a large thermal zone and modeled them as one unit.

This addendum saves energy by reducing the compressor energy needed to transfer heat from the data center area and reject it outside. Because there is less compressor heat to reject, there is also a reduction in the fan use in the dry cooler that provides heat rejection for the water cooled CRAC units.

B.2.9 Addendum *bq*: Heat Rejection Efficiency

Addendum Description. Addendum *bq* raises the minimum efficiencies for axial and centrifugal fan evaporative condensers due to a change in the rating fluid to R-448A from R-507A, with R-448A having a lower Global Warming Potential (GWP). The addendum also adds axial fan, air cooled fluid coolers (better known as dry coolers) to Table 6.8.1.7. The addendum saves energy for buildings with heat rejection equipment.

Modeling Strategy. The minimum efficiency requirement for dry coolers introduced by this addendum impacts the Large Office prototype. The dry cooler in the Large Office prototype is modeled using the FluidCooler:TwoSpeed object. Since the dry cooler efficiency is not a direct EnergyPlus input, modeled efficiency must be calculated as:

$$\text{Dry Cooler efficiency} = \text{pump (gpm)} / \text{fan (bhp)},$$

Where,

$$\text{fan(bhp)} = \text{fan (hp at high speed)} * 0.9.$$

The pump flow rate is dependent on the loads it serves, and the dry cooler serves the computer rooms and IT closets, in which the loads remain relatively constant across different climate zones. Per suggestions from SSPC 90.1 Mechanical Subcommittee experts, the baseline efficiency is assumed to be 4.0 gpm/hp and that for the advanced model is 4.5 gpm/hp based on Addendum *be*.

B.3 Lighting Addenda

B.3.1 Addenda *bb* and *cg*: LPD Values

Addendum Description. Addendum *bb* modifies the lighting power density (LPD) allowances using the space-by-space method. This addendum results in changes in Table 9.6.1. Addendum *cg* modifies the lighting power allowances using the building area method. The values from Addendum *bb* (Table 9.6.1, space-by-space) were used by the SSPC 90.1 Lighting Subcommittee to update Table 9.5.1, building area method as part of Addendum *cg*. The changes in LPD are the result of improving lighting technology, changes in lighting baseline (model is 100% LED), changes to Illuminating Engineering Society (IES) recommended light levels, changes to space geometry assumptions, and additional room surface reflectance values. The addenda save energy in multiple ways. There is direct lighting power reduction. In addition, the reduced lighting power reduces the internal gains which reduces cooling loads and saves cooling energy. In some climate zones, the reduction in lighting power results in an increased need for heating during colder outside conditions, so there may be an increase in heating energy use. These three impacts are combined for a net savings of building energy.

Modeling Strategy. Addenda *bb* and *cg* collectively affect all prototypes. The following describes how the appropriate LPD allowance is chosen for the prototype buildings:

1. The Large Office, Medium Office, and Small Office prototypes use the office building LPD allowance from the building area method (Table 9.5.1). Similarly, the basement zone in the Large Hotel, Hospital, and the office zone in the Non-refrigerated Warehouse use the LPD allowance from the building area method.
2. Most other zones in the prototypes are mapped to a single space-by-space category and the LPD allowance from that category is used directly.
3. A few zones in the prototypes (for example, the Back Space zone in the Stand-alone Retail prototype) are considered a mix of two or more space types; in such cases, the NC3 database (Richman et al. 2008) is used to determine the mix of spaces and their proportion. This weighting is then applied to determine a single LPD allowance for those spaces.
4. A room cavity ratio adjustment has been applied to a few spaces such as corridors, and exercise rooms.

Using these rules and the values in Addenda *bb* and *cg*, the LPD allowances for all prototypes and zones were determined. The design LPD allowance is modeled in EnergyPlus as a direct input to the zone general lighting object.

B.3.2 Addendum *cw*: Continuous Dimming Control

Addendum Description. Addendum *cw* changes daylight responsive requirements from either continuous dimming or stepped dimming to continuous dimming for all spaces. This measure saves energy because a stepped control cannot switch to the next lower power level until enough daylight is available to maintain the desired light level. This results in a period between steps where more than the required light level is maintained, resulting in a higher average power level that would be achieved with continuous dimming that adjusts the power smoothly to maintain just the needed lighting level. There is also a modest impact on HVAC energy use similar to the LPD reduction addenda.

Modeling Strategy. Several prototype models already have stepped daylighting control for either top lighting or side lighting, including Small, Medium, and Large Offices, Stand-alone Retail, Primary and Secondary Schools, Outpatient Healthcare, Hospital, Small and Large Hotels, Warehouse, and Quick

Service and Full Service Restaurants. This addendum affects all of them. The control type in the Energyplus prototype was changed from three steps (i.e., power fraction of 0.66, 0.33, and 0) to ContinousOff (proportionally reduces the lighting power as the daylight increases until a minimum power fraction of 0.2). The lights will be completely off when the daylight reaches the target illuminance level.

B.4 Appendix B References

Arens, E., H. Zhang, T, Hoyt, S. Kaam, J. Goins, F. Bauman, Y. Zhai, T.Webster, B. West, G. Paliaga, J. Stein, R. Seidl, B. Tully, J. Rimmer, and J. Toftum. 2012. *Thermal air quality acceptability in buildings that reduce energy by reducing minimum airflow from overhead diffusers*. Final report for ASHRAE RP-1515.

Davis R, P Francisco, M Kennedy, D Baylon, and B Manclark. 2002. *Enhanced Operations & Maintenance Procedures for Small Packaged Rooftop HVAC Systems: Protocol Development, Field Review, and Measure Assessment*. Ecotope for Eugene Water & Electric Board.

Glazer, J. 2016. *RP-1651 -- Development of Maximum Technically Achievable Energy Targets for Commercial Buildings*. Page 190, Final report for ASHRAE RP-1651.

Goel S., R.A. Athalye, W. Wang, J. Zhang, M.I. Rosenberg, Y. Xie, and R. Hart, V. Mendon. 2014. *Enhancements to ASHRAE Standard 90.1 Prototype Building Models*. PNNL-23269. Richland, WA: Pacific Northwest National Laboratory. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23269.pdf.

Richman EE, E Rauch, J Knappek, J Phillips, K Petty, and P Lopez-Rangel. 2008. "National Commercial Construction Characteristics and Compliance with Building Energy Codes: 1999-2007." *2008 ACEEE Summer Study on Energy Efficiency in Buildings*, ACEEE Publications, Washington D.C.

Thornton B.A., M.I. Rosenberg, E.E. Richman, W. Wang, Y. Xie, J. Zhang, H. Cho, VV Mendon, R.A. Athalye, and B. Liu. 2011. *Achieving the 30% Goal: Energy and Cost Savings Analysis of ASHRAE Standard 90.1-2010*. PNNL-20405. Richland, WA: Pacific Northwest National Laboratory. https://www.energycodes.gov/sites/default/files/documents/BECP_Energy_Cost_Savings_STD2010_May2011_v00.pdf.

(This page intentionally left blank)

U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

For more information, visit: energy.gov/eere/buildings

DOE/EE-2345 • 2021

Pacific Northwest
NATIONAL LABORATORY

PNNL-XXXXX

Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019 for Ohio - DRAFT

June 2021

M Tyler
Y Xie
M Rosenberg

U.S. DEPARTMENT OF ENERGY

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

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

Printed in the United States of America

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

Available to the public from the National Technical Information Service
5301 Shawnee Rd., Alexandria, VA 22312
ph: (800) 553-NTIS (6847)
email: orders@ntis.gov <https://www.ntis.gov/about>
Online ordering: http://www.ntis.gov

PNNL-XXXXX

Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019 for Ohio - DRAFT

June 2021

M Tyler
Y Xie
M Rosenberg

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

Pacific Northwest National Laboratory
Richland, Washington 99354

Acronyms and Abbreviations

AVert	U.S. EPA Avoided Emissions and GeneRation Tool
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BECP	Building Energy Codes Program
CH_4	Methane
DOE	U.S. Department of Energy
E.O.	Executive Order
eGRID	EPA Emissions & Generation Resource Integrated Database dataset
EIA	Energy Information Administration
EPA	Environmental Protection Agency
FEMP	Federal Energy Management Program
HVAC	Heating, Ventilating, and Air-Conditioning
LCC	Life-Cycle Cost
MMT	Million Metric Tons
N_2O	Nitrous Oxide
NIST	National Institute of Standards and Technology
PNNL	Pacific Northwest National Laboratory
SC-CH_4	Social cost of Methane
SC-CO_2	Social cost of carbon
SC-N_2O	Social cost of Nitrous Oxide
UPV	Uniform Present Value

1.0 Highlights

Moving to the ASHRAE Standard 90.1-2019 (ASHRAE 2019) edition from Standard 90.1-2016 (ASHRAE 2016) is cost-effective for Ohio. Standard 90.1-2019 will provide an annual energy cost savings of $0.054 per square foot on average across the state. It will reduce statewide CO_2 emissions by 9.2 MMT (30 years cumulative), equivalent to the CO_2 emissions of 66,978 cars driven for one year.

Updating the state energy code based on Standard 90.1-2019 will also stimulate the creation of high-quality jobs across the state. Standard 90.1-2019 is expected to result in buildings that are energy efficient, more affordable to own and operate, and based on current industry standards for health, comfort, and resilience.

The tables below show the expected impact of upgrading to Standard 90.1-2019 from a consumer perspective and statewide perspective. These results are weighted averages for all building types in all climate zones in the state, based on weightings shown in Table 4. The methodology used for this analysis is consistent with the methodology used in the national cost-effectiveness analysis.[1] Additional results and details on the methodology are presented in the following sections.

Consumer Impact	
Annual (first year) energy cost savings, $/ft^2	$0.054
Added construction cost, $/ft^2	-$1.225
Publicly-owned scenario LCC Savings, $/ft^2	4.02
Privately-owned scenario LCC Savings, $/ft^2	3.57

Statewide Impact - Emissions	First Year	30 Years Cumulative
Energy cost savings, $	1,335,733	596,839,086
CO_2 emission reduction, Metric tons	13,250	9,239,187
Social cost of carbon savings, $	705,148	604,747,104
CH_4 emissions reductions, Metric tons	1.34	938
Social Cost of CH_4 savings, $	2,123	2,007,306
N_2O emissions reductions, Metric tons	0.191	133
Social Cost of N_2O savings, $	3,680	3,251,249
NOx emissions reductions, Metric tons	6.99	4,875
SOx emissions reductions, Metric tons	8.99	6,271

Statewide Impact - Jobs Created	First Year	30 Years Cumulative
Jobs Created Reduction in Utility Bills	134	4,230
Jobs Created Construction Related Activities	336	10,613

[1] National cost-effectiveness report: https://www.energycodes.gov/development/commercial/cost_effectiveness

The report provides analysis of two LCC scenarios:

- **Scenario 1**, representing *publicly-owned* buildings, considers initial costs, energy costs, maintenance costs, and replacement costs—without borrowing or taxes.
- **Scenario 2**, representing *privately-owned* buildings, adds borrowing costs and tax impacts.

Figure 1 compares annual energy cost savings, first cost for the upgrade, and net annualized LCC savings. The net annualized LCC savings per square foot is the annual energy savings minus an allowance to pay for the added cost under scenario 1. Figure 2 shows overall state weighted net LCC results for both scenarios. When net LCC is positive, the updated code edition is considered cost-effective.

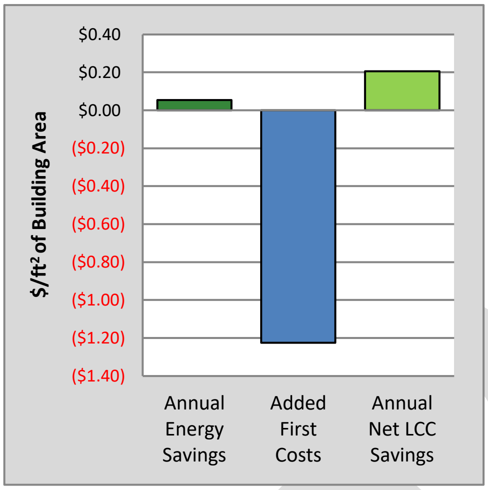


Figure 1. Statewide Weighted Costs and Savings

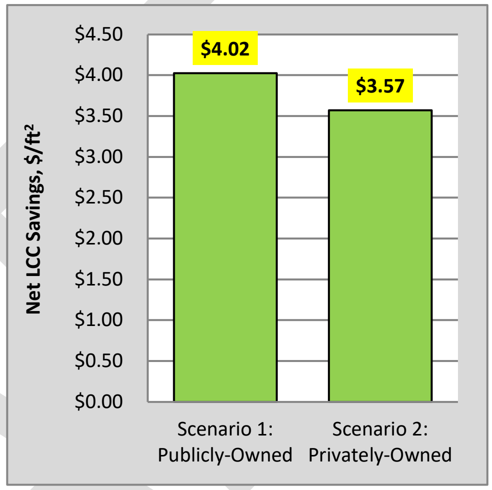


Figure 2. Overall Net Life-Cycle Cost Savings

2.0 Cost-Effectiveness Results for ASHRAE Standard 90.1-2019 in Ohio

This section summarizes the cost-effectiveness analysis results applicable to the building owner. Life Cycle Cost (LCC) savings is the primary measure established by the U.S. Department of Energy to assess the cost effectiveness and economic impact of building energy codes. Net LCC savings is the calculation of the present value of energy savings minus the present value of non-energy incremental costs over a 30-year period. The non-energy incremental costs include initial equipment and construction costs, and maintenance and replacement costs, less the residual value of components at the end of the 30-year period. When net LCC is positive, the updated code edition is considered cost-effective. Savings are computed for two scenarios:

- **Scenario 1:** represents *publicly-owned buildings*, includes costs for initial equipment and construction, energy, maintenance and replacement and does not include loans or taxes.

- **Scenario 2:** represents *privately-owned buildings*, includes the same costs as Scenario 1, with the initial investment financed through a loan amortized over 30 years and federal and state corporate income tax deductions for interest and depreciation.

Both scenarios include the residual value of equipment with remaining useful life at the end of the 30-year assessment period. Totals for building types, climate zones, and the state overall are averages based on Table 4 construction weights. Factors such as inflation and discount rates are different between the two scenarios, as described in the Cost-Effectiveness Methodology section.

LCC is affected by many variables, including the applicability of individual measures in the code, measure costs, measure lifetime, replacement costs, state cost adjustment, energy prices, and so on. In some cases, the LCC can be negative for a given building type or climate zone based on the interaction of these variables. However, the code is considered cost-effective if the weighted statewide LCC is positive.

Table 1 shows the present value of the net LCC savings over 30 years for buildings in scenario 1 averages $4.02 per square foot for Standard 90.1-2019.

Table 1. Net LCC Savings for Ohio, Scenario 1 ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
4A	$3.78	$3.79	$3.99	$4.54	$12.83	$1.90	$3.76
5A	$3.73	$3.79	$4.06	$4.50	$12.79	$1.88	$4.22
State Average	$3.75	$3.79	$4.04	$4.51	$12.80	$1.89	**$4.02**

Table 2 shows the present value of the net LCC savings over 30 years averages $3.57 per square foot for scenario 2.

Table 2. Net LCC Savings for Ohio, Scenario 2 ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
4A	$3.26	$3.21	$3.51	$3.91	$12.37	$1.73	$3.33
5A	$3.21	$3.21	$3.57	$3.88	$12.33	$1.72	$3.74
State Average	$3.23	$3.21	$3.55	$3.89	$12.34	$1.73	**$3.57**

2.1 Energy Cost Savings

Table 3 shows the economic impact of upgrading to Standard 90.1-2019 by building type and climate zone in terms of the annual energy cost savings in dollars per square foot. The annual energy cost savings across the state averages $0.054 per square foot.

Table 3. Annual Energy Cost Savings for Ohio ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
4A	$0.039	$0.048	$0.077	$0.056	$0.069	$0.017	$0.049
5A	$0.038	$0.048	$0.078	$0.056	$0.067	$0.016	$0.057
State Average	$0.038	$0.048	$0.078	$0.056	$0.068	$0.017	**$0.054**

2.2 Construction Weighting of Results

Energy and economic impacts were determined and reported separately for each building type and climate zone. Cost-effectiveness results are also reported as averages for all prototypes and climate zones in the state. To determine these averages, results were combined across the different building types and climate zones using weighting factors shown in Table 4. These weighting factors are based on the floor area of new construction and major renovations for the six analyzed building prototypes in state-specific climate zones. The weighting factors were developed from construction start data from 2003 to 2007 (McGraw Hill Construction 2007) based on an approach developed by Jarnagin and Bandyopadhyay (2010).

Table 4. Construction Weights by Building Type

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
4A	4.3%	3.8%	13.2%	6.9%	1.6%	12.4%	42.1%
5A	7.7%	1.9%	24.7%	11.9%	2.9%	8.6%	57.9%
State Average	12.0%	5.8%	37.9%	18.8%	4.5%	21.0%	100.0%

2.3 Incremental Construction Cost

Cost estimates were developed for the differences between Standard 90.1-2016 and Standard 90.1-2019 as implemented in the six prototype models. Costs for the initial construction include material, labor, commissioning, construction equipment, overhead and profit. Costs were also estimated for replacing equipment or components at the end of the useful life. The costs were developed at the national level for the national cost-effectiveness analysis and then adjusted for local conditions using a state construction cost index (Hart et al. 2019, Means 2020a,b).

Table 5 shows incremental initial cost for individual building types in state-specific climate zones and weighted average costs by climate zone and building type for moving to Standard 90.1-2019 from Standard 90.1-2016.

The added construction cost can be negative for some building types, which represents a reduction in first costs and a savings that is included in the net LCC savings. This is typically due to the interaction between measures and situations such as the following:

- Fewer light fixtures are required when the allowed lighting power is reduced. Also, changes from fluorescent to LED technology result in reduced lighting costs in many cases and longer lamp lives, requiring fewer lamp replacements.
- Smaller heating, ventilating, and air-conditioning (HVAC) equipment sizes can result from the lowering of heating and cooling loads due to other efficiency measures, such as better building envelopes. For example, Standard 90.1-2019 has more stringent fenestration U-factors for some climate zones. This results in smaller equipment and distribution systems, resulting in a negative first cost.

Table 5. Incremental Construction Cost for Ohio ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
4A	($1.722)	($1.967)	($1.266)	($1.990)	$0.646	($0.362)	($1.158)
5A	($1.701)	($1.975)	($1.297)	($1.973)	$0.651	($0.366)	($1.274)
State Average	($1.708)	($1.970)	($1.286)	($1.979)	$0.649	($0.364)	**($1.225)**

2.4 Simple Payback

Simple payback is the total incremental first cost divided by the annual savings, where the annual savings is the annual energy cost savings less any incremental annual maintenance cost. Simple payback is not used as a measure of cost-effectiveness as it does not account for the time value of money, the value of energy cost savings that occur after payback is achieved, or any replacement costs that occur after the initial investment. However, it is included in the analysis for states who wish to use this information. Table 6 shows simple payback results in years.

Table 6. Simple Payback for Ohio (Years)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
4A	Immediate	Immediate	Immediate	Immediate	9.4	Immediate	Immediate
5A	Immediate	Immediate	Immediate	Immediate	9.7	Immediate	Immediate
State Average	Immediate	Immediate	Immediate	Immediate	9.6	Immediate	**Immediate**

3.0 Societal Benefits

3.1 Benefits of Energy Codes

It is estimated that by 2060, the world will add 2.5 trillion square feet of buildings, an area equal to the current building stock. As a building's operation and environmental impact is largely determined by upfront decisions, energy codes present a unique opportunity to assure savings through efficient building design, technologies, and construction practices. Once a building is constructed, it is significantly more expensive to achieve higher efficiency levels through later modifications and retrofits. Energy codes ensure that a building's energy use is included as a fundamental part of the design and construction process. Making this early investment in energy efficiency will pay dividends to residents of Ohio for years into the future.

3.2 Greenhouse Gas Emissions and Social Costs

The urban built environment is responsible for 75% of annual global greenhouse gas (GHG) emissions while buildings alone account for 39%.[2] On January 20, 2021, President Biden issued Executive Order (E.O.) 13990,[3] which noted that it is essential that agencies capture the full costs of greenhouse gas emissions as accurately as possible, including by taking global damages into account and that doing so facilitates sound decision-making, recognizes the breadth of climate impacts, and supports the international leadership of the United States on climate issues. To that end, DOE is including estimates of the absolute cost and relative costs savings of greenhouse gas emissions associated with the building energy use examined in this analysis.

The principal greenhouse gas associated with building energy use as examined in this analysis is carbon dioxide (CO_2). The current analysis estimates the global social benefits of CO_2 emission reductions expected from implementation of Standard 90.1-2019 using the social cost of carbon (SC-CO_2) estimates presented in the *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990* (IWG 2021). These SC-CO_2 estimates are interim values established by the U.S. Government for use in benefit-cost analyses until an improved estimate of the impacts of climate change can be developed based on the best available science and economics. These SC-CO_2 estimates are the same as those used in the *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866* (IWG 2016), but are updated to 2020$.

While carbon dioxide emissions represent the largest share of greenhouse gas emissions, building electricity use and on-site fossil fuel consumption also contribute to the release of other emissions, two of which methane (CH_4) and nitrous oxide (N_2O) are significant greenhouse gases in their own right. In order to characterize the global social benefits of CH_4 and N_2O emission reductions, the current analysis uses estimates of the social cost of methane (SC-CH_4) and social cost of nitrous oxide (SC-N_2O) also presented in *Technical Support Document: Social*

---

[2] Architecture 2030, https://architecture2030.org/2030_challenges/2030-challenge

[3] Exec. Order No. 13990, 86 Fed. Reg. 7037 (January 20, 2021) https://www.federalregister.gov/documents/2021/01/25/2021-01765/protecting-public-health-and-the-environment-and-restoring-science-to-tackle-the-climate-crisis

Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990 (IWG 2021).

Four separate scenarios are presented in IWG 2021 for evaluating the global social cost for greenhouse gas emissions. A value of $51 (2020$/Metric Ton CO2) is used in this analysis reflecting a SC-CO_2 present value per metric ton of carbon dioxide emissions avoided in 2020. A value of $1,485 (2020$/Metric Ton CH_4) is used reflecting a SC-CH_4 present value per metric ton of methane emissions avoided in 2020, and a value of $18,405 (2020$/Metric Ton N_2O) is used reflecting a SC-N_2O present value per metric ton of nitrous oxide emissions avoided in 2020. Each of these valuations are based on a 3% discount rate and the average global damage estimate from three integrated assessment models (IAMs). The social cost valuation in 2020$ for each listed emission increases in later years as identified in the above reference based on the analysis of the cost of future damage impacts and the 3-percent discounting of those damages. While the social cost valuations per ton are significantly larger for CH_4 and N_2O than for CO_2, the associated physical emissions due to building energy consumption are significantly smaller. Carbon emission savings are calculated based on the changes in site energy consumption by fuel for the state. For natural gas combusted on site, emission metrics are developed using nationwide emission factors from U.S. Environmental Protection Agency publications for CO_2, NOx, SO_2, CH_4 and N_2O (EPA 2014).

For electricity, marginal carbon emission factors are provided by the U.S. Environmental Protection Agency (EPA) AVoided Emissions and GeneRation Tool (AVert) version 3.0 (EPA 2020). The AVert tool forms the basis of the national marginal emission factors for electricity also published by EPA on its Greenhouse Gas Equivalencies Calculator website and are based on a portfolio of energy efficiency measures examined by EPA. AVert is used here to provide CO_2 emission factors at the State level.[4] AVert also provides marginal emission factor estimates for gaseous pollutants associated with electricity production, including NOx and SO_2 emissions. While not considered significant greenhouse gases, these are EPA tracked pollutants. The current analysis uses AVert to provide estimates of corresponding emission changes for NOx and SO_2 in physical units but does not monetize these.

AVert does not develop associated marginal emissions factors for CH_4 or N_2O. To provide estimates for the associated emission reductions for CH_4 and N_2O, this report uses emission factors separately provided through the U.S. Environmental Protection Agency (EPA) Emissions & Generation Resource Integrated Database (eGRID) dataset. eGRID is a comprehensive source of data on the environmental characteristics of almost all electric power generated in the United States and the emission characteristics for electric power generation for each of the above emissions can also be found aggregated down to the state level in eGRID (EPA 2021a). The summary emission factor data provided by eGRID does not provide marginal emission factors, but instead summarizes emission factors in terms of total generation emission factors and non-baseload generation emission factors. Non-baseload emission factors established in eGRID are developed based on the annual load factors for the individual generators tracked by

[4] AVert models avoided emissions in 14 geographic regions of the 48 contiguous United States and includes transmission and distribution losses. Where multiple AVERT regions overlap a state's boundaries, the emission factors are calculated based on apportionment of state electricity savings by generation across generation regions. The most recent AVert 3.0 model uses EPA emissions data for generators from 2019. Note that AVert estimates are based on marginal changes to demand and reflect current grid generation mix. Emission factors for electricity shown in Table 14 do not take into account long term policy or technological changes in the regional generation mix that can impact the marginal emission benefits from new building codes.

the EPA (EPA 2021b). Because changes in building codes are unlikely to significantly impact baseload electrical generators, the current analysis uses the 2019 non-baseload emission factors established in eGRID by state to estimate CH_4 or N_2O emission reductions due to changes in electric consumption.

Table 7 summarizes the marginal emission factors available from AVert, eGRID and the EPA Greenhouse Gas Equivalencies Calculator.

Table 7. Greenhouse Gas Emission Factors by Fuel Type

GHG	Electricity lb/MWh	Natural Gas (lb/mmcf)
CO_2	1,567	120,000
SO_2	1.194	0.6
NO_X	0.774	96
N_2O	0.025	0.23
CH_4	0.175	2.3

Table 8 shows the emissions-related societal benefits due to efficiency gains in Standard 90.1-2019. Results are statewide and weighted by building type and climate zone.

Table 8. Societal Benefits of Standard 90.1-2019

Statewide Impact	First Year	30 Years Cumulative
Energy cost savings, million $	1,335,733	596,839,086
CO_2 emission reduction, Metric tons	13,250	9,239,187
Social cost of carbon savings, $	705,148	604,747,104
CH_4 emissions reductions, Metric tons	1.34	938
Social Cost of CH_4 savings, $	2,123	2,007,306
N_2O emissions reductions, Metric tons	0.191	133
Social Cost of N_2O savings, $	3,680	3,251,249
NOx emissions reductions, Metric tons	6.99	4,875
SOx emissions reductions, Metric tons	8.99	6,271

3.3 Jobs Creation through Energy Efficiency

Energy-efficient building codes impact job creation through two primary value streams:

1. Dollars returned to the economy through reduction in utility bills and resulting increase in disposable income, and;
2. An increase in construction-related activities associated with the incremental cost of construction that is required to produce a more energy efficient building.

When a building is built to a more stringent energy code, there is the long-term benefit of the ratepayer paying lower utility bills.

- This is partially offset by the increased cost of that efficiency, establishing a relationship between increased building energy efficiency and additional investments in construction activity.

- Since building codes are cost-effective, (i.e., the savings outweigh the investment), a real and permanent increase in wealth occurs that can be spent on other goods and services in the economy, just like any other income, generating economic benefits and creating additional employment opportunities.

Table 9 shows the number of jobs created because of efficiency gains in Standard 90.1-2019.

Table 9. Jobs Created from Standard 90.1-2019

Statewide Impact	First Year	30 Years Cumulative
Jobs Created Reduction in Utility Bills	134	4,230
Jobs Created Construction Related Activities	336	10,613

4.0 Overview of the Cost-Effectiveness Methodology

This analysis was conducted by Pacific Northwest National Laboratory (PNNL) in support of the DOE Building Energy Codes Program. DOE is directed by federal law to provide technical assistance supporting the development and implementation of residential and commercial building energy codes. The national model energy codes – the International Energy Conservation Code (IECC) and ANSI/ASHRAE/IES Standard 90.1 – help adopting states and localities establish minimum requirements for energy-efficient building design and construction, as well as mitigate environmental impacts and ensure residential and commercial buildings are constructed to modern industry standards.

The current analysis evaluates the cost-effectiveness of Standard 90.1-2019 relative to Standard 90.1-2016. The analysis covers six commercial building types. The analysis is based on the current prescriptive requirements of Standard 90.1. The simulated performance rating method is not in the scope of this analysis, as it is generally based on the core prescriptive requirements of Standard 90.1, and due to the unlimited range of building configurations that are allowed. Buildings complying via this path are generally considered to provide equal or better energy performance compared to the prescriptive requirements, as the intent of these paths is to provide additional design flexibility and cost optimization, as dictated by the builder, designer, and owner.

The current analysis is based on the methodology by DOE for assessing building energy codes (Hart and Liu 2015). The LCC analysis perspective described in the methodology appropriately balances upfront costs with longer term consumer costs and savings and is therefore the primary economic metric by which DOE evaluates the cost-effectiveness of building energy codes.

4.1 Cost-Effectiveness

DOE has established standard economic LCC cost-effectiveness analysis methods in comparing Standard 90.1-2019 and Standard 90.1-2016, which are described in *Methodology for Evaluating Cost-effectiveness of Commercial Energy Code Changes* (Hart and Liu 2015). Under this methodology, two metrics are used:

- **Net LCC Savings:** This is the calculation of the present value of energy savings minus the present value of non-energy incremental costs over a 30-year period. The costs include initial equipment and construction costs, maintenance and replacement costs, less the residual value of components at the end of the 30-year period. When net LCC is positive, the updated code edition is considered cost-effective.
- **Simple Payback:** While not a true cost-effectiveness metric, simple payback is also calculated. Simple payback is the number of years required for accumulated annual energy cost savings to exceed the incremental first costs of a new code.

Two cost scenarios are analyzed:

- **Scenario 1** represents publicly-owned buildings, considers initial costs, energy costs, maintenance costs, and replacement costs without borrowing or taxes.
- **Scenario 2** represents privately-owned buildings and includes the same costs as Scenario 1 plus financing of the incremental first costs through increased borrowing with tax impacts

including mortgage interest and depreciation deductions. Corporate tax rates are applied. Economic analysis factors such as discount rates are also different, as described in Table 9.

The cost-effectiveness analysis compares the cost for new buildings meeting Standard 90.1-2019 versus new buildings meeting Standard 90.1-2016. The analysis includes energy savings estimates from building energy simulations and LCC and simple payback calculations using standard economic analysis parameters. The analysis builds on work documented in *Energy Savings Analysis: ANSI/ASHRAE/IES Standard 90.1-2019* (DOE 2021), and the national cost-effectiveness analysis documented in *National Cost-effectiveness of ANSI/ASHRAE/IES Standard 90.1- 2019* (Tyler et al. 2021).

4.2 Building Prototypes and Energy Modeling

The cost-effectiveness analysis uses six building types represented by six prototype building energy models. These six models represent the energy impact of five of the eight commercial principal building activities that account for 74% of the new construction by floor area covered by the full suite of 16 prototypes. These models provide coverage of the significant changes in ASHRAE Standard 90.1 from 2016 to 2019 and are used to show the impacts of the changes on annual energy usage. The prototypes represent common construction practice and include the primary conventional HVAC systems most commonly used in commercial buildings.[5]

Each prototype building is analyzed for each of the climate zones found within the state. Using the U.S. DOE EnergyPlus software, the six building prototypes summarized in Table 9 are simulated with characteristics meeting the requirements of Standard 90.1-2016 and then modified to meet the requirements of the next edition of the code (Standard 90.1-2019). The energy use and energy cost are then compared between the two sets of models.

Table 9. Building Prototypes

Building Prototype	Floor Area (ft²)	Number of Floors
Small Office	5,500	1
Large Office	498,640	13
Stand-Alone Retail	24,690	1
Primary School	73,970	1
Small Hotel	43,210	4
Mid-Rise Apartment	33,740	4

4.3 Climate Zones

Climate zones are defined in ASHRAE Standard 169, as specified in ASHRAE Standard 90.1, and include eight primary climate zones in the United States, the hottest being climate zone 1 and the coldest being climate zone 8. Letters A, B, and C are applied in some cases to denote the level of moisture, with A indicating humid, B indicating dry, and C indicating marine. Figure 3 shows the national climate zones. For this state analysis, savings are analyzed for each climate zone in the state using weather data from a selected city within the climate zone and state, or where necessary, a city in an adjoining state with more robust weather data.

[5] More information on the prototype buildings and savings analysis can be found at www.energycodes.gov/development/commercial/90.1_models

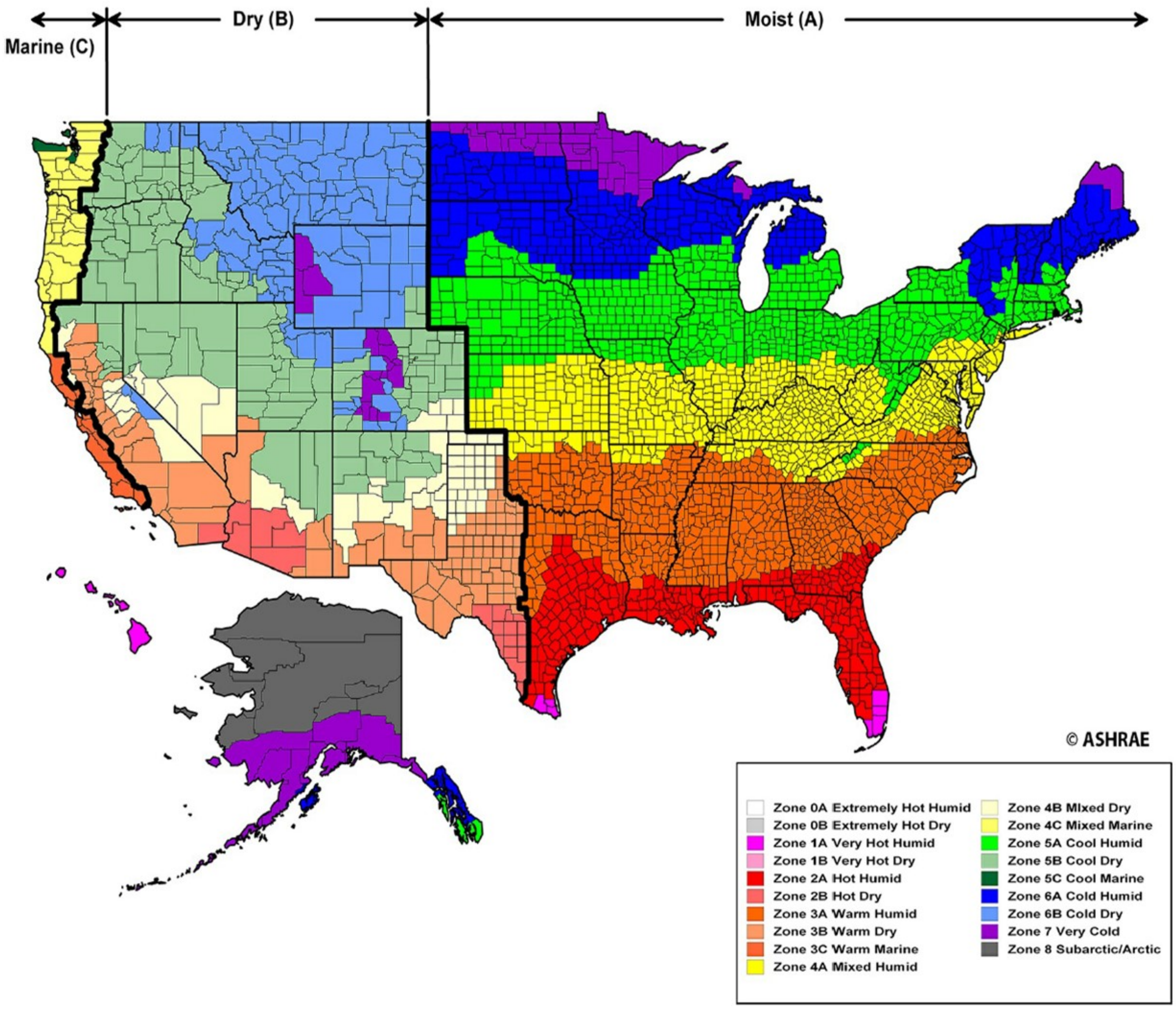


Figure 3. National Climate Zones

4.4 Cost-Effectiveness Method and Parameters

The DOE cost-effectiveness methodology accounts for the benefits of energy efficient building construction over a multi-year analysis period, balancing initial costs against longer term energy savings. DOE evaluates energy codes and code proposals based on LCC analysis over a multi-year study period, accounting for energy savings, incremental investment for energy efficiency measures, and other economic impacts. The value of future savings and costs are discounted to a present value, with improvements deemed cost-effective when the net LCC savings (present value of savings minus cost) is positive.

The U.S. DOE Building Energy Codes Program has established LCC analysis criteria similar to the method used for many federal building projects, as well as other public and private building projects (Fuller and Petersen 1995). The LCC analysis method consists of identifying costs (and revenues if any) and in what year they occur; then determining their value in today's dollars (known as the present value). This method uses economic relationships about the time value of money. Money in-hand today is normally worth more than money received in the future, which is why we pay interest on a loan and earn interest on savings. Future costs are discounted to the present based on a discount rate. The discount rate may reflect the interest rate at which money can be borrowed for projects with the same level of risk or the interest rate that can be earned on other conventional investments with similar risk.

The LCC includes incremental initial costs, repairs, maintenance, and replacements. Scenario 2 also includes loan costs and tax impacts including mortgage interest and depreciation deductions. The residual value of equipment (or other component such as roof membrane) that has remaining useful life at the end of the 30-year study period is also included for both scenarios. The residual value is calculated by multiplying the initial cost of the component by the years of useful life remaining for the component at year 30 divided by the total useful life, a simplified approach included in the Federal Energy Management Program (FEMP) LCC method (Fuller and Petersen 1995). A component will have zero residual value at year 30 only if it has a 30-year life, or if it has a shorter than 30-year life that divides exactly into 30 years (for example, a 15-year life).

The financial and economic parameters used for the LCC calculations are shown in Table 10.

Table 10. LCC Economic Parameters

Economic Parameter	Scenario 1	Scenario 2
Study Period – Years[1]	30	30
Nominal Discount Rate[2]	3.10%	5.25%
Real Discount Rate[2]	3.00%	3.34%
Effective Inflation Rate[3]	0.10%	1.85%
Electricity Prices[4] (per kWh)	$0.0941	$0.0941
Natural Gas Prices[4] (per therm)	$0.5352	$0.5352
Energy Price Escalation Factors[5]	*Uniform present value factors*	*Uniform present value factors*
Electricity Price UPV[5]	19.17	17.37
Natural Gas Price UPV[5]	23.45	21.25
Loan Interest Rate[6]	NA	5.25%
Federal Corporate Tax Rate[7]	NA	21.00%
State Corporate Tax Rate[8]	NA	0.00%
Combined Income Tax Impact[9]	NA	21.00%
State and Average Local Sales Tax[10]	7.17%	7.17%
State Construction Cost Index[11]	0.925	0.925

[1] A 30-year study period captures most building components useful lives and is a commonly used study period for building project economic analysis. This period is consistent with previous and related national 90.1 cost-effectiveness analysis. It is also consistent with the cost-effectiveness analysis that was done for the residential energy code as described in multiple state reports and a summary report (Mendon et al. 2015). The federal building LCC method uses 25 years and the ASHRAE Standard 90.1 development process uses up to 40 years for building envelope code improvement analysis. Because of the time value of money, results are typically similar for any study periods of 20 years or more.
[2] The Scenario 1 real and nominal discount rates are from the National Institute of Standards and Technology (NIST) 2019 annual update in the *Report of the President's Economic Advisors, Analytical Perspectives* (referenced in the NIST 2019 annual supplement without citation) (Lavappa and Kneifel 2019). The Scenario 2 nominal discount rate is taken as the marginal cost of capital, which is set equal to the loan interest rate (see footnote 6). The real discount rate for Scenario 2 is calculated from the nominal discount rate and inflation.
[3] The Scenario 1 effective inflation rate is from the NIST 2019 annual update for the federal LCC method (Lavappa and Kneifel 2019). The Scenario 2 inflation rate is the 30 year average Producer Price Index for non-residential construction, June 1990 to June 2020 (Bureau of Labor Statistics 2021).
[4] Scenario 1 and 2 electricity and natural gas prices are state average annual prices for 2020 from the United States Energy Information Administration (EIA) *Electric Power Monthly* (EIA 2021a) and *Natural Gas Monthly* (EIA 2021b).
[5] Scenario 1 energy price escalation rates are from the NIST 2019 annual update for the FEMP LCC method (Lavappa and Kneifel 2019). The NIST uniform present value (UPV) factors are multiplied by the first-year annual energy cost to determine the present value of 30 years of energy costs and are based on a series of different annual escalation rates for 30 years. Scenario 2 UPV factors are based on NIST UPVs with an adjustment made for the scenario difference in discount rates.
[6] The loan interest rate is estimated from multiple online sources listed in the references (Commercial Loan Direct 2021; Realty Rates 2021).
[7] The highest federal marginal corporate income tax rate is applied.
[8] The highest marginal state corporate income tax rate is applied from the Federation of Tax Administrators (FTA 2021).
[9] The combined tax impact is based on state tax being a deduction for federal tax and is applied to depreciation and loan interest.
[10] The combined state and average local sales tax is included in material costs in the cost estimate (Tax Foundation 2020).
[11] The state construction cost index is based on weighted city indices from the state (Means 2020b).

5.0 Detailed Energy Use and Cost

On the following pages, specific detailed results for Ohio are included:

- Table 11 shows the average energy rates used.
- Table 12 shows the per square foot energy costs for Standard 90.1-2016 and Standard 90.1-2019 and the cost savings from Standard 90.1-2019.
- Table 13 shows the per square foot energy use for Standard 90.1-2016 and Standard 90.1-2019 and the energy use savings from Standard 90.1-2019.
- Tables 14.A and 14.B show the energy end use by energy type for each climate zone in the state.

Table 11. Energy Rates for Ohio, Average $ per unit

Electricity	$0.0941	kWh
Gas	$0.5352	Therm

Source: Energy Information Administration, annual average prices for 2020 (EIA 2021a,b)

Table 12. Energy Cost Saving Results in Ohio, $ per Square Foot

Climate Zone:	4A				5A			
Code:	90.1-2016	90.1-2019	Savings		90.1-2016	90.1-2019	Savings	
Small Office								
Electricity	$0.703	$0.663	$0.039	5.5%	$0.715	$0.676	$0.039	5.5%
Gas	$0.007	$0.008	$0.000	0.0%	$0.009	$0.010	-$0.001	-11.1%
Totals	$0.710	$0.671	$0.039	5.5%	$0.724	$0.686	$0.038	5.2%
Large Office								
Electricity	$1.409	$1.361	$0.048	3.4%	$1.414	$1.368	$0.047	3.3%
Gas	$0.016	$0.015	$0.001	6.3%	$0.019	$0.018	$0.001	5.3%
Totals	$1.425	$1.377	$0.048	3.4%	$1.434	$1.386	$0.048	3.3%
Stand-Alone Retail								
Electricity	$0.859	$0.776	$0.083	9.7%	$0.862	$0.778	$0.084	9.7%
Gas	$0.110	$0.116	-$0.006	-5.5%	$0.130	$0.136	-$0.006	-4.6%
Totals	$0.969	$0.892	$0.077	7.9%	$0.991	$0.914	$0.078	7.9%
Primary School								
Electricity	$0.840	$0.786	$0.055	6.5%	$0.839	$0.784	$0.054	6.4%
Gas	$0.065	$0.063	$0.002	3.1%	$0.073	$0.071	$0.002	2.7%
Totals	$0.905	$0.849	$0.056	6.2%	$0.912	$0.856	$0.056	6.1%
Small Hotel								
Electricity	$0.850	$0.782	$0.069	8.1%	$0.859	$0.792	$0.067	7.8%
Gas	$0.131	$0.131	$0.000	0.0%	$0.134	$0.134	$0.000	0.0%
Totals	$0.982	$0.913	$0.069	7.0%	$0.992	$0.926	$0.067	6.8%
Mid-Rise Apartment								
Electricity	$0.939	$0.920	$0.019	2.0%	$0.943	$0.925	$0.018	1.9%
Gas	$0.018	$0.020	-$0.002	-11.1%	$0.024	$0.027	-$0.003	-12.5%
Totals	$0.956	$0.940	$0.017	1.8%	$0.968	$0.952	$0.016	1.7%

Table 13. Energy Use Saving Results in Ohio, Energy Use per Square Foot

Climate Zone:	4A				5A			
Code:	90.1-2016	90.1-2019	Savings		90.1-2016	90.1-2019	Savings	
Small Office								
Electricity, kWh/ft^2	7.469	7.050	0.419	5.6%	7.601	7.188	0.413	5.4%
Gas, therm/ft^2	0.013	0.014	-0.001	-7.7%	0.017	0.018	-0.001	-5.9%
Totals, kBtu/ft^2	26.841	25.486	1.355	5.0%	27.634	26.327	1.307	4.7%
Large Office								
Electricity, kWh/ft^2	14.973	14.467	0.506	3.4%	15.030	14.533	0.497	3.3%
Gas, therm/ft^2	0.030	0.028	0.001	3.3%	0.036	0.034	0.002	5.6%
Totals, kBtu/ft^2	54.060	52.226	1.833	3.4%	54.887	53.036	1.851	3.4%
Stand-Alone Retail								
Electricity, kWh/ft^2	9.127	8.246	0.881	9.7%	9.157	8.266	0.891	9.7%
Gas, therm/ft^2	0.206	0.217	-0.011	-5.3%	0.242	0.254	-0.012	-5.0%
Totals, kBtu/ft^2	51.796	49.873	1.922	3.7%	55.490	53.634	1.856	3.3%
Primary School								
Electricity, kWh/ft^2	8.932	8.348	0.584	6.5%	8.914	8.335	0.579	6.5%
Gas, therm/ft^2	0.121	0.118	0.003	2.5%	0.136	0.133	0.003	2.2%
Totals, kBtu/ft^2	42.545	40.263	2.283	5.4%	44.053	41.773	2.280	5.2%
Small Hotel								
Electricity, kWh/ft^2	9.038	8.306	0.731	8.1%	9.124	8.416	0.707	7.7%
Gas, therm/ft^2	0.245	0.245	0.000	0.0%	0.250	0.250	0.001	0.4%
Totals, kBtu/ft^2	55.344	52.820	2.524	4.6%	56.162	53.692	2.470	4.4%
Mid-Rise Apartment								
Electricity, kWh/ft^2	9.977	9.776	0.200	2.0%	10.023	9.827	0.196	2.0%
Gas, therm/ft^2	0.033	0.037	-0.004	-12.1%	0.046	0.051	-0.005	-10.9%
Totals, kBtu/ft^2	37.325	37.079	0.246	0.7%	38.771	38.640	0.131	0.3%

Table 14.A. Annual Energy Usage for Buildings in Ohio in Climate Zone 4A

Energy End-Use	Small Office		Large Office		Stand-Alone Retail		Primary School		Small Hotel		Mid-Rise Apartment	
	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr
ASHRAE 90.1-2016												
Heating, Humidification	0.641	0.013	0.715	0.018	0.000	0.170	0.000	0.058	0.698	0.016	0.000	0.033
Cooling	0.682	0.000	1.648	0.000	1.400	0.000	1.327	0.000	1.575	0.000	0.750	0.000
Fans, Pumps, Heat Recovery	0.900	0.000	1.383	0.000	1.719	0.000	1.500	0.000	1.060	0.000	0.612	0.000
Lighting, Interior & Exterior	1.898	0.000	1.959	0.000	3.822	0.000	1.406	0.000	2.118	0.000	1.054	0.000
Plugs, Refrigeration, Other	2.439	0.000	9.269	0.000	2.186	0.000	4.602	0.046	3.587	0.092	4.209	0.000
Service Water Heating (SWH)	0.910	0.000	0.000	0.011	0.000	0.037	0.097	0.016	0.000	0.136	3.351	0.000
Total	7.469	0.013	14.973	0.030	9.127	0.206	8.932	0.121	9.038	0.245	9.977	0.033
ASHRAE 90.1-2019												
Heating, Humidification	0.649	0.014	0.714	0.017	0.000	0.181	0.000	0.056	0.789	0.016	0.000	0.037
Cooling	0.642	0.000	1.531	0.000	1.305	0.000	1.252	0.000	1.467	0.000	0.720	0.000
Fans, Pumps, Heat Recovery	0.826	0.000	1.324	0.000	1.648	0.000	1.383	0.000	1.003	0.000	0.595	0.000
Lighting, Interior & Exterior	1.585	0.000	1.630	0.000	3.107	0.000	1.158	0.000	1.461	0.000	0.900	0.000
Plugs, Refrigeration, Other	2.438	0.000	9.269	0.000	2.186	0.000	4.458	0.046	3.587	0.092	4.209	0.000
Service Water Heating (SWH)	0.910	0.000	0.000	0.011	0.000	0.037	0.097	0.016	0.000	0.136	3.352	0.000
Total	7.050	0.014	14.467	0.028	8.246	0.217	8.348	0.118	8.306	0.245	9.776	0.037
Total Savings	0.419	-0.001	0.506	0.001	0.881	-0.011	0.584	0.003	0.731	0.000	0.200	-0.004

Table 14.B. Annual Energy Usage for Buildings in Ohio in Climate Zone 5A

Energy End-Use	Small Office		Large Office		Stand-Alone Retail		Primary School		Small Hotel		Mid-Rise Apartment	
	Electric kWh/ft^2·yr	Gas therms/ft^2·yr	Electric kWh/ft^2·yr	Gas therms/ft^2·yr	Electric kWh/ft^2·yr	Gas therms/ft^2·yr	Electric kWh/ft^2·yr	Gas therms/ft^2·yr	Electric kWh/ft^2·yr	Gas therms/ft^2·yr	Electric kWh/ft^2·yr	Gas therms/ft^2·yr
ASHRAE 90.1-2016												
Heating, Humidification	0.812	0.017	0.766	0.024	0.000	0.206	0.000	0.074	0.848	0.019	0.000	0.046
Cooling	0.671	0.000	1.650	0.000	1.374	0.000	1.290	0.000	1.517	0.000	0.741	0.000
Fans, Pumps, Heat Recovery	0.877	0.000	1.386	0.000	1.776	0.000	1.522	0.000	1.056	0.000	0.620	0.000
Lighting, Interior & Exterior	1.893	0.000	1.959	0.000	3.821	0.000	1.403	0.000	2.117	0.000	1.054	0.000
Plugs, Refrigeration, Other	2.439	0.000	9.269	0.000	2.186	0.000	4.602	0.046	3.587	0.092	4.209	0.000
Service Water Heating (SWH)	0.910	0.000	0.000	0.011	0.000	0.037	0.097	0.016	0.000	0.138	3.399	0.000
Total	7.601		15.030	0.036	9.157	0.242	8.914	0.136	9.124	0.250	10.023	0.046
ASHRAE 90.1-2019												
Heating, Humidification	0.819		0.766	0.023	0.000	0.217	0.000	0.071	0.955	0.019	0.000	0.051
Cooling	0.634	0.000	1.529	0.000	1.279	0.000	1.226	0.000	1.415	0.000	0.713	0.000
Fans, Pumps, Heat Recovery	0.805	0.000	1.339	0.000	1.694	0.000	1.395	0.000	1.000	0.000	0.605	0.000
Lighting, Interior & Exterior	1.582	0.000	1.631	0.000	3.106	0.000	1.158	0.000	1.460	0.000	0.900	0.000
Plugs, Refrigeration, Other	2.439	0.000	9.269	0.000	2.186	0.000	4.458	0.046	3.587	0.092	4.209	0.000
Service Water Heating (SWH)	0.910	0.000	0.000	0.011	0.000	0.037	0.097	0.016	0.000	0.138	3.400	0.000
Total	7.188		14.533	0.034	8.266	0.254	8.335	0.133	8.416	0.250	9.827	0.051
Total Savings	0.413	-0.001	0.497	0.002	0.891	-0.012	0.579	0.003	0.707	0.001	0.196	-0.005

6.0 References

(ASHRAE) ANSI/ASHRAE/IES – American National Standards Institute, American Society of Heating, Refrigerating and Air-Conditioning Engineers, and Illuminating Engineering Society. 2016. *ANSI/ASHRAE/IES 90.1-2016, Energy Standard for Buildings Except Low-Rise Residential Buildings.* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia.

(ASHRAE) ANSI/ASHRAE/IES – American National Standards Institute, American Society of Heating, Refrigerating and Air-Conditioning Engineers, and Illuminating Engineering Society. 2019. *ANSI/ASHRAE/IES 90.1-2019, Energy Standard for Buildings Except Low-Rise Residential Buildings.* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia.

Bureau of Labor Statistics. 2021. “Producer Price Indexes.” Washington, D.C. Accessed April 20, 2021 at www.bls.gov/data

Commercial Loan Direct. 2021. “Commercial Mortgage Interest Rates - Nationwide Lending, Mid Balance - Investor/Owner Occupied.” Atlanta, Georgia. Accessed April 20, 2021 at www.commercialloandirect.com/commercial-rates.php

DOE – U.S. Department of Energy. 2021. *Energy Savings Analysis: ANSI/ASHRAE/IES Standard 90.1-2019.* DOE/EE-2345, U.S. Department of Energy, Washington, D.C. Available at https://www.energycodes.gov/development/determinations

EIA – United States Energy Information Administration. 2021a. *Electric Power Monthly, March 2021.* Energy Information Administration, Washington, D.C. Available at https://www.eia.gov/electricity/monthly/

EIA – United States Energy Information Administration. 2021b. *Natural Gas Monthly, March 2021*. Energy Information Administration, Washington, D.C. Available at https://www.eia.gov/naturalgas/monthly/

EPA. 2014. *Compilation of Air Pollutant Emission Factors, AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources (Chapter 1)*. U.S. Environmental Protection Agency, Washington, D.C. Available at: https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors

EPA. 2020 *AVoided Emissions and geneRation Tool (AVERT), User Manual Version 3.0*. U.S. Environmental Protection Agency, Washington, D.C. Available at https://www.epa.gov/avert/avert-user-manual

EPA. 2021a. *THE EMISSIONS & GENERATION RESOURCE INTEGRATED DATABASE eGRID Technical Guide with Year 2019 Data*. U.S. Environmental Protection Agency, Washington, D.C. Available at https://www.epa.gov/sites/production/files/2021-02/documents/egrid2019_technical_guide.pdf

EPA. 2021b. *Emission Factors for Greenhouse Gas Inventories*. U.S. Environmental Protection Agency, Washington, D.C. Available at https://www.epa.gov/sites/production/files/2021-04/documents/emission-factors_apr2021.pdf

FTA – Federation of Tax Administrators. 2021. "Range of State Corporate Income Tax Rates." Washington, D.C. Accessed April 20, 2021 at https://www.taxadmin.org/assets/docs/Research/Rates/corp_inc.pdf

Fuller SK and SR Petersen. 1995. *Life-Cycle Costing Manual for the Federal Energy Management Program*, NIST Handbook 135. U.S. Department of Commerce, Washington, D.C.

Hart PR and B Liu. 2015. *Methodology for Evaluating Cost-effectiveness of Commercial Energy Code Changes.* PNNL-23923 Rev 1. Pacific Northwest National Laboratory, Richland, WA. Available at https://www.energycodes.gov/sites/default/files/documents/commercial_methodology.pdf

IWG – Interagency Working Group on Social Cost of Greenhouse Gases, United States Government. 2016. *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*. Available at https://www.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf

IWG – Interagency Working Group on Social Cost of Greenhouse Gases, United States Government. 2021. *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990*. Available at https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf

Tyler M, R Hart, Y Xie, M Rosenberg, M Myer, M Halverson, C Antonopoulos, and J Zhang. 2021. *National Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019.* PNNL-29940. Pacific Northwest National Laboratory, Richland, WA.

Jarnagin RE and GK Bandyopadhyay. 2010. *Weighting Factors for the Commercial Building Prototypes Used in the Development of ANSI/ASHRAE/IESNA 90.1-2010*. PNNL-19116. Pacific Northwest National Laboratory, Richland, Washington.

Lavappa P and J Kneifel. 2019. *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis-2019: Annual Supplement to NIST Handbook 135*. National Institute of Standards and Technology, U.S. Department of Commerce, Washington, D.C. Available at https://doi.org/10.6028/NIST.IR.85-3273-34

McGraw Hill Construction. 2007. *McGraw Hill Construction Database (2003-2007)*. McGraw Hill Construction, New York, New York. Available for purchase at http://dodge.construction.com

Mendon VV, A Selvacanabady, M Zhao, and ZT Taylor. 2015. *National Cost-Effectiveness of the Residential Provisions of the 2015 IECC*. PNNL-24240. Pacific Northwest National Laboratory, Richland, WA. Available at www.energycodes.gov/development/residential/iecc_analysis

RealtyRates.com Investor Survey – 1st Quarter 2021 Permanent Financing." Bradenton, Florida. Accessed April 20, 2021 at www.realtyrates.com/commercial-mortgage-rates.html

RS Means. 2020a. *RSMeans Mechanical Cost Data*, 43rd Ed. Construction Publishers & Consultants. Norwell, Massachusetts.

RS Means. 2020b. *RSMeans Building Construction Cost Data*, 78th Ed. Construction Publishers & Consultants. Norwell, Massachusetts.

Tax Foundation. 2020. "State and Local Sales Tax Rates 2020." Washington, D.C. Available at https://taxfoundation.org/state-and-local-sales-tax-rates-2020

The U.S. Department of Energy (DOE) provides estimates of energy and cost savings from code adoption at the National, Climate Zone, and State levels. For more information on how these estimates were developed, visit the DOE Building Energy Codes website: www.energycodes.gov/development/commercial

U.S. Department of Energy
Energy Efficiency and Renewable Energy
BUILDING TECHNOLOGIES OFFICE

EERE Information Center
www.energy.gov/eere

Building Energy Codes
For information on Building Energy Codes, visit
http://www.energycodes.gov/

Pacific Northwest National Laboratory

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99354
1-888-375-PNNL (7665)

www.pnnl.gov