Phius REVIVE 2024

RETROFIT STANDARD FOR BUILDINGS v0.8

Good for the planet | Good for your buildings | Quality assured results

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(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard.)

Foreword

This foreword documents a thought process about what to do about existing buildings, starting completely over from the Phius vision statement. The perspective changes a bit as it moves from Initial Concepts to a Program Vision and then to Key Requirements Concepts. After that the Standard proper begins to manifest those concepts into actual requirements.

Initial concepts
Phius' vision statement is that every building supports the health of people and the planet. Development of this standard began with a recognition that our existing retrofit standard, that held retrofit projects to almost the same standards as new construction, might not be the right idea at the scale of "all existing buildings." Though the operational impact of the buildings on the planet would be greatly reduced, the cost of the retrofit work would be high and the impact near-term, front-loaded. Avoiding near-term impacts is important because our planet is so close to climate tipping-points.

Accordingly, our initial thinking proceeded from three goals for all existing buildings:

1. *Decarbonize building operation.*
2. *Decarbonize the building delivery and maintenance process itself.*
3. *Operate buildings on local renewable energy.*

As to Goal 1, decarbonizing building operation, that could be achieved for any building with two steps:

- *Electrify everything.*
- *Power the building with zero-emission renewable electricity.*

For all-electric buildings in some places, this can be done without installing anything, just by signing up for a "green power" program from the electric utility or "community choice aggregation" program from the local government. Arguably, this takes care of the building's civic duty to the planet, though there is a difference between "100% renewable" programs and "24/7 carbon-free" programs.

However, such an approach puts most of the responsibility for impact onto the utility and it does "nothing" for the building. In cold climates it is likely to actually increase the energy bills, perhaps greatly. When done at scale it will tend to shift the peak season for the grid from summer to winter, in heating-dominated climates.

Therefore a question arises as to what is the best balance among these kinds of actions or investments:

1. *Reducing the load, especially the winter peak, with passive measures such as air-sealing, insulation, superwindows.*

2. *Reducing the load with equipment efficiencies such as heat pumps and LED lights, and perhaps time-shifting the load with smart-grid interactive controls or thermal energy networks.*
3. *Generating and storing renewable energy on-site.*
4. *Procuring carbon-free renewable energy from off-site.*

The idea for this program was to decide this question primarily using building simulation with a resilience lens, and on a project-specific basis.

There would be two performance criteria: firstly, that the building remains habitable during both a winter storm power outage and a summer heat wave power outage of some days duration. This outage use-case constitutes most of the response to Goal 3 - functioning on local renewable energy. (Functioning on local RE in normal operation is also desirable. Larger buildings will have difficulty doing that with onsite generation alone and probably need the support of a microgrid.)

Secondly, and to Goal 2, getting rid of the embodied carbon or upfront emissions of the building delivery (and maintenance) process itself, the program would eschew the idea of "offsets" for the embodied carbon of the building sector of the economy, and hold Absolute Zero as the ideal – that no emissions ever happen: nowhere in its supply chain, none are caused by anyone involved, neither directly or indirectly, neither in their personal or professional life. As that absolute zero ideal cannot be done in the current system of industrial civilization, the idea is to start by keeping score, from a zero base, and in light of that, make efforts to reduce the upfront emissions. Because of the all-encompassing scope, there are many opportunities to improve and anyone involved can contribute.

That implied two aspects to the scoring:
- *Life-cycle carbon emissions.*
- *Life-cycle "full-cost", including cost of carbon.*

The inclusion of a life-cycle cost metric keeps the principle of economic feasibility involved, but this metric internalizes the cost of carbon emissions, so as to motivate more effort to reduce them.

The cost metric should also include operating energy cost and the cost of any implied capacity additions to the grid. Rate structures that are strongly tiered and seasonal or time-of-use-dependent could be used, in anticipation that these will become more common as the grid decarbonizes.

Another way to think about this would be that minimizing the expanded life cycle cost is the objective, and outage resilience are the constraints on that optimization problem. Conceptually, the calculation could be done with some clever optimization-under-constraints algorithm or by a brute-force parametric dragnet followed by filtering - for upgrade packages that "meet resilience" and are "best n-th percentile" for life-cycle cost.

Program vision

A missing piece in the initial thinking above was the fact that existing buildings have various problems that need to be fixed. Consideration of what kinds of problems to address within the scope of this program, and distillation of the above, led to this five point vision for the program:

1. *The retrofitted buildings do not cause greenhouse gas (GHG) emissions in operation, directly or indirectly. This entails electrification and the use of carbon-free renewable electricity, but those steps alone are not sufficient. If those are the only measures taken to decarbonize operations, there is no benefit to the building, its utility bills might actually increase, and dependence on the electric grid / utility is increased.*
2. *Therefore, building enclosure improvements and equipment efficiency improvements are designed such that the building can function using locally-generated renewable energy. This is true in both normal operation, maintaining comfortable conditions, and for some degree of reduced function but still habitable conditions during utility outages, summer or winter. The outage-resilience consideration is a key factor determining the design of the envelope improvements. We also view it as a characteristic that every building should have, as a matter of fairness or equity.*
3. *The emissions associated with the retrofit process itself are "low". Ideally, they would be zero, without the use of offsets, even with the widest possible lens – in space: materials and labor throughout the entire global supply chain; in time: from the moment of project conception through the rest of the life of the building. Together with 1), this would mean* ***absolute zero – no GHG emissions occurring anywhere in the building renovation process, supply chain, or future operating life, at any time****. Although this cannot currently be done, some steps can be taken, such as beginning to calculate carbon scores. It is appropriate to keep in mind both radical ideals and practical realities.*
4. *Existing deficiencies are fixed. These include risks to indoor air quality per US EPA, such as radon and pests, and site hazards per US FEMA such as seismic and flood risk, including emerging extreme-weather hazards due to climate change.*
5. *Unlike previous Phius programs, the time horizon extends beyond design and construction into operations, and can encompass phased retrofits. Like previous programs, a quality-assurance process verifies and documents that the facility meets our requirements, and closely-related Owner's requirements. Data is captured on how well the retrofitted building performs, on project costs, and on solutions to retrofit issues.*

Key requirements concepts

This standard aspires to be adoptable as mandatory by authorities having powers of enforcement, to issue and withhold permits for building construction and certificates of occupancy, and even to impose fines for poor performance in operation. As such it must feature "hard" requirements, and be transparent and open.[1]

[1] *A voluntary standard may have additional "tiers" of performance above a mandatory minimum level, to which greater incentives can be applied, and could require proprietary software or proprietary credentialed professionals. A rating system need not set any criteria on performance at all, only rating methods.*

These are the 7 concepts for the key hard requirements:

1) *There is a commissioning / quality-assurance process that covers all phases, from pre-design through operations, and through all the renovation phases. Planning for an end state that eventually meets all the requirements is done in the beginning. The plan could be revised, but the planning cannot be deferred.*
2) *Early in the process, the existing building is assessed in these ways:*
    a) *Whether it is a good candidate for retrofit, as opposed to redeveloping or rewilding its site.*
    b) *Energy performance.*
    c) *Risks to indoor air quality (per US EPA) and site hazards (per US FEMA.)*
3) *Direct emissions cease soon (electrification preferably in the first construction phase.)*
4) *In both summer and winter grid outage situations, the building remains habitable and critical loads are covered by on-site or local-microgrid generation / storage, with priority to renewable generation.*
5) *Fix any existing deficiencies that pose risks to indoor air quality. (The fortification against site hazards mentioned above is mostly elective.)*
6) *Life-cycle calculations are done for both carbon emissions and for cost, for a full-cost metric called ADORB (or FCALC) that includes a cost of carbon.*
    a) *This is done for a baseline case of continuing to operate the building as-is, and for the retrofit scenario.*
    b) *The life-cycle cost of the retrofit scenario must be lower than the baseline scenario.*
    c) *A decarbonization challenge is accepted: Efforts are made to find ways to reduce the upfront emissions from the materials and labor of the retrofit work, compared to usual practice. (Phius will figure out (or facilitate a consensus process on) how to credit these practices in the life cycle carbon calculation – let us see how low we can go. Such measures could include using refrigerant gases in mechanical systems that have low global warming potential (GWP), and avoiding cellular plastic insulation types that are foamed using high GWP gases.*
7) *Project cost data and post-retrofit measured energy performance are reported, at least to some minimum level of granularity.*

<u>Administration / compliance / enforcement concepts</u>

The scope of the specific alterations / improvements implied by the above concepts could vary greatly from project to project, in terms of the <u>specific</u> envelope, systems, and controls changes needed. A good quality-assurance process will focus the effort and resources on the elements that need to be addressed to meet the goals. Therefore, the main idea is that enforcement is closely tied to the quality-assurance process - in jargon: the determination of compliance leverages commissioning.

ASHRAE has developed a number of guidelines/standards for "commissioning", by which they mean quality assurance - commissioning is defined as, e.g. "a quality-focused process for enhancing the delivery of a project. The process focuses on verifying and <u>documenting</u> that the facility and all of its systems and assemblies are planned, designed, installed, tested, operated,

and maintained to meet the Owner's Project Requirements (OPR) [or in the case of retrofits, Current Facility Requirements (CFR)]."

This Standard relies upon the commissioning process as structured by ASHRAE – particularly ASHRAE Guideline 0.2 and ASHRAE Standards 230, 202 – as a quality control/quality assurance mechanism. It is thus imperative that a user of this Standard be comfortably familiar with the ASHRAE commissioning process. ASHRAE Standard 230, ASHRAE Guideline 0.2, and several supporting commissioning guidelines are available from the ASHRAE Bookstore: https://www.techstreet.com/ashrae/pages/home

The adaptations of these guidelines for use in enforcement or certification are that:
Although the Owner does still have some input, the requirements in the OPR / CFR consist mostly of the requirements of this standard, and therefore:

- *The documentation is mainly focused on documenting compliance with this standard.*
- *The major process gates labeled "Obtain Owner acceptance and decision to proceed" and the like require the concurrence of both the Authority and the Owner.*

Guideline 0.2 has the feature that it integrates the investigation of the existing conditions and focuses them on relevance to the requirements, rather than defaulting to a more generic "energy audit" standard.

Figure D-1 in Guideline 0.2 (reproduced below) provides a graphical representation of the documentation to be provided as formal deliverables at each phase of the EBCx Process. The figure can be used to understand which documents are generated in which phase of the process and at what intervals they are updated.

EBCx Phase	Section	Multiple Facility Program Plan	CFR	EBCx Plan	EBCx Report	Systems Manual	OCx Plan	OCx Report	OCx Training Plan
Multiple Facilities Planning	5	■							
Assessment	6		■	■	■				
Investigation	7		▒	▒	▒				
Implemenation	8		▒	▒	▒				
Hand Off	9				▒	■	■		
On-Going Commissioning	10					▒	▒	■	■

■ New or Existing Document ▒ Updated Document

ASHRAE Guideline 0.2 Figure D-1. EBCx documentation matrix. In this standard the Multiple Facilities Planning phase is renamed Programming.

The scope of Standard 230 is rather narrow - repairs, in-kind replacements, and adjustments to the systems, and it does require a full ASHRAE 211 Energy Audit in the Assessment phase. The treatment of the planning phase seems more apt in 230, but herein some of its content has been moved to the Assessment phase to focus the first phase on building selection and ranking. Because the scope of the required improvements might extend into design work and "capital projects" that are outside the scope of 0.2 and 230, Standard 202 is looked to in those cases.

In its own use of this standard in the voluntary REVIVE Pilot certification program:

- *Phius acts in the role of the Authority.*
- *Phius Certified Consultants (CPHC®) act in the role of the Commissioning Provider.*
    - *Owner contributions to the OPR / CFR beyond the requirements of this standard are limited (mostly to the electives spelled out in this standard, and on a case by case basis.)*
- *The required verification and testing providers are Phius Raters and Verifiers.*
- *Large additions outside the scope of this standard must meet Phius' new construction standards.*

Other Phius-specific practices appear herein with this highlight color.

In the case of adoption of this standard by an authority with funding to incentivize a voluntary program, or with powers of legal enforcement for a mandatory code, CPHCs would offer services as commissioning providers, not to the exclusion of others, and Phius credentialed professionals would likewise offer their services as design, verification and testing providers, not to the exclusion of others. Phius itself would maintain the standard, provide training for professionals, and provide quality assurance services for authorities.

1 Purpose

1.1

To establish:

- Requirements for retrofit improvement work on existing buildings.
- Criteria for the selection of buildings for retrofit (as opposed to razing or replacement with new buildings.)

1.2

The purposes of the improvements are to:

- Eliminate direct and indirect greenhouse gas emissions, in normal operation.
- Provide resilience to winter and summer power outages.
- Fix defects of concern to the US EPA, that pose risks to indoor air quality.
- Where appropriate, fortify the building against certain site hazards of concern to US FEMA, and insurers.
- Meet specific Owner elective requirements closely related to the above.

1.3

And in addition:

- To employ a commissioning / quality assurance process.
- To calculate the climate impact of the retrofit work itself and make efforts to reduce it.
- To collect data on project costs, post-retrofit performance, and lessons learned.

2 Scope

2.1

This standard provides requirements for:

- The assessment and investigation of existing buildings.
- The planning of retrofit phases.
- The design, installation, and testing of retrofit improvements.
- The operation, monitoring, and maintenance of the buildings after each retrofit phase.

2.2

This standard applies to all kinds of buildings.[2]

2.3

Its provisions also apply to additions having an interior conditioned floor area no greater than that of: the existing building including (prior-to) any planned demolitions.

[2] For multifamily residential buildings (or nonresidential buildings with multiple HVAC zones) some of the protocol has been placed in Normative Appendix MZ because the current software engine is limited to single-zone modeling. Appendix MZ contains temporary workarounds for this limitation.

3 Definitions

ADORB cost: *Annualized Decarbonization Of Retrofitted Buildings cost* - a “full-cost-accounted” annualized life-cycle cost metric for building projects. It includes the direct costs of retrofit and maintenance, direct energy costs, a carbon cost for both operating and embodied/upfront greenhouse gas emissions, and a renewable-energy system-transition cost based on the required electrical service capacity. See Appendix A for calculation protocol details.

Authority: the agency or agent that adopts this standard, or the agency or agent responsible for enforcing this standard, or the officer charged with the administration and enforcement of this standard, or a duly authorized representative. [a la 90.1 - combination of adopting authority, authority having jurisdiction, and building official]

Commissioning (Cx): a quality-focused process for enhancing the delivery of a project. The process focuses on verifying and documenting that the facility and all of its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet specified requirements. [combination 90.1 and 0.2]

Commissioning Provider (CxP): an entity who manages the Commissioning Team to implement building commissioning. [90.1]
Informative: The corresponding term in ASHRAE Guideline 0.2 is Commissioning Authority.

Commissioning Team (Cx Team or EBCx Team): individuals who through coordinated actions are responsible for implementing the Cx Process - Owner staff, operations and maintenance entity, and CxP Team working in collaboration. The smaller CxP Team comprises the CxP and subcontractors to the CxP who acts as the contact to the Owner. Similarly, the OCx Team includes internal facility staff, service contractors, external professionals, commissioning contractors, and Cx Process providers. [combination 0.2 and 230]

community solar: any solar project or purchasing program, within a geographic area, in which the benefits of a solar project flow to multiple customers such as individuals, businesses, nonprofits, and other groups. In most cases, customers are benefitting from energy generated by solar panels at an off-site array. Community solar customers can either buy or lease a portion of the solar panels in the array, and they typically receive an electric bill credit for electricity generated by their share of the community solar system – similar to someone who has rooftop panels installed on their home. [aligns with US DOE definition]

conditioned space: An area, room or space that is enclosed within the building thermal envelope and that is directly or indirectly heated or cooled. Spaces are indirectly heated or cooled where they communicate through openings with conditioned spaces, where they are separated from conditioned spaces by uninsulated walls, floors or ceilings, or where they contain uninsulated ducts, piping or other sources of heating or cooling. [IECC]

Construction Team: consists of professionals responsible for providing materials and labor to construct the systems and assemblies in the project. Where a construction project follows a design/build approach, the Construction Team includes licensed design professionals who are part of the Design Team.

Current Facility Requirements (CFR): a written document in which the Owner details the current functional requirements of a facility and the expectations of how it should be used and operated. *Informative: The corresponding term for new construction and additions is Owner's Project Requirements (OPR)*.

Design Team: Design Team: the licensed professionals responsible for producing the complete set of permit documents required for construction.

Facility Guide: a subsection of the Systems Manual. Similar to an operator's manual, the Facility Guide is intended to provide the basic information necessary for the building operations staff to operate the building on a day-to-day basis. It includes a simple description of the building systems and their normal operation, schedules, set points, and limitations. The Facility Guide also includes routine maintenance for the systems to keep them in good condition, but not major maintenance or repair functions. Scheduled start-up and shutdown functions should be included.
Informative: Refer to ASHRAE Guideline 1.4, Preparing Systems Manuals for Facilities, for additional information.

functional performance testing (FPT): a systematic process to verify that controls and other elements of the building project are capable of and configured to operate or perform as required.

HVAC zone: a space or group of spaces within a building with heating and cooling requirements that are sufficiently similar so that desired conditions (e.g., temperature) can be maintained throughout using a single sensor (e.g., thermostat or temperature sensor).

hurricane-prone regions: areas vulnerable to hurricanes as defined in ASCE 7.

- For ASCE 7-05, hurricane-prone regions are locations along the Gulf of Mexico and Atlantic coasts where the design wind speed is greater than 90 mph, plus Hawaii, Puerto Rico, the Virgin Islands, Guam, and American Samoa.
- For ASCE 7-10 and ASCE 7-16, hurricane-prone regions are locations along the Gulf of Mexico and Atlantic coasts where the wind speed for Risk Category II buildings is greater than 115 mph, plus Hawaii, Puerto Rico, the Virgin Islands, Guam, and American Samoa.

interior conditioned floor area (iCFA): iCFA is the interior-dimension (drywall-to-drywall) projected floor area of the conditioned spaces with at least 7 feet ceiling height. It includes stairs, cabinets, interior walls, mechanical spaces, storage, but excludes open-to-below. More specifically:

● Include the floor area of interior spaces at least 7 feet in height, measured from the interior finished surfaces that comprise the thermal boundary of the building. Spaces that are open-to-below shall not be counted. *Informative: The general concept is "walkable."*
● Other than open-to-below, the projected floor area of all spaces within this shall count toward the iCFA measurement, including walls, cabinets, mechanical spaces, storage, etc.
● Projected floor area of the stair treads counts toward iCFA on all floors, that is, once per floor. (By the 7 foot height rule, some floor area under the stairs on the first floor would be excluded. This conflict is resolved by including it). [a la Phius Certification Guidebook 4.4.1.4]

island: A part of an electric power system that is disconnected from the remainder of the interconnected system, but remains energized. An island can be either the result of the action of automatic protections or the result of a deliberate action.

islanding: The process whereby a Microgrid separates itself electrically from the main power grid and operates independently, using its own internal power source(s); it may later rejoin the main grid. [LLNL/GMLC definition]

Measurement and Verification (M&V) Plan: a plan for gathering relevant data over time to evaluate performance and benefits.

microgrid: a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode.'' [US DOE definition]

Ongoing Commissioning (OCx): a continuation of the Cx and EBCx well into occupancy and operations to continually improve the operation and performance of a facility to meet current and evolving CFR or OPR. Ongoing Cx activities occur throughout the life of the facility; some of these will be close to continuous in implementation, and others will be either scheduled or unscheduled as needed.

Project Team: select members of all the teams defined in this standard. The Project Team provides a venue for coordinating actions and information flows between all staff who are involved in the project and Cx Activities.

semiheated space: an enclosed space within a building that is heated by a heating system whose output capacity is greater than or equal to 3.4 Btu/h·ft2 of floor area but is not a conditioned space.

Systems Manual: a system-focused composite document that includes the design and construction documentation, Facility Guide and operations and maintenance manual, maintenance information, training information, Cx records, and additional information of use to the Owner during occupancy and operations.

thermal block: a collection of one or more HVAC zones grouped together for simulation purposes. Spaces need not be contiguous to be combined within a single thermal block.

thermal energy network: an ambient temperature loop system that connects multiple buildings by using some combination of ground-source heat pumps, geothermal infrastructure, waste heat energy, and utility-owned load balancing systems. [a la ConEdison]

unconditioned space: an enclosed space within a building that is not a conditioned space or a semiheated space. Crawlspaces, attics, and parking garages with natural or mechanical ventilation are not considered enclosed spaces.

verification and testing provider (V&T provider): an entity who completes the activities needed to implement the building functional performance testing (FPT) activities or verify that elements of the building project meet stated requirements.

4 Process, Part One

4.1 General

4.1.1 Changes in Space Conditioning

Whenever unconditioned space or semiheated space in a building is converted to a conditioned space, such conditioned space shall be brought into compliance with all the applicable requirements of this standard. [a la 90.1 4.1.1.5]

4.1.2 Interpretations, Exemptions and Appeals

Interpretations, claims of exemption, and rights of appeal are specified by the Authority. [a la 90.1 4.1.2]

4.1.3 Validity

If any term, part, provision, section, paragraph, subdivision, table, chart, or referenced standard of this standard shall be held unconstitutional, invalid, or ineffective, in whole or in part, such determination shall not be deemed to invalidate any remaining term, part, provision, section, paragraph, subdivision, table, chart, or referenced standard of this standard. [90.1 4.1.4]

4.1.4 Other Laws

The provisions of this standard shall not be deemed to nullify any provisions of local, state, or federal law. Where there is a conflict between a requirement of this standard and such other law affecting construction of the building, precedence shall be determined by the Authority. [a la 90.1 4.1.5]

4.1.5 Normative Appendices

The normative appendices to this standard are considered to be integral parts of the mandatory requirements of this standard, which, for reasons of convenience, are placed apart from all other normative elements. [90.1 4.1.7]

4.1.6 Informative Appendices

The informative appendices to this standard and informative notes located within this standard contain additional information and are not mandatory or part of this standard. [90.1 4.1.8]

4.2 Commissioning and Compliance

Informative: ASHRAE Guideline 0.2 [is the primary basis of]/[forms the primary framework for] the quality assurance process in this standard, and a general familiarity with it is recommended.

Commissioning shall be performed and shall document in sufficient detail compliance with the provisions of this standard. [a la 90.1 4.2.5.2]

Commissioning shall use specific sections of ASHRAE Guideline 0.2 *Commissioning Process for Existing Systems and Assemblies* and ASHRAE Standard 230 *Commissioning Process for Existing Buildings and Systems*, as detailed and modified in this standard.

Projects that include additions and/or modifications requiring design and construction during the Implementation Phase shall utilize specific sections of ANSI/ASHRAE/IES Standard 202, *Commissioning Process for New Buildings and New Systems*, for new design and construction activities performed to an existing building - again as detailed in this standard. [a la 230 section 4.1]

The process gates and requirements in Guideline 0.2 and Standard 202 and 230 labeled "Obtain Owner acceptance and decision to proceed" and the like require the concurrence of both the Authority and the Owner.

The corresponding documentation deliverables are produced by the EBCx Team.

The documentation deliverables go to both the Authority and the Owner.

4.2.1 Qualifications

The commissioning provider shall be (1) a third-party entity not associated with the building project, or (2) an individual associated with the design firm or contractor but not directly associated with design or installation of the elements being commissioned. [a la 90.1 4.2.5.2, excluding owner's employees]

The commissioning team shall include V&T providers with the necessary FPT equipment. [a la 90.1 4.2.5.2]

V&T providers shall be commissioning providers, design professionals, qualified designers, or qualified technicians experienced with verification or FPT of the designated systems. V&T providers shall not be individuals who performed design or installation of the systems or assemblies being verified or tested. [a la 90.1 4.2.5.1, excluding owner's employees] Informative Appendix V contains a list of V&T provider credentials that might suffice.

Phius practice is that there is a CPHC acting as an independent commissioning provider that has overall responsibility for Cx; Phius Raters and Verifiers are used for V&T.

4.2.2 Fees

Fees shall be paid to the authority as required by its schedules. [a la IECC C104.2, R104.2]

Informative: Depending on the project delivery business model, the Owner might also need to pay an independent commissioning provider and/or V&T providers.

See TBD for Phius fees acting in its role as an Authority certifying REVIVE Pilot projects to this standard.

4.3 Owner's Participation

The Owner shall develop the EBCx scope on which the CxP will base their service proposal (see Facility Summary in section 8.6.1). [a la 230 4.2.1]

The Owner and Cxp shall develop the scope of work on which the V&T providers will base their service proposal. [a la 230 4.2.1]

Owner and/or their designated representatives shall do the following: [a la 230 5.2.1.2]

a. Provide direction, reviews, and acceptance as required throughout the EBCx project.
b. Reserved.
c. Attend EBCx planning meetings.
d. Provide contact information and access to the Owner's team leader (main point of contact), building manager, and support staff involved in the EBCx project to the CxP.
e. Make Owner's team members, including related staff and vendors, participate in EBCx Activities (interviews, CFR development).
f. Confirm that the CxP develops the EBCx Plan and provide approval prior to the start of the EBCx Investigation Phase.
g. Review submittals and develop contracts with designers and contractors needed to implement the upgrades and changes to the building. [a la 0.2 8.4.3.1]
   Informative note: some implementation work may be done by Owner's representatives or in-house staff.
h. Provide occupant schedules and limitations of access for performing EBCx Activities to the CxP.
i. Provide the EBCx Team access required to perform EBCx activities.
j. Disseminate surveys, schedule of EBCx activities, and communication protocols provided by the CxP to stakeholders.
k. Review and approve commissioning assessment, investigation, implementation, and hand-off reports.
l. Together with the Authority, review and approve the ongoing commissioning (OCx) implementation plan.
m. Participate in staff and occupant training [a la 0.2 8.4.3.1].

4.4 Reserved

4.5 Programming – Building Triage and Ranking

Informative: The objective of the Programming phase is to make an initial determination of which buildings to retrofit, and if the Owner has more than one, in what order. The reasoning is recorded in a Program Plan document.

4.5.1 Buildings excused from retrofit

Reflect upon the question of whether the building should be retrofitted at all. [a la 0.2, 5.2.2.1.4 - Exclusions]

In addition to doing “nothing” - continuing to use and maintain the building as-is - there are three general options:

Repair and retrofit the building.
Replace the building or redevelop the site.
Raze the building and rewild the site.

Make this decision only after considering the building and site factors in sections 4.5.1.1-3.

4.5.1.1 Intended building life

What is the intended life of the retrofitted or replacement building?

4.5.1.2 Building functionality

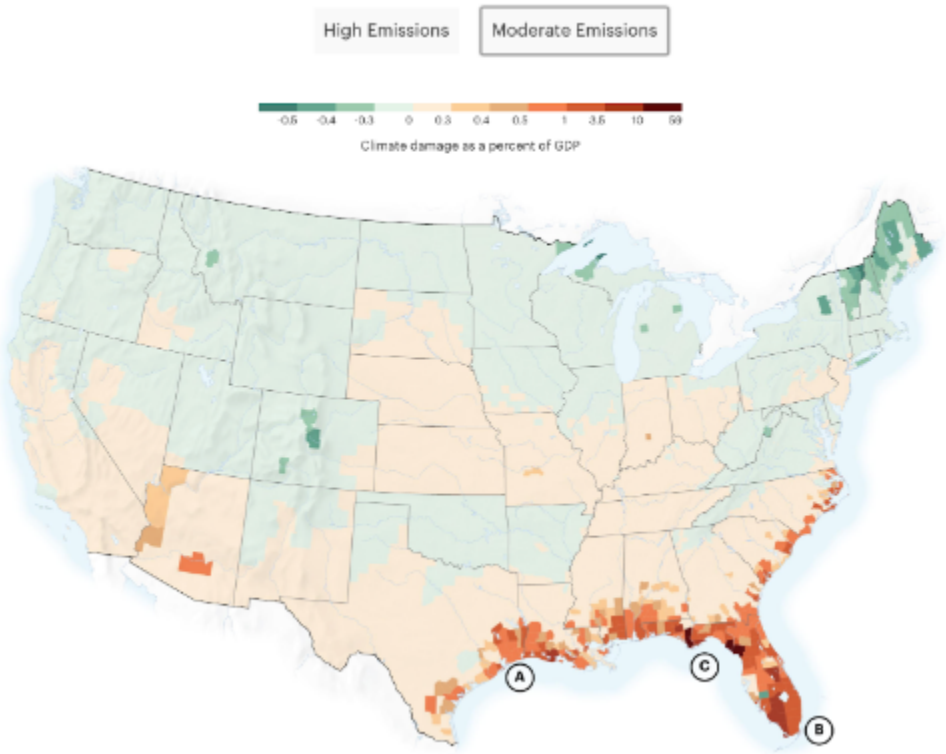
With regard to its floor plan, and plumbing, is the building basically functional and suitable for the intended uses?
If not, can that be remedied with a modest addition?

4.5.1.3 Site and Land Use

4.5.1.3.1 Climate migration

Informative: Research suggests that climate change "will profoundly interrupt the way we live and farm in the United States. ... Across the United States, some 162 million people — nearly 1 in 2 — will most likely experience a decline in the quality of their environment, namely more heat and less water. ... In much of the developing world, vulnerable people will attempt to flee the emerging perils of global warming, seeking cooler temperatures, more fresh water and safety. But here in the United States, people have largely gravitated toward environmental danger, building along coastlines from New Jersey to Florida and settling across the cloudless deserts of the Southwest."

Review this climate migration reporting and consider whether it bears on the decision to retrofit the building.



For projects in Pacific coastal areas, also consider whether tsunami risk bears on the decision to retrofit the building.

4.5.1.3.2 Zoning

Does the building make the best use of its site? Consider whether zoning would allow higher density or more uses. If not, could a variance be sought to allow such?
Determine the zoning designation and record the definition of the zone.

4.5.2 Multiple-Facility Planning

If there are multiple facilities and a need to decide the order in which they will be addressed, establish a protocol for ranking the order. [a la 230 5.2.1.2 h]
See Informative Appendix M for a recommended approach.

Develop a plan for benchmarking the performance of the buildings around the metrics used for evaluation. [0.2 5.2.2.1.3]

> If the metrics include the Resilience and ADORB metrics of this standard, discuss and define an approach to sampling and the use of simplified representative buildings for purposes of this planning phase.

4.5.2.1 Funding

If this standard is being used in a voluntary program, discuss potential grants or incentive programs that may be available from government, utility, or other entities that may apply to the project. [a la 0.2 5.2.9]

4.5.3 Programming Phase Deliverables

4.5.3.1 Multiple buildings: Program Plan

In the case of multiple facilities, assemble a Program Plan document containing the following:

a. Facility identification
b. Ranking metrics
c. Prioritized list of facilities
d. Phase plan or execution schedule
e. Program planning team (names, affiliation, and title)

4.5.3.2 Each building: Rationale to Retrofit

For each building, collect narrative answers to the questions posed in sections 4.5.1.1-3 into a rationale to retrofit.

The development of an EBCx Plan for each of the prioritized individual buildings is discussed in Section 8 – Process, Part Two, after the technical requirements in Sections 5, 6, and 7.

5 Mitigate Existing Deficiencies

Upon completion of the final Implementation phase of the Cx Process, all the requirements stated in this section, and any of the electives included in the CFR, shall have been fulfilled.

5.1 Indoor Air Quality and Moisture risk mitigation

Perform all the Minimum Actions described in the EPA Energy Savings Plus Health Guidelines.

- For single-family buildings, refer to Publication No. EPA 402K21001.
- For multifamily buildings, refer to Publication No. EPA 402K21002.

Informative: See Informative Appendix E for a summary of the scope of said EPA Guidelines.

Comply with Phius Certification Guidebook Appendix B - Moisture Control for Opaque Assemblies, or ASHRAE Standard 227P - Passive Building Design, Advisory Public Review Draft, section 7.5.5.

5.1.1 Indoor Air Quality Electives

Consider the Expanded Actions in the EPA Energy Savings Plus Health documents.

Consider complying with ASHRAE Standard 241 - Control of Infectious Aerosols.
Informative: Recirculating air filtration and upper room UV are the preferred approaches.

5.1.2 New additions

New additions shall comply with the requirements of US EPA Indoor airPLUS and US EPA ENERGY STAR for New Homes.
Informative: There are separate ENERGY STAR requirements documents for single-family, multifamily, and manufactured housing.
Exceptions:

a. The eligibility limitations do not apply.
b. For nonresidential additions, apply the multifamily new construction requirements.
c. The verification, partnership, training, and credentialing requirements do not apply; they are superseded by the commissioning requirements of this standard (section 4.2).

5.2 Hazard mitigation

5.2.1 Earthquake

Buildings in locations with a Seismic Design Category (SDC) of C through E (as specified in the *International Residential Code*), and within the scope of FEMA P-50, shall be improved to a Seismic Performance Grade of B-minus or higher. Consult FEMA P-50-1 *Seismic Retrofit*

Guidelines for Detached, Single-Family, Wood-Frame Dwellings and the resources cited therein to develop the seismic part of the EBCx Plan.

Informative: according to FEMA P-50, The International Building Code (IBC) provides engineered design guidance that can be applied to any retrofit.

For buildings in locations with an SDC C through E, but outside the scope of FEMA P-50:

- The design of improvements requires the involvement of a licensed engineer or architect experienced in structural engineering.

5.2.1.1 Earthquake electives

Consider upgrades beyond the minimum B-minus level.

5.2.2 Flood

In FEMA designated flood zones V, A, B, D, and X-shaded [a la FORTIFIED 2.4.1], electrical and mechanical systems shall be protected from flood according to:

- FEMA P-348 *Protecting Building Utility Systems From Flood Damage*, or
- The requirements of IBHS FORTIFIED Commercial Silver, reproduced below:

"3.2.4 Electrical and Mechanical Systems and Connections (Flood Protection)
All electrical and mechanical equipment and connections necessary to operate critical systems shall be elevated at minimum above the 500-year flood level, if known, or 3 ft above the base flood elevation (BFE) for the property. If the equipment cannot be sufficiently elevated as described above, permanent dry flood protection such as flood gates, walls, doors, or similar devices shall be used to prevent water intrusion to the heights described above. Flood depth, duration, velocity, and condition of water shall be considered (including floating debris).

3.2.5 Electrical Connections for Backup Power
In hurricane-prone regions, electrical connections shall be installed with a transfer switch or docking station (sometimes referred to as a storm switch) in order to support connection of backup power for critical electrical and mechanical systems. All connections shall be located above the 500-year flood level if known, or 3 ft above the known base flood elevation (BFE) or design flood elevation (DFE) for the property."

5.2.2.1 Flood electives

In FEMA designated flood zones including V, A, B, D, and X-shaded, consider the flood protection measures in FEMA P-1037 - Reducing Flood Risk to Residential Buildings That Cannot be Elevated.

If funding is being sought from FEMA's Hazard Mitigation Assistance Program, see also FEMA's Guidance for Applying ASCE 24 Engineering Standards to HMA Flood Retrofitting and Reconstruction Projects.

5.2.2.1.1 Tsunami elective

Consider FEMA P-646 - Guidelines for Design of Structures for Vertical Evacuation from Tsunamis, Third Edition.

5.2.3 Hail

Roof-mounted photovoltaic (PV) systems require the following:
[a la 2020 FORTIFIED Commercial, section 5.1.3 and 2020 FORTIFIED Home, section 7.5]

- Flexible PV modules that are FM Approved for hail or meet FM Approval Standard 4476 that includes a Severe Hail rating.
- Rigid PV modules that are FM Approved for hail or meet FM Approval Standard 4478 that includes a Class 4 rating.
- Rigid modules that meet UL 1703 Standards for Flat-Plate Photovoltaic Modules and Panels.
  Informative: UL 1703 is for fire performance characterization of modules and panels.

5.2.3.1 Hail electives

In hail-prone counties, consider including additional requirements of the IBHS FORTIFIED Hail Supplement material in addition to the PV system requirements.

Informative: Following the FORTIFIED requirements referred to herein DOES NOT constitute compliance with FORTIFIED or imply that the property is a FORTIFIED property. In order to be considered as a FORTIFIED Home™, FORTIFIED Commercial Building or FORTIFIED Multifamily, the properties would have to participate in the FORTIFIED program, which requires formal documentation and review by IBHS.

5.2.4 Structural and High Wind concerns

5.2.4.1 Single family residential - structural and high wind

This section applies to single-family detached homes, duplexes, HUD manufactured homes on permanent foundations, and townhouses.

Homes on a foundation constructed of unrestrained stacked masonry or stone (a dry-stack foundation) shall be retrofitted in accordance with a professional engineering plan and comply with HUD-Code Manufactured Home foundation requirements - US Department of Housing and Urban Development (HUD) Permanent Foundation Guide for Manufactured Housing (HUD4930.3G) dated September 1996 or later. [a la FORTIFIED Home 2.3, 2.4]

See Figures 2.1, 2.2, and 2.3 in IBHS FORTIFIED Home, reproduced below:

☐ **Unreinforced (dry-stack) foundations**

Figure 2.1. Ineligible dry-stack foundation

Figure 2.2. Ineligible dry-stack foundation

Figure 2.3. Ineligible dry-stack foundation

Homes shall meet the requirements of a. or b. below:

a. IBHS FORTIFIED Home Standard, Section 3 - Existing Roof.
    - The requirements for hurricane designation apply where the ultimate design wind speed (Vult) is greater than 115 mph as specified in ASCE 7-10 through ASCE 7-16 or the nominal design wind speed (Vasd) is greater than 90 mph as specified in ASCE 7-98 through ASCE 7-05.
    - Elsewhere, the requirements for high wind designation apply.
b. FEMA P-804 Wind Retrofit Guide for Residential Buildings, section 4.1 - Basic Mitigation Package

Homes must comply with any applicable local structural codes.

5.2.4.1.1 Residential Structural and High Wind Electives

Consider the Intermediate, Advanced, and Additional wind retrofit mitigation packages in FEMA P-804, Chapter 4.

Consider IBHS FORTIFIED Home Standard, Section 6.5 Continuous Load Path for Retrofit of Existing Homes.
Informative: FORTIFIED Home, Section 6.5, is aimed at getting existing buildings to the Gold level.

For new additions in hurricane-prone regions, consider the higher tiers of the IBHS FORTIFIED Home Standard.

5.2.4.2 Structural and high wind - other than single-family

Buildings shall meet the requirements of IBHS FORTIFIED Commercial, Section 3.1 - FORTIFIED Roof.

5.2.4.2.1 Structural and high wind electives, other than single-family

For new additions in hurricane-prone regions, consider higher tiers of IBHS FORTIFIED Commercial.

Consider the additional improvements described in:

- FEMA P-1000 A Guide to Improving School Natural Hazard Safety, Supplement W, and
- FEMA P-424 Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds, Chapter 6.

5.2.5 Snow load and ice dams

If ice dams have been a regular occurrence, diagnose and mitigate them.
Informative: See Lstiburek (2018).

5.2.5.1 Snow Load Electives

FEMA P-957 Snow Load Safety Guide
FEMA Roof Snowdrift Design Guide

5.2.6 Wildfire

In areas where the FEMA designated wildfire risk is “Relatively Moderate” or higher, take the actions listed in the Defensible Space & Home Hardening Self-Inspection Checklist of the City of Berkeley Fire Department, reproduced below:

- Do you have any accumulated vegetation waste?
- Is your car blocking any fire apparatus access to roads? Fire trucks need a minimum lane of 26 feet wide and 13’ 6” tall for clearance. We recommend backing your vehicle into driveways on Red Flag warning days.

- Can you see your address from the street? Address identification must be seen from the street in the day or night time and contrast in color from their background.
- Are the power lines cleared? There must be a minimum of 4 feet of clearance from the high voltage conductor. If the power lines are obstructed, contact PG&E to request trimming around the power lines.
- Is there clearance of brush from roadways? Minimum of 10-feet on each side of the roadway must be cleared of vegetation such as tall grass, weeds or brush.
- Is there defensible space around your home? Some things to consider:
    - Cut grass and flammable vegetation
    - Remove combustible items from areas such as decks, overhangs and stairs
    - Relocate combustible outdoor furniture
    - Create space between plants and between plants and structures
    - Trim trees 10 feet back from chimney(s) and if possible from overhanging your roof
    - Remove old leaves and pine needles from roofs, eaves and gutters
    - Remove branches within 10 feet from the ground (limbing)
    - Remove dead wood / or thin overly dense tree crowns
    - Remove understory, brush and ground fuel beneath trees
    - Thin stands of trees / shrubs by removing individual stems or plants
    - Strip loose bark 8-feet from the ground (eucalyptus)
- Do you have Spark Arrestors installed? Spark arrestors are required for chimneys, fireplaces, barbecues, incinerators or heating appliances (Berkeley Building Code 704A1.6 for specifications).
- Can you maintain an effective fire break by removing anything combustible 30 feet from the structure?
- Remember, brush and debris does not need to be completely removed but may be chipped into pieces less than 3 inches in size.

5.2.6.1 Wildfire Electives

in areas where the FEMA designated wildfire risk is “Relatively Moderate” or higher, and for new additions, consider:

- The mitigations listed in FEMA P-737 - Home Builder's Guide to Construction in Wildfire Zones.

- The IBHS Wildfire Prepared Home standard.

6 Performance requirements

6.1 Simulation Requirements

Informative: An input-file driven calculation engine compliant with this standard is available open-source at (github link here).

6.1.1 General capabilities

[a la ASHRAE 90.1-2019 Section 11.4.1, modified below]

11.4.1 Simulation Program
The simulation program shall be a computer-based program for the analysis of energy consumption in buildings. ~~For components that cannot be modeled by the simulation program, the exceptional calculation methods requirements in Section 11.4.5 shall be used.~~
~~Informative Note~~
~~ASHRAE Standing Standard Project Committee 90.1 recommends that the simulation program implement the rules of Section 11 that control simulation inputs and outputs be adopted for the purposes of easier use and simpler compliance.~~

11.4.1.1
The simulation program shall be approved by the ~~adopting~~ authority and shall, at a minimum, have the ability to explicitly model all of the following:

a. 8760 hours per year
b. Hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat set points, and HVAC system operation, defined separately for each day of the week and holidays
c. Thermal mass effects
d. Ten or more thermal zones
e. Part-load performance curves for mechanical equipment
f. Capacity and efficiency correction curves for mechanical heating and mechanical cooling equipment
g. Air-side economizer and fluid economizer with integrated control
h. Capable of simulating an outage in which the mechanical and electrical equipment is not available

~~h. The budget building design characteristics unless otherwise specified in Section 11.5~~

11.4.1.2
The simulation program shall have the ability to either

a. directly determine the design energy cost and <u>baseline</u> energy cost ~~budget~~ or
b. produce hourly reports of energy use by energy source suitable for determining the design energy cost and <u>baseline</u> energy cost ~~budget~~ using a separate calculation.

11.4.1.3

The simulation program shall be capable of performing design load calculations to determine required HVAC equipment capacities and air and water flow rates in accordance with Section ~~6.4.2~~ 6.1.8 for both the proposed design and the ~~budget~~ baseline building design.

11.4.1.4
The simulation program shall be tested according to ASHRAE Standard 140, except for Sections 7 and 8 of Standard 140. The test results and modeler reports shall be posted on a publicly available website and shall include the test results of the simulation program along with the results of the other simulation programs included in ASHRAE Standard 140, Annexes B8 and B16. The modeler report in Standard 140, Annex A2, Attachment A2.7, shall be completed for results exceeding the maximum or falling below the minimum of the reference values or for missing results.
Informative: There are no pass/fail criteria established by this requirement. The forthcoming update to Standard 140 is expected to be pass/fail and might moot some of the requirements in 6.1.1.

6.1.2 Weather / climatic data

The simulation program shall perform the simulation using hourly values of climatic data, such as temperature and humidity from representative climatic data, for the site in which the proposed design is to be located. For cities or urban regions with several climatic data entries, and for locations where weather data are not available, the designer shall select available weather data that best represent the climate at the construction site. The selected weather data shall be approved by the..authority. [a la 90.1 G2.3]

US locations:
The weather data for annual simulations shall be EPW.
Phius practice is to limit the number of design days in the DDY file to four.

The weather data for the outage resilience tests shall comply with 6.1.2.1 or 6.1.2.2.

6.1.2.1 Resilience extreme week morphing

For both Dry bulb and Dew point temps:

Txweek2_dry_h = Txweek_dry_h + Delta_dry*sin(phase)
Txweek2_dew_h = Txweek_dew_h + Delta_dew*sin(phase)

Txweek is the temperature history in the extreme week period of the TMY STAT file.
Txweek2 is the morphed temperature history.

Do likewise for dry bulb and dew point:

h is the hour within the outage period, 0 ≤ h ≤ hout
hout = 167 # outage duration in hours minus 1
Phase_h = pi * h / hout

Iteration:
Delta_init = Treturn - avg(Txweek)
Treturn are the n-year return extreme values of DB and dewpoint, converted from DB and Wet bulb, from ASHRAE Climatic Design Conditions data.
For winter, use the 10-year return values.
For summer, use the 20-year return values.
Delta = Delta_init
Repeat
Txweek2_h = Txweek_h + Delta*sin(phase_h)
K is a relaxation factor = 0.1
X = [max(Txweek2) for hot week,
min(Txweek2) for cold week]
Deltanext = Delta+K*(Treturn-X)
Delta = Deltanext
Until abs(Treturn-X) < tolerance ~ 0.01 F

Then limit the dew point to be less than or equal to the dry bulb temperature, for all hours.

Informative: A possible improvement for the winter case is to calculate dew points that keep the RH the same as in the TMY.

6.1.2.2 Reserved

Informative: Reserved for protocol on future-weather extremes TBD. The protocol in 6.1.2.1 is based on historical data. For the summer condition, forcing the n-year extremes of temperature and humidity into coincidence is extra stressful. A protocol based on climate science for future weather extremes would be preferable and might be either more or less stressful.

6.1.3 Thermal blocks

Multifamily and mixed-use buildings shall be modeled in multiple thermal blocks, with each dwelling unit as a thermal block.

Exception: Buildings less than four stories in height and with six units or less.
Exception: To use single-zone modeling, see the additional requirements in Normative Appendix MZ - single-zone approximation for multifamily / multizone buildings.

6.1.4 Accounting for thermal bridges

Account for thermal bridges in accordance with ASHRAE Standard 227P - *Passive Building Design, Advisory Public Review Draft*, sections 5.2.2 through 5.2.5.
Exceptions:

- Skinny assemblies may be used to represent weakly-insulated sills and top plates.
- Point thermal bridges may be represented by a small area of weakly-insulated assembly.

Informative:

- *To account for linear thermal bridges in EnergyPlus, an object could be created for psi-value-based linear thermal bridging. This can be accounted for by using an EnergyManagementSystem:Program to calculate a conduction heat transfer based on the temperature delta, and applying that gain or loss to an OtherEquiptment object.*
- *To account for window installation thermal bridges in EnergyPlus, a WindowProperty:FrameAndDivider object could be used.*

6.1.5 Contact to the ground

Building ground contact shall be modeled using the Kiva™ method.

6.1.6 Thermal mass of interior partitions and furnishings

Thermal mass shall be accounted for in the simulation, calculated by the design of the building in situ, and as designed for the proposed case.

Exception: For the partition wall mass, use either a) the actual design / existing condition, or b) a partition wall assembly of light construction and area equal to the floor area of the thermal block. [Per BAHSP 2014]

6.1.7 Infiltration model

For buildings three stories or less in height, use the Flow Coefficient model.
Informative: According to the EnergyPlus Engineering reference, "... the "Flow Coefficient" model [is] based on Walker and Wilson (1998)…The model formulations for the Effective Leakage Area and Flow Coefficient models are from the ASHRAE Handbook of Fundamentals (2001 Chapter 26; 2005 Chapter 27) where they are referred to as "Basic" and "Enhanced", respectively.

For buildings greater than three stories in height, use the Design Flow Rate model with NIST parameters.
Informative: According to the EnergyPlus Engineering Reference, "The "Design Flow Rate" model … was inherited from EnergyPlus' predecessor programs. It ... is based on environmental conditions modifying a design flow rate. The basic equation [is from] Coblenz and Achenbach (1963)."

6.1.7.1 Existing building air-tightness assumption

Informative: 12 ACH50 is suggested as a default assumption for existing building air-tightness. For single family homes, a possible improvement is to use the median value (at y=0.5 on the cumulative distribution plot) from the LBNL Residential Diagnostics Database (ResDB) calculator, with inputs appropriate to the specific case.

6.1.8 Schedules for annual / normal-operation calculation

Use the schedules in Appendix SC for:

Occupancy

Hot water
Lighting
Major Appliances
Miscellaneous electric loads
Miscellaneous gas loads

6.1.9 Design load calculations

Equipment sizing and design loads for residential spaces shall be calculated using a dynamic heat balance method, and shall account for design air ventilation rates, design occupancy.

Internal gains are to be calculated according to the RLF method from ASHRAE RP-1199, equations (18) and (19), applied per dwelling unit, as follows.

The contributions of internal gains to peak sensible and latent loads are:
$Q_{ig,s} = G0,s + Gcf,s*Acf + Goc,s*Noc$
$Q_{ig,l} = G0,l + Gcf,l*Acf + Goc,l*Noc$

Where

$Q_{ig,s}$ is the sensible cooling load due to internal gains, Btu/h (W)
$Q_{ig,l}$ is the latent cooling load due to internal gains, Btu/h (W)

Gx = coefficients as follows:

	Sensible IP (SI)	Latent IP (SI)
G0	464 (136)	68 (20)
Gcf	0.7 (2.2)	0.07 (0.22)
Goc	75 (22)	41 (12)

Acf = conditioned floor area of building, ft2 (m2)
Noc = number of occupants; if not known, use the number of bedrooms plus one, per dwelling unit.

The internal gains shall be active during the cooling sizing, but absent from the heating sizing period. Occupants are present for both sizing periods.

6.1.10 Reflectance of blinds

Effectiveness of exterior blinds for shading shall be either “medium” or “high” as follows:
Medium: 0.4 solar transmittance, 0.5 solar reflectance
High: 0.1 solar transmittance, 0.8 solar reflectance

6.2 Winter Resilience

6.2.1 Winter Resilience Requirements

6.2.1.1
In its final configuration, the post-retrofitted building shall be capable of meeting the winter performance criteria (section 6.2.2) using space heating energy only from sources that are passive or renewable, and on-site, and without resort to combustion (or fuel cells) directly or indirectly.

> Exception: For nonresidential buildings, including hospitality or transient dwelling units, the space heating energy sources shall be:
> Passive or renewable, and on-site, or
> Provided by local electrical microgrid or thermal energy network having primary energy sources that are all renewable.

For nonresidential buildings, including hospitality or transient dwelling units, in the final configuration, the post-retrofitted building shall also be capable of covering winter-critical electrical and process loads, as defined in the CFR, using energy only from sources that are:

> Renewable and on-site or
> Provided by local electrical microgrid or thermal energy network having primary energy sources that are all renewable.

6.2.1.2
On-site renewable energy generation systems shall have the capability to disconnect from the grid and to operate without a grid connection.

6.2.2 Winter Resilience Criteria

During the simulated outage, each thermal block shall have:

a. Zero hours below 36 °F, and
b. No more than 216 SET-hours, base 54 °F, at 1 clo, 120 W/person, 0.16 m/s air speed.

Exception:
For nonresidential buildings, in thermal blocks that are intended to be unoccupied during a winter outage, only 6.2.2.a applies.

6.2.3 Winter Resilience Evaluation Protocol

Outage duration 7 days.
HRV/ERV @ 5 cfm/person.

Residential miscellaneous electric load of TBD (about 33 Watts continuous or 289 kWh/year.)
Informative: equivalent to the class of off-grid refrigerator formerly known as SunFrost.

Nonresidential internal heat gains are consistent with the nonresidential winter-critical electrical loads as defined in the CFR.
Occupancy schedule
Residential: there all the time.
Nonresidential: As defined in the CFR, and same as for the summer outage.
Residential heating system load calculation per ASHRAE RP-1199.
Nominal/default PV system: 2 watts of rated power per square foot of roof area, tilted latitude+15 degrees, facing south.

6.3 Summer Resilience

6.3.1 Summer Resilience Requirements

6.3.1.1
In its final configuration, the post-retrofitted building shall be capable of meeting the summer performance criteria (section 6.3.2) without resort to combustion directly or indirectly, and with space cooling energy that comes from either:

a. Sources that are passive or renewable, and on-site, or
b. A local electrical microgrid or thermal energy network having primary energy sources that are all renewable.

For nonresidential buildings, including hospitality or transient dwelling units, in the final configuration, the post-retrofitted building shall also be capable of covering summer-critical electrical and process loads, as defined in the CFR, using energy only from sources that are:
Renewable and on-site or
Provided by local electrical microgrid or thermal energy network having primary energy sources that are all renewable.

6.3.1.2 Same as 6.2.1.2.

6.3.2 Summer Resilience Criteria

During the simulated outage, each thermal block shall have:

a. Heat Index: Zero hours in Danger, Extreme Danger, and
b. Zero deadly days per Mora et al.

Exception:
For nonresidential buildings, in thermal blocks that are intended to be unoccupied during a summer outage, the summer-outage heat exposure criteria defined in the CFR shall be met.

6.3.3 Summer Resilience Evaluation Protocol

Outage duration, Occupancy schedule, ventilation rate, residential MEL, and PV all the same as 6.2.3.
Residential cooling system sizing per ASHRAE RP-1199.

Nonresidential internal gains consistent with the nonresidential summer-critical electrical loads as defined in the CFR.

Deadly day criterion:
During the summer outage,

Tday - Tdead <=0, where

Tdead [C] = 49.593 - 48.580*RHday + 25.887*RHday^2
Tday is the mean daily temperature in the thermal block.
RHday is the mean relative humidity in the thermal block, as a fraction 0≤RHday≤1.

Building Operation modes:

Shading & Nat Vent

Open area - Use operable window areas for natural ventilation based on a 1.5°C delta dry bulb to passively cool the space

Control logic - Use above operable windows and delta dry bulb controls, but only allow for natural ventilation based upon photocell control, not allowing for any ventilation during the day while the sun is up

Reduction factors for interior and exterior blinds, see 6.1.9. - use exterior blinds to keep solar heat gains from entering the space, triggered to close if there is greater than 100 W/m2 of incident radiation on the window

Evap cooling - Supply active cooling by an evaporative cooler (dry climates only)

Shading & heat pump cooling

Control logic - Set the heat pump to run when on site renewable power makes its usage possible. If no renewable power is available, run the heat pump on a setback of 80.6°F (27°C) and 70% RH.

Informative - The aim is to keep the space heat index at Caution or below (heat index of 90°F (32°C)).

Any electrical energy purchased through the meter is to be accounted for in the cooling battery sizing calculation.

Informative - Further development is needed on the control sequences for mixed mode operation and could be a future refinement for optimization

6.4 Life Cycle Cost and Impact Control

6.4.1 Life cycle cost limit

The ADORB cost of the proposed retrofit is to be no greater than that of a baseline case, in which the building is operated and maintained as-is. The calculation protocol for ADORB cost is in Appendix A.

Exception: Exclude costs associated with new construction additions.

6.4.2 Additional Decarbonization Effort

6.4.2.1 Operational decarbonization

In their final configuration, dwelling units shall have the following:

- Each air-source heat pump shall be
    - Controlled by a smart thermostat that is US EPA Energy Star certified, or by an equivalent thermostat acceptable to the Authority, or
    - Meet EPA's connected criteria, or an equivalent acceptable to the Authority.
- Each heat pump water heater shall meet EPA's connected criteria, or an equivalent acceptable to the Authority.

Do one of the following:

a. Electrify building operation in the first implementation phase and comply with the requirements for Phius ZERO in Appendix A of the Phius Certification Guidebook, from the first implementation phase onward.

    Exceptions:
    On-site stored combustion fuel for emergency backup electricity generation.
    On-site stored combustion fuel for outdoor cooking.

b. From the first implementation phase onward, subscribe to a community solar project or program at a level of commitment that would cover at least 100% of the building's expected annual electrical energy consumption in its final post-retrofit condition, net of any on-site renewable energy production.

6.4.2.1.1 Community solar plus storage elective

The community solar project includes community-scale storage or constitutes a microgrid.

Informative:
See the US DOE Community Solar Resource Page for more information.

According to Utility Dive, "Community-scale solar and storage could also form an anchor for a community-level microgrid that could isolate from the larger grid in such situations, but doesn't require waiting for these plans to materialize before creating a basic community resilience resource."

6.4.2.2 Embodied decarbonization

Include least one level 2 embodied carbon measure - a material substitution, business practice change, or personal choice change.

The calculation protocol for Level 2 embodied carbon measures is further elaborated in Appendix A, and implemented in the example worksheet linked below. Download a copy to edit.

https://docs.google.com/spreadsheets/d/1xcI1zpPAcboNRSyDyfOptMsiaZhPgXulhF5ozSGP9bU/edit?usp=sharing

7 Monitoring Requirements, measurement & verification

Register the building with Energy Star Portfolio Manager and track its energy and water utility meters.

Share with or grant access to the data, for both the CxP and the Authority.

7.1 Indoor environment monitoring electives

Monitor some chosen quantities listed in this section at least hourly and maintain a data log going back at least 15 months.

7.1.1 Hazardous gas monitoring elective

- Carbon monoxide
- Radon

7.1.2 Indoor Environment Quality (IEQ) monitoring elective

Informative: The following measurements are aligned in scope with the RESET Air standard. If actually pursuing RESET Air certification, the core-and-shell option seems preferable.

- Temperature
- RH
- Carbon dioxide (CO2)
- PM2.5
- TVOC

Informative: Additional measurements within the scope of Building 4 Health:

- NO2
- Ozone
- PM10
- PM1.0
- SO2

7.2 Energy end-use monitoring elective

Monitoring for energy end use breakdown in the following priority order:

1. Other miscellaneous loads
2. Supplemental dehumidification
3. Space heating
4. Space cooling
5. Domestic / service hot water heating
6. Lighting
7. Major appliances

8. Humidification

7.3 Water quality monitoring elective

RESET Water quality

Informative note: the current scope of RESET Water is for water used by the occupants of commercial interior spaces, or for the water quality of central water systems and public spaces in a building.

7.4 Waste/Materials tracking elective

Use Energy Star Portfolio Manager to track Waste/Materials.

8 Process, Part Two

8.6 Assessment

Informative:
"The Assessment Phase consists of preparatory activities of the EBCx Process in which Current Facility Requirements (CFR) and an Existing-Building Commissioning (EBCx) Plan are developed and defined for a single facility, and an assessment of the facility is performed. … The purpose of the Assessment Phase is to gain enough of an understanding about the individual facility to develop an initial scope, schedule, budget, and general approach for the Investigation Phase as well as … a general estimate of the cost and timeline for the total project." [0.2 6.1.1]

"...It is not a full evaluation but rather a cursory data gathering and brief walkthrough of the facility, resulting in sufficient information to develop the EBCx Plan and assess the benefits of proceeding with the process." [0.2 6.7.1]

"This phase concludes with the completion of the EBCx Plan and…acceptance of the Assessment Phase report." [0.2 6.1.1]

8.6.1 Facility information

[a la Standard 230 section 5.2.1.1.1, 5.2.1.2.1.1]
The Owner shall provide to the CxP:

- Facility Summary. A narrative describing facility location, size, occupancy type, construction, systems, and facility usage.
- All available facility information, including the following:
    a. Construction documents (drawings; specifications; submittals, especially HVAC controls; as-builts; previous modifications to the facility).
    b. For multifamily residential buildings, and to the best of the Owner's ability, fill out the US DOE Multifamily Building Efficiency Screening Tool (MBEST) workbook.
    c. Scheduled maintenance worksheets and work order history for systems included in the EBCx scope.
    d. Previous new-construction commissioning Systems Manual, including its final commissioning report, or previous EBCx systems and facility manuals (as applicable, from previous projects).
    e. Any previous consultant reports for systems included in the EBCx scope (as applicable).
    f. Utility rates, suppliers, and meter (and submeter) locations, data availability (hard copy or electronic).
    g. Operations and maintenance (O&M) plan.
    h. O&M report of operating problems, malfunctioning equipment, maintenance costs, and revisions to O&M procedures pertaining to systems included in Cx scope.

i. Annual maintenance cost breakdown of interior building costs, building enclosure maintenance cost, and repair budget.
j. Onsite energy production (as applicable).
k. Any occupant surveys conducted.
l. A budget for low-cost repairs to be performed within the operations and maintenance (O&M) budget for the facility, where such a budget exists. If no budget exists, the Owner shall develop a budget for low-cost repairs. (for safety, security, health, or operational issues that can be easily remedied, do not require further investigation, and thus can be immediately implemented as the team develops the initial information on the facility. [a la 0.2 6.7.6.1]

8.6.2 Occupant Survey

Prepare an occupant satisfaction survey for Owner distribution. [a la 230 5.2.1.3 and 6.2.1.1a]
The occupant survey shall ask questions to evaluate the level of satisfaction of the occupants and the impact their living space or workspace has on their activities.
If the occupant survey is conducted verbally, record the responses in writing.

8.6.2.1 Occupant Survey Minimum Content

[a la 230 5.2.1.3.3.1]
a. Reserved
b. Age range (e.g. under 14, 14 to 22, 35 to 50, over 80 etc.)
c. Type of space (dwelling, office, classroom, retail shop etc.)
d. Acoustical privacy
e. Ambient noise negatively impacting concentration
f. Perception of thermal comfort (hot, warm, slightly warm, neutral, slightly cold, cold) and areas of the body affected (neck, back, arms, hands, thighs, lower legs, feet)
g. Adequate lighting for tasks and activities
h. Visual comfort
    1. Light quality impacting tasks and activities
    2. Lighting color discrimination
    3. Problematic light flicker
    4. Glare
    5. Difficulty seeing computer screen
    6. Adequacy of light levels in common areas
i. Indoor air quality
    1. Air quality (stuffy/stale conditions)
    2. Unpleasant odors (food, carpet, other occupants, perfume, cleaning products, outside sources)
j. Approximate or specific location in building (except for single-family detached)
k. Is it generally safe to open windows on summer nights for natural ventilation cooling ?

8.6.3 Processing Owner-Provided Information

The CxP shall: [a la 230 5.2.1.3.1]

a. Assemble a CxP Team with the technical expertise required to perform the EBCx scope of work.
   Informative: Each team member needs a clear understanding of the overall EBCx goals and objectives, what is expected of them, and where their portion of the work fits in the process. The CxP plays a vital role in ensuring that the roles and responsibilities are properly defined, well communicated, and continually met by the team members [a la 0.2 6.3.4].
b. reserved.
c. The CxP shall assist the Owner with development of the CFR in accordance with this standard, and with approval of the CFR document developed by the CxP.
d. Evaluate Owner-provided input to the CFR and verify that the information is clear in meaning and defines measurable project criteria.
e. reserved.

[a la 230 5.2.1.2.1.5]

8.6.4 Development of Current Facility Requirements - round 1

[a la 0.2 6.4]

Informative: A cornerstone of the EBCx Plan is the establishment of a document defining the CFR. [0.2 6.4.1] The CFR is a living document. The latest version of the CFR will remain the standard for evaluating the decisions throughout the EBCx Process. Documentation of changes in each update of the CFR shall be maintained along with the reasons for modification to prevent incorrectly going back to a prior statement of requirements without justification. These documents are included in the deliverables from this and all other phases of the process. [a la 0.2 6.4.11]

Write the CFR using the outline given in Appendix T-1.

This first pass is to capture Facility requirements, and M&V electives from section 7. The CFR is to be updated with additional electives after performing the Assessment, per section 8.6.7.5.

Give each owner-determined and owner-elected requirement a unique identifier. For the IAQ electives per section 5.1, use the codes from the referenced EPA documents.

8.6.4.1 Facility requirements

For both the existing building and any intended additions, capture facility requirements including [a la 0.2 6.4.4 and 230 5.2.1.2.1.2-4]:

a. Regulatory and jurisdictional requirements (any violations of other codes that need to be addressed).
b. Financial requirements.
c. Functional uses, functional activities/tasks performed in the building and associated requirements to facilitate efficient execution of occupant mission.
d. Space needs.

e. Occupancy requirements and occupancy schedules in normal operation.
f. Indoor environmental requirements (temperature, humidity, air quality, ventilation, lighting).
g. Level of systems control.
h. Preferred vendors / contractors.

8.6.4.1.1 Nonresidential - critical loads and other outage resilience requirements

Describe the critical electrical and process loads - those to be kept operational during the winter outage scenario per section 6.2.3, and during the summer outage scenario per section 6.3.3. Tabulate the peak power and estimate a diversity factor for each critical load.

Define the nonresidential occupancy schedule for the outage scenarios, if different from the normal-operation occupancy. Per section 6.3.3, the outage occupancy is to be the same for summer and winter.

For thermal blocks that are intended to be unoccupied during a summer outage, define the heat exposure criteria to be met.

8.6.4.2 OCx / measurement and verification (M&V) electives

Determine the level of implementation: Review the measurement and verification electives in section 7, make an initial determination of which ones to include.

8.6.5 Development of Commissioning Plan (EBCx Plan)

[a la 0.2 6.5]
Informative: The efforts and documents developed throughout the Assessment phase compose the groundwork for the EBCx Plan. The EBCx Plan provides the foundation from which the Investigation and Implementation Phases proceed. [a la 0.2 6.5.1] The initial EBCx scope, schedule, and budget are developed based on the EBCx Plan, the assessment, and other criteria established by the EBCx Team. [0.2 6.5.5] The EBCx Plan is first developed prior to the assessment and then updated after the assessment is complete. [0.2 6.5.4]

Use Normative Appendix T-2 as the framework for developing the commissioning plan.

Analyze occupant survey data to identify areas needing investigation. [a la 230 6.2.1.2.1 d]

8.6.5.1 Site visit planning

Review the assessment protocols in the US EPA *Energy Savings Plus Health Indoor Air Quality Guidelines* to identify locations to be inspected on site.

- Identify pertinent unknowns about the existing condition that could be discovered in a walkthrough, and record these in the Assessment section of the EBCx Plan.
- Rearrange the order of the IAQ Assessment items in the EBCx Plan Outline to make the best use of time on site.

8.6.5.2 Initial modeling to meet performance requirements

Review utility rate schedules and incentives from government and utilities that could benefit the project. [a la 230 6.2.1.2.1 h]

Simulate the existing building according to the protocol in section 6.1 to determine its performance versus the resilience and ADORB cost metrics of section 6.2, 6.3, 6.4.

If there is pre-existing building air tightness test data (according to ANSI 380, ASTM E779, ASTM E1827, ASTM E3158, ABAA T0001, or ISO 9972) use that data for modeling the baseline case. Otherwise, use the protocol per section 6.1.7.1 Existing building air-tightness assumption.
Informative: air tightness testing for compartmentalization of dwelling units will usually be required in the Investigation Phase, but whole-building testing is not required.

Begin modeling of retrofit upgrade packages with a view to determining a final post-retrofit configuration that meets the resilience requirements of section 6.2 and 6.3. See Informative Appendix P - retrofit package tiers.

Determine at least one post-retrofit configuration that meets the performance requirements of section 6. Give each package or case a unique identifier.
Informative: Ground source heat pumps are not out of the question for retrofit and might be applicable to low rise multifamily buildings.

Record the results for the baseline and post-retrofit cases in the Assessment Report.

- Include energy end-use breakdown and ADORB cost component breakdown.
- Further break down the direct costs, per the budget categories for performance-related upgrades in Appendix T-6.

8.6.5.3 Phase Plan for performance-related measures

Review the decarbonization compliance paths and electives in section 6.4.2. Make an initial determination of which approaches to take, record them in the CFR, and capture any related Investigation actions in the EBCx Plan.

In the Assessment Phase of the EBCx Plan, include an initial strategic plan as to the sequence in which the performance-related upgrades will be implemented. Retrofit phases comprise sets of upgrades separated by periods of time during which the building is put fully back in service.

If Section 6.4.2.1.a is being used for operational decarbonization, address early electrification.

Informative: More comprehensive planning that includes the upgrades to meet other requirements takes place in the Investigation phase.

8.6.5.4 M&V Plan

Make an initial plan to fulfill the minimum and elected M&V requirements (see section 7 and 8.6.4.2).

8.6.5.5 Approach to maintenance and persistence of benefits

Outline an approach to ensuring that improvements remain in place, as appropriate, over time - through training and putting mechanisms in place to regularly check the performance and the improvements. [a la 0.2 4.5, 6.5.1.e.4]

8.6.5.6 Process elective: Lessons-learned workshop

Consider conducting a lessons-learned workshop in the Hand-off phase, per section 8.9.6. Record the intent in the Hand-Off section of the EBCx Plan.

8.6.6 Begin the Systems Manual

The CxP is to organize pertinent facility information received from the Owner in the format of the Systems Manual. See Appendix T-4. If information defined in Section 8.6.1 is incomplete, identify missing information and discuss the issue with the Owner. [a la 230 5.2.1.3.1]

8.6.7 Perform Assessment

8.6.7.1 Site Hazard Risk Assessments

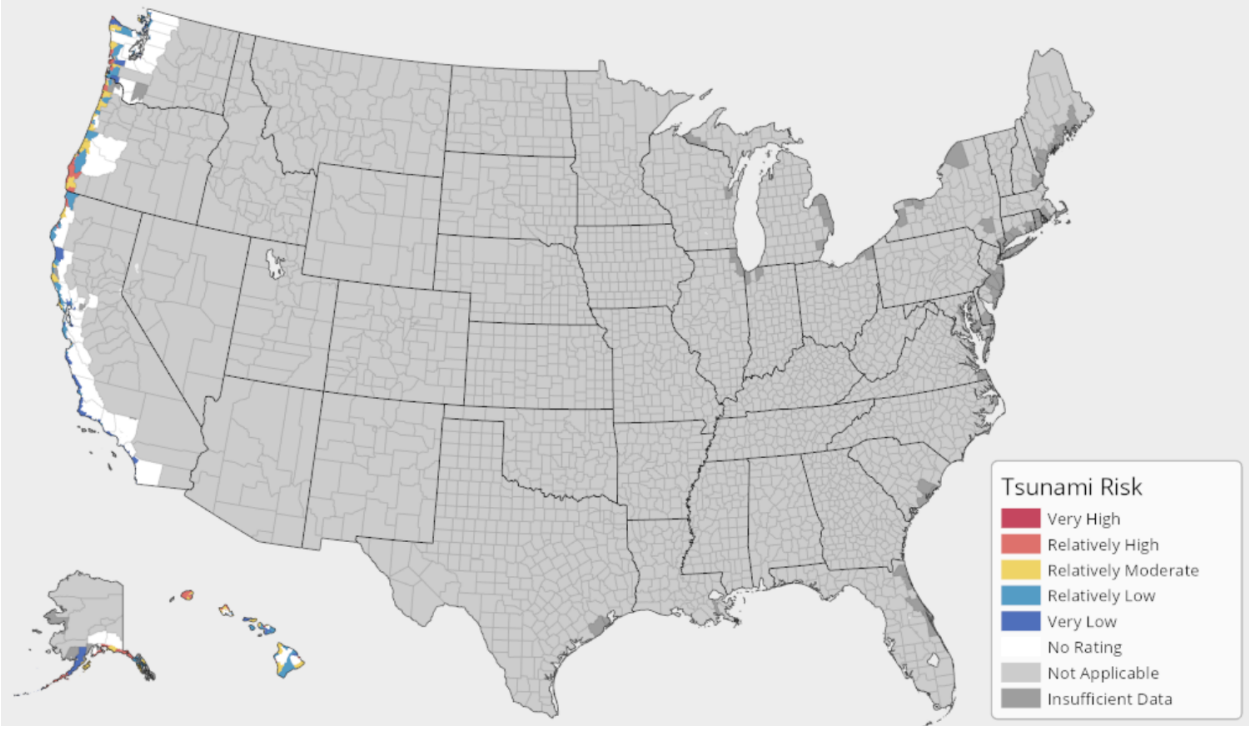
Informative: This section pertains to the requirements of section 5.2. The assessments mostly pertain to properties of the location rather than the building and do not require a site visit.

Determine the Seismic Design Category of the building location using FEMA's earthquake hazard map.
Alternatively, a licensed engineer experienced in geotechnical engineering can provide reassessment of the Seismic Hazard Score.

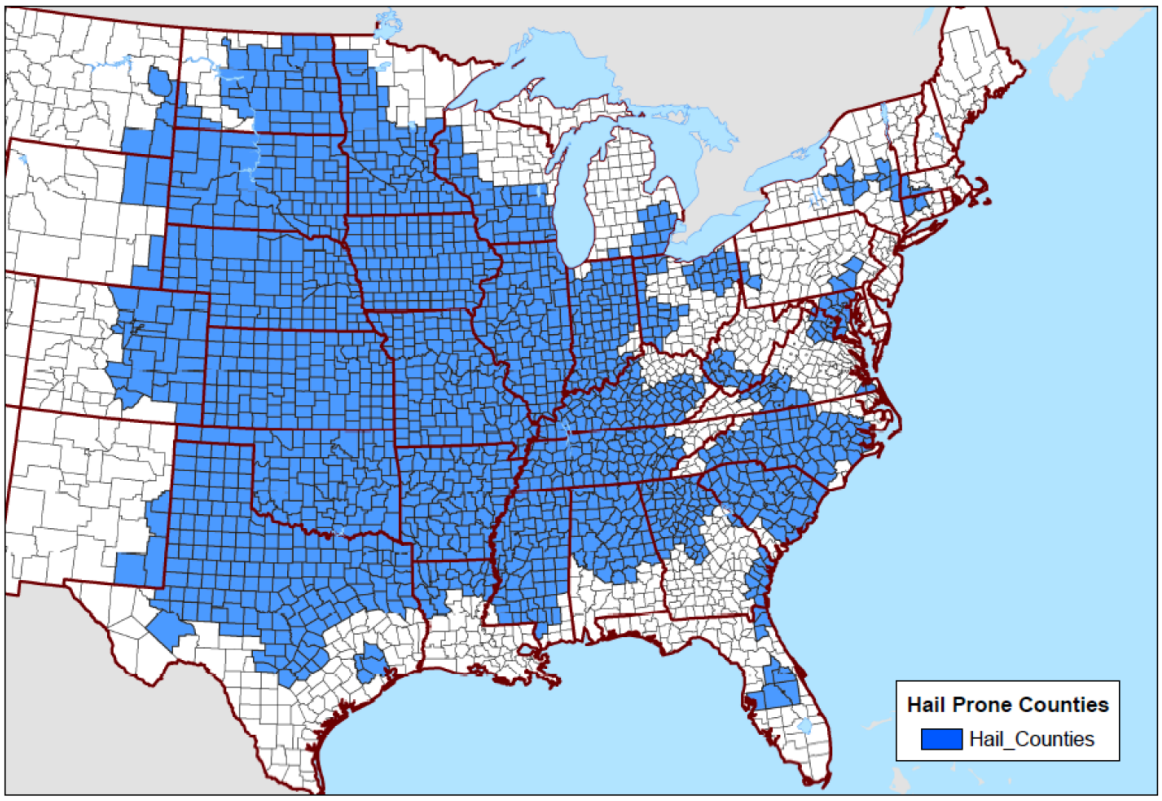
Follow FEMA P-154 - Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook, Third Edition.

Determine the FEMA designated flood zone.
Informative: How to read a flood map

For pacific coastal areas, also determine the tsunami risk level according to FEMA.



Determine whether the project location is in a hail-prone county according to the map in Figure 1 of IBHS 2020 FORTIFIED Commercial Wind Standards, reproduced below.



Hail-Prone Counties

Figure 1. The hail-prone counties shown here are based on hail reports compiled by the Storm Prediction Center. Counties in blue are subject to a high frequency of damaging hailstorms with a maximum hailstone size of 1 in. or larger. Source: IBHS

Determine whether the project location is in a hurricane or special wind region according to Figure 2-1 of FEMA P-804, reproduced below.

Use the Applied Technology Council online tool ATC Hazards by Location to determine design wind speed based on site address per ASCE 7-16, 7-10, and 7-05 (Refer to Risk Category II wind speeds):

Check local code requirements for wind speed as well, in case they differ from the wind speeds provided by the ATC website.
Informative: Appendix W summarizes some wind retrofit structural code compliance checks.

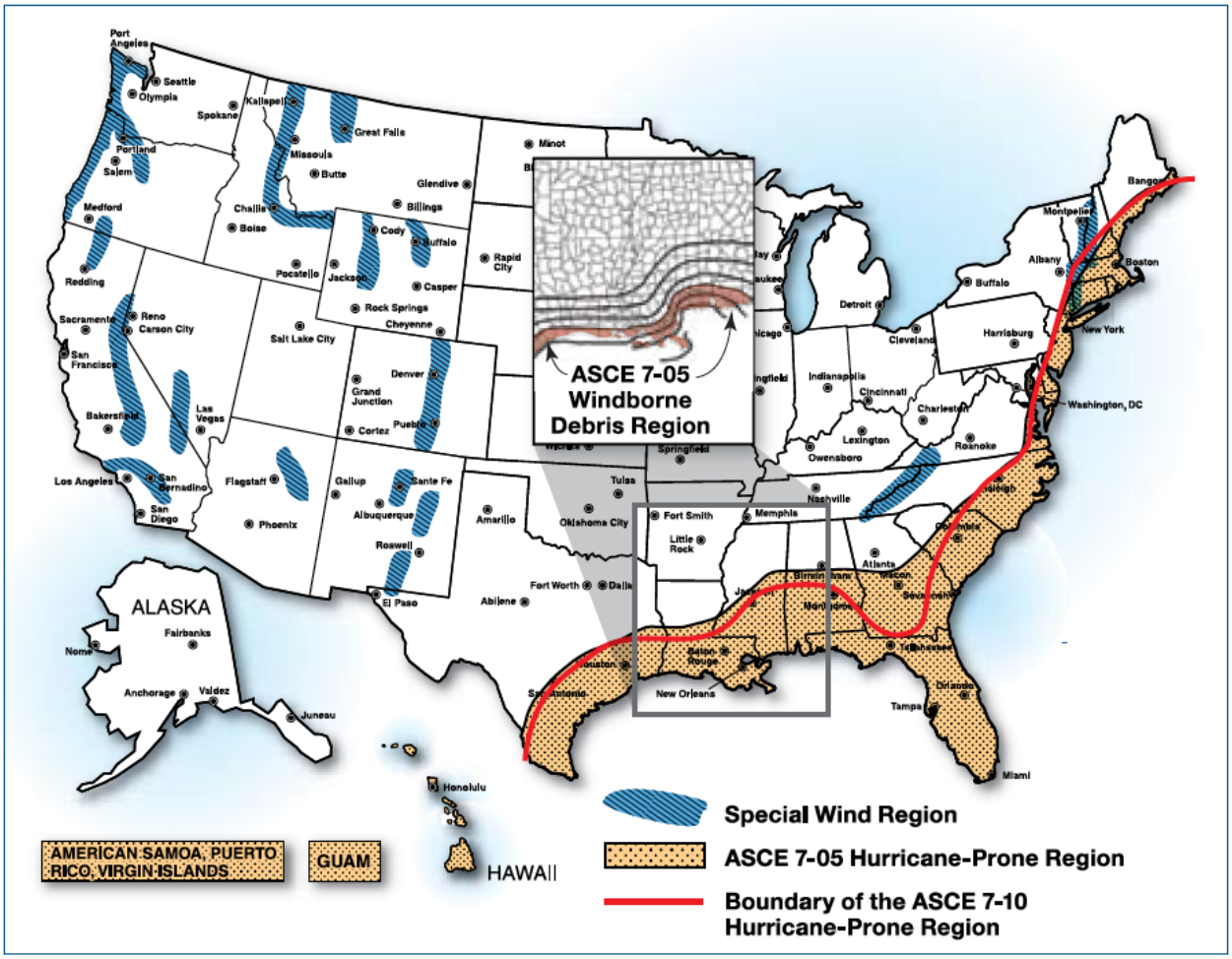
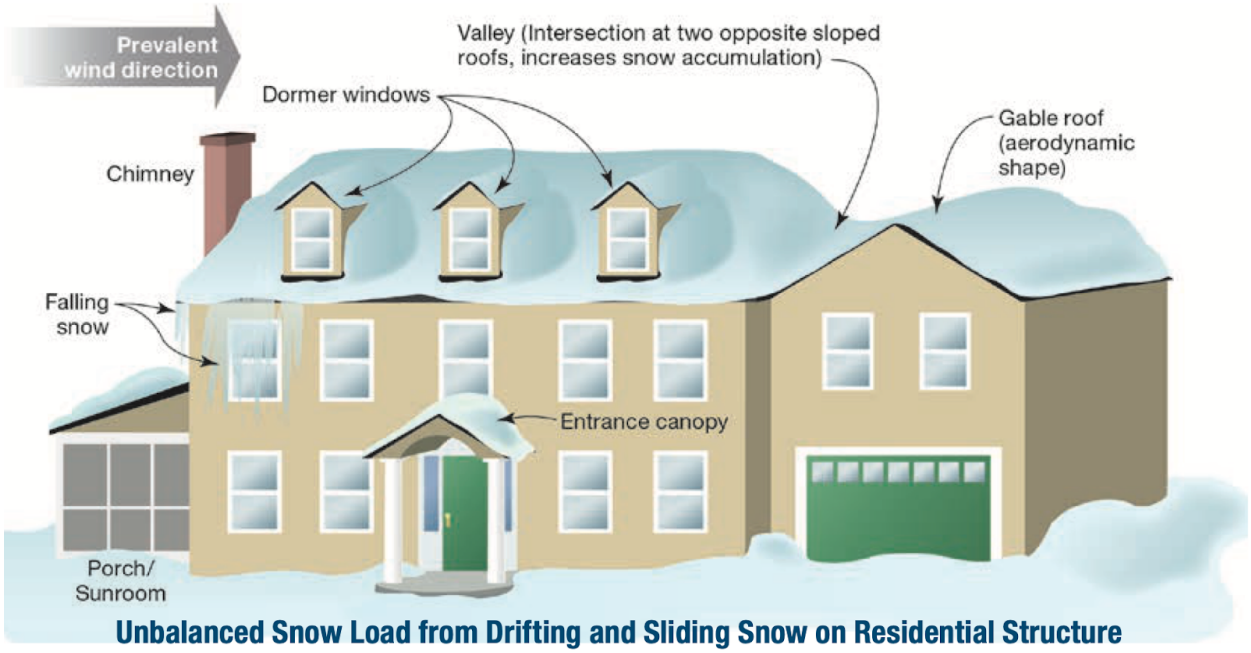


FIGURE 2-1:
Illustration of the hurricane-prone region of the United States

Assess whether ice dam or snow load needs to be addressed, in light of the info from the FEMA P-957 Fact Sheet, particularly:

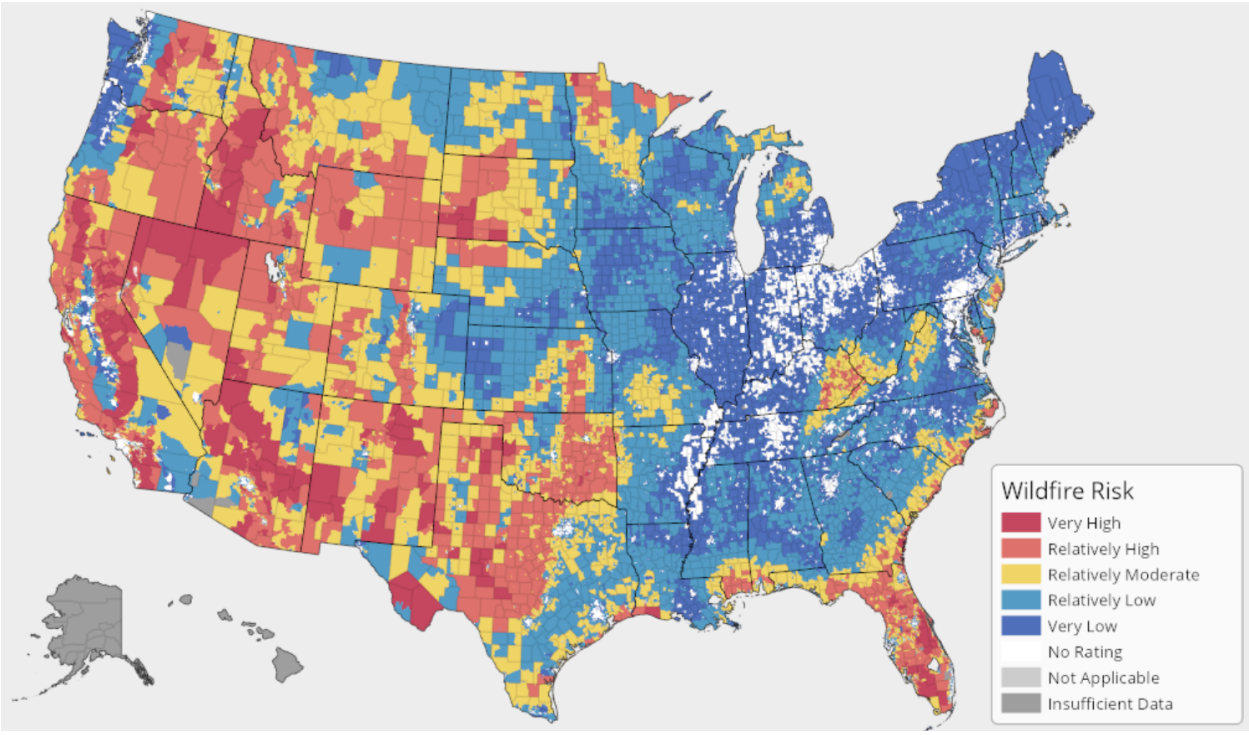
“If the roof drainage system is blocked, improperly designed or maintained, ice dams may form, which creates a concentrated load at the eaves and reduces the ability of sloped roofs to shed snow. On flat or low slope roof systems, snow melt may accumulate in low areas on roofs, creating a concentrated load.”

“Simple roofs with steep slopes shed snow most easily. Roofs with geometric irregularities and obstructions collect snow drifts in an unbalanced pattern. These roof geometries include flat roofs with parapets, stepped roofs, saw-tooth roofs, and roofs with obstructions such as equipment or chimneys.”



Unbalanced Snow Load from Drifting and Sliding Snow on Residential Structure

Determine the [Wildfire risk level according to FEMA].



8.6.7.2 Indoor Air Quality Risk Assessments

Informative: This section pertains to the requirements of section 5.1.

Visit the site and perform all the Assessment Protocols of the US EPA *Energy Savings Plus Health Indoor Air Quality Guidelines* that can be done in a walkthrough.

Capture assessments into the Assessment Report part of the EBCx Report.

Capture items that need further attention in the Investigation Phase, into the Investigation Plan section of the EBCx Plan.

8.6.7.3 Reserved

8.6.7.4 Issues and Resolution Log

[a Ia 0.2 6.7.4]

Set up an issues and resolution log. Include the following items (from ASHRAE SSPC 300 Informative Annex 11) in the issues and resolution log:

a. Project title
b. Project location
c. Name of the Cx Provider (CxP) managing the issues and resolution log, with e-mail address and phone number
d. Issue number
e. Issue description
f. Pictures of item if available and appropriate
g. Date issue discovered
h. Issue found by name
i. Effects of issue on project or building operation
j. Possible cause of issue or problem
k. Recommendation for resolution if available
l. Person(s) assigned to resolve issue
m. Actions taken
n. Approvals of issue resolution, including approver's name"

Informative: "The CxP maintains an issues log for commissioned systems. The general contractor typically maintains logs for RFIs and punchlist items on all systems (commissioned or not). There may be duplication between these logs, so finding a mechanism which reduces duplication while still allowing easy access to up-to-date information for all stakeholders is desirable. It is up to the Owner, the CxP, and the Project Team in general to decide how the various project elements requiring resolution are tracked, and by whom. All three types of document are commonly employed, and multiple instances of each may also be used." [ASHRAE SSPC 300 Informative Annex 11]

8.6.7.5 Update the CFR with electives

[a la 0.2 6.7.5, update CFR as required]

Review the Expanded Actions in the EPA Energy Savings Plus Health Guidelines referenced in section 5.1, and make an initial determination of which ones to include in the CFR.

Review the hazard mitigation electives listed in section 5.2 and make an initial determination of which ones to include in the CFR.

8.6.7.6 Implement Immediate Improvements

[a la 0.2 6.7.6]
Issues of safety, security, health, or operational issues, identified during the walkthroughs or discussions with building occupants or operating staff that can be easily remedied and that do not require further evaluation (i.e., will obviously not adversely impact other systems), are to be immediately implemented as the team develops the initial information on the facility. These modifications and actions shall be immediately documented and included in ~~the EBCx Plan and~~ the Assessment Report.

8.6.8 Initiate EBCx Report with Assessment Report

[a la 0.2 6.8.2]
Use Normative Appendix T-6 as the framework for writing the Assessment Report.

8.6.9 Assessment phase deliverables

[a la 0.2 6.9, 6.6, 6.7.4]

- CFR/OPR [0.2 6.9.1]
- EBCx Plan [0.2 6.9.2]
- Systems Manual First Draft [0.2 6.6]
- EBCx Report, including the Assessment Report [0.2 6.9.3]
- Issues & Resolution Log [0.2 6.7.4]
- Updated Program plan (if applicable and affected) [0.2 6.9.4]

8.6.10 Acceptance and Decision to Proceed

Submit the deliverables to the Authority and the Owner. If they approve, the EBCx Team proceeds to the Investigation Phase per section 8.7. If they do not approve, the EBCx Team is to change the CFR and EBCx Plan so as to resolve the comments. [a la composite of: 0.2 6.10.3 and 230 6.2.1.2.3.2]

8.7 Investigation

Informative:

"The Investigation Phase consists of the detailed site investigation, which compares the actual building conditions and system performance with the Current Facility Requirements (CFR)…Some issues that are discovered during the Investigation Phase can be corrected with minimal time and effort, do not require additional evaluation, and can be documented immediately. This phase concludes with the completion of the Investigation Report, which identifies scope and benefits of recommended facility modifications and improvements as well as the improvements already implemented during the Investigation." [0.2 7.1.1]

8.7.1 Roles and Responsibilities

[a la 230 7.2.1]
The Owner and the CxP team shall work collaboratively to:

Resolve conditions impeding the execution of the Investigation Plan.
Resolve issues identified during the Investigation Phase.

8.7.1.1 Owner

a. Reserved.
b. Review the initial test procedures in the Investigation Plan with regard to changes in operating conditions and risks to Owner's property or production means. [a la 0.2 7.5.1.6.2]
c. Provide access to areas required to perform EBCx Activities. If the CxP is required to be accompanied by the Owner's staff, that staff shall be dedicated to the CxP Team during the duration of EBCx Activities.
d. Review field reports and issues and resolution log, and attend meetings with the CxP to resolve conditions impeding the execution of the EBCx Plan.
e. Review the Investigation Report and provide comments as appropriate.

8.7.1.2 CxP Team

a. Execute the investigation as defined in the Investigation Plan.
b. Develop project-specific test procedures. [a la 0.2 7.5.1.6.1]
c. Provide field and test reports on a weekly basis with the issues and resolution log.
d. Provide regular progress reports as the Investigation Plan is executed, and identify conditions impeding the execution of the Plan.

8.7.2 Update the Cx Team

Identify personnel to compose the Cx Team.
Review roles and responsibilities of continuing team members.
Assign roles and responsibilities of new team members.
Include revised roles and responsibilities in the updated Cx Plan. [a la 0.2 7.2.1, 7.3.2.5]

Informative: A structural engineer will often be needed.

Informative: Facility operating staff and service contractors can make the Investigation Phase more efficient through their knowledge of the facility systems and assemblies. The knowledge gained by O&M staff increases their ability to maintain persistence of benefits and encourages continued identification of performance enhancements during the OCx Phase. [a la 0.2 7.3.2.6]

8.7.3 Update the CFR

If the CFR is older than one year, or if there are known changes since the CFR was developed, verify that the conditions on which the CFR was based are still valid. If the needs and requirements have changed since the initial CFR was prepared, update the CFR. [a la 0.2 7.3.2.1]

8.7.4 Review Facility Documentation

[a la 0.2 7.4]
Review the documentation gathered during the Assessment phase to determine whether there are any additional documents or information required for the Investigation activities.

8.7.5 Update EBCx Plan

[a la 0.2 7.5]
Do the following activities and update the Investigation Plan part of the EBCx Plan.

8.7.5.1 Reserved

8.7.5.2 Pre-site-visit tests

Determine if any tests are required prior to the site investigations. Develop a list of pre-site-visit tests with written descriptions, who will do the tests, and when they will be completed. [a la 0.2 7.5.1.2]

8.7.5.2.1 Potential disruptions

Identify any changes to the operational state of existing systems planned as part of the tests, and identify potential risks and disruptions. [a la 0.2 7.5.1.2.1]

8.7.5.3 Stakeholder interviews

Describe the interviews to be conducted with facility stakeholders to augment direct investigation. Identify stakeholders to be interviewed and outline the interview procedures. [a la 0.2 7.5.1.3]

8.7.5.4 Reserved

8.7.5.5 Reserved

8.7.5.6 Develop Test Procedures

The CxP Team is to use information gathered during the Assessment Phase to create test procedures applicable to the scope of work. Include initial test procedures in the investigation plan and transmit them to the Owner for review. [a la 0.2 7.5.1.6.1]

The Owner is to propose modifications to test procedures if required by considerations of building access and security systems, disturbance of occupants, interactions with housekeeping staff, and shutdown of facilities. [a la 0.2 7.5.1.6.2]

Informative Appendix T-2.1 has forms for documenting the condition of equipment, and for writing test procedures.

8.7.5.7 Acceptance of the Investigation Plan

If the Owner reviews and approves the Investigation Plan and updated CFR, the EBCx Team shall proceed with the investigation. If the Owner does not approve, the EBCx Team shall resolve comments and obtain the Owner's approval. [a la 0.2 7.5.3 and 230 6.2.1.2.3.2]

8.7.6 Perform Site Investigation and Testing

Informative: Site investigation may not be a linear process. Often, multiple iterations are necessary due to new understanding of existing conditions that drive the team back to Assessment Phase activities. [0.2 7.6.5.2]

Keep a list of deferred testing and investigation to remind the team of what may need to be completed after the bulk of the investigation is finished. [a la 0.2 7.6.7.4]

Implement and document immediate improvements to the operation of the facility to eliminate obvious issues so they do not mask underlying major issues, especially as they relate to achieving the CFR. [0.2 7.6.3]

8.7.6.1 Indoor Air Quality Investigation

Perform all the Assessment Protocols of the US EPA *Energy Savings Plus Health Indoor Air Quality Guidelines* that require more than a walkthrough and were omitted from the Assessment Phase.

Informative:
In the single family version, the first point under AP 17.2 Determine Whether the Home Meets Ventilation Requirements of ASHRAE Standard 62.2 *states:*

> *"Use ASHRAE 62.2-2019 Section 4 requirements **OR** Appendix A – Existing*

Buildings if local exhaust ventilation in bathrooms and kitchens is deficient. Blower door testing, and measuring fan flows (e.g., bathroom or kitchen exhaust) will be required."

But in fact, the blower door testing required by ASHRAE 62.2-2019 is aimed at compartmentalization of attached dwelling units, and is not absolutely required - Appendix A refers back to section 6.1.1 where the blower door test appears for attached units, but there is a prescriptive air-sealing path in Appendix A itself. Section 4 does not absolutely require it, if no infiltration credit is being taken in the ventilation rate design.

The corresponding section in the multifamily protocol AP 18.2 Determine Whether Dwelling Unit Mechanical Ventilation Systems Meet ASHRAE Standard 62.2-2019 Requirements *states:*

*"Determine whether the mechanical ventilation systems in dwelling units meet ASHRAE Standard 62.2-2019 requirements (**including** Appendix A for existing buildings). This includes…"*

In the multifamily EPA protocol, AP 16.2 Assess Spaces for Compartmentalization refers to ASTM E1186 as useful in guiding the assessment work. ASTM E1186-22 Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems *covers several methods including:*

1. *Combined building pressurization / depressurization and infrared scanning*
2. *Building pressurization / depressurization and smoke tracers or theatrical fog*
3. *Building pressurization / depressurization and airflow measuring devices*
4. *Generated sound and sound detection*
5. *Tracer gas detection*

Methods 1, 3, 4 are preferred over the methods 2, 5 that introduce compounds into the air.

8.7.6.2 Structural and Seismic Investigation

8.7.6.2.1 Earthquake Hazard Investigation

For locations with an SDC of C through E, perform a simplified seismic assessment as described in FEMA P-50 *Simplified Seismic Assessment of Detached, Single-Family, Wood-Frame Dwellings*, and determine the Seismic Performance Grade, for building types within its scope (light-wood-frame single-family detached, duplexes and modular/panelized, but not manufactured housing.)

For buildings outside the scope of FEMA P-50, use one of the resources listed in Section 1.3 of FEMA P-154, quoted below in Informative Appendix S.

8.7.6.2.2 General structural and high wind

For Single-family, Duplex, HUD manufactured, and Townhouses:

- Investigate to determine the alterations needed to comply with section 5.2.4.
- Do the code compliance checks listed in Table 5-1 of FEMA P-804, reproduced in Informative Appendix W.

For other buildings types follow a, b, or c below:

a. ASCE 11-99 - Guideline For Structural Condition Assessment Of Existing Buildings. A professional engineer must perform site inspections(s) to identify structural components that need retrofitting to meet minimum structural safety requirements.
b. FEMA P-424 - Design Guideline for Improving School Safety in Earthquakes, Floods, and High Winds, Section 6.6, Table 6-2, Checklist for Building Vulnerability of Schools Exposed to High Winds.
c. FEMA P-2062 - Guidelines for Wind Vulnerability Assessments of Existing Critical Facilities.

8.7.7 Issues Analysis and Recommendations

[a la 230 7.2.1.2.2 f, 0.2 7.7]

Update the issues and resolution log with identified issues and related recommendations. [a la 0.2 7.7.3]

Develop initial pricing estimates for implementation. [a la 0.2 7.7.4.1]

Near the end of the investigation phase, organize the major findings and recommendations requiring review and decisions from the Owner into a list. Derive this list from the issues and resolution log.
Informative: Multiple issues may be addressed with one recommendation.
[a la 0.2 7.7.5, 7.7.5.1]

Include, in the list of findings and recommendations, only key information useful to the Owner in making decisions about the approach to meeting the CFR - additional information goes into the Investigation report. [a la 0.2 7.7.5.1, 7.7.5.8]

The CxP shall assist the Owner in narrowing the possible approaches to meeting the performance criteria, and the CFR overall, by selecting specific approaches for more information gathering or by removing approaches deemed undesirable by the Owner. [a la 0.2 7.7.5.5]

Include in the approaches any strategy for implementing the project in phases, that is, update the phase plan from section 8.6.5.3.

Also update:

- The M&V plan from section 8.6.5.4
- The approach to maintenance and persistence of benefits from section 8.6.5.5

Informative: The list serves as a tool that is updated through a refinement period during which approaches to meeting the performance criteria and electives are evaluated. This refinement period may include several iterations through the Assessment and Investigation phases. [a la 0.2 7.7.5.6]

Include in the list of findings and recommendations the ADORB cost breakdown. [a la 7.7.5.7 c]

8.7.8 Update EBCx Report with Investigation Report

[a la 0.2 7.8.1]
At the end of a review period during which the previous steps may be repeated iteratively a number of times, create an Investigation Report. The report contains the largest number of approaches that meet the CFR criteria and initial budgetary requirements.
Use the Investigation Report section of Normative Appendix T-6 to create the report.

8.7.8.1 New Discovery

[a la 0.2 7.8.2.1]
In the event new information is discovered that requires more site investigation, the EBCx Team shall further update the EBCx Plan for investigation and the CFR, if necessary, and then proceed with activities needed to substantiate the new information and include it in the final Investigation Report.

8.7.9 Investigation Phase Deliverables

[a la 0.2 7.9]

- Updated EBCx Plan. [a la 0.2 7.9.1]
- Updated EBCx Report including the addition of the Investigation Report. [a la 0.2 7.9.2]

8.7.10 Acceptance and Decision to Proceed

[a la 0.2 7.10]
8.7.10.1 The Owner and Authority shall review the deliverables and unresolved issues from this phase and either accept them in total or make comments. The comments shall be addressed by the EBCx Team.
Informative: The resolution of the comments may result in changes to the EBCx Plan, CFR, scope, and budget of the work.

8.7.10.2 If the Investigation Report is acceptable to the Owner and the Authority, then the Team will continue the process as described in the EBCx Plan for the Implementation Phase.

8.7.10.3 If the Investigation Report is not acceptable, the Investigation Phase team shall, if possible, resolve the issues raised and resubmit the Investigation Report for the Owner and Authority's review. If the Owner decides not to proceed with the Implementation Phase for the specific facility just assessed, the process stops for this facility.
Informative: The CFR, EBCx Plan, and Assessment and Investigation Phase reports for the facility just assessed should be filed for future reference. If an EBCx Program Plan was developed for multiple facilities, the Owner and team shall refer back to the Program Plan to determine the next facility to be assessed and begin the Assessment Phase for that facility.

8.8 Implementation

Informative: The objectives of the Implementation Phase are to execute the approach selected by the Owner from the Investigation reports, verify that performance meets the CFR, and report the results of implementation. [a la 0.2 8.1.1, 8.1.2]

8.8.1 Select a specific approach

The EBCx Team shall review the Investigation report and the Owner shall select a specific approach to meeting the performance requirements of this standard and the other requirements of the CFR. [a la 0.2 8.2]

8.8.2 Update the EBCx Team

Informative: Essential team members during the Implementation Phase include Owner's representatives, the CxP, Owner's operations and maintenance (O&M) staff and any design professionals, and contractors or suppliers/vendors needed to implement the selected measures. [a la 0.2 8.4.2]

8.8.2.1 Select Implementation Providers

Prepare a package of any selected measures that require design services or supply and installation by contractors. [a la 0.2 8.4.4.1]

Include the EBCx Team in the preparation of requests for proposal (RFPs), development of electronic bids, or negotiations with known contractors for services.

Define specific roles and responsibilities of any contractors, designers, and in-house staff for the implementation and verification of the selected measures, including any unique contract document requirements. [a la 0.2 8.4.4.2]

The EBCx Team shall review any proposals and contracts for services and make recommendations on the selection of contractors and designers. The Owner shall make the final selection of the contractors and designers and establish the necessary contracts for services. [a la 0.2 8.4.4.3]

8.8.3 Basis of Design

If the services of design professionals are involved, comply with ASHRAE Standard 202 Section 8 - Basis of Design, reproduced below.
Exceptions:

- Read "OPR" therein as CFR in the context of this standard.
- Clause 8.2.3c does not apply.

[from 202]:
8. BASIS OF DESIGN

8.1 Introduction. The Basis of Design (BoD) is a written document that shall provide detailed information on the Design Team's approach to meeting the ~~OPR~~ CFR to provide the Owner with a better understanding of design issues and secure the Owner's approval of critical design decisions.
8.2 Requirements
8.2.1 The BoD shall be developed by the Design Team in accordance with the ~~Owner's Project Requirements (OPR)~~ CFR. The BoD shall be updated and expanded during design and construction as the project evolves. The function of the BoD shall be to

a. describe the building systems and assemblies the Design Team is proposing to meet the ~~OPR~~ CFR for the Owner's approval;
b. describe in detail the Design Team's technical approach to each of the Owner's requirements, which are part of the Cx scope;
c. provide a platform for the review of the design and changes as the project progresses; and
d. coordinate applicable technical and code requirements.

8.2.2 The Design Team shall submit the BoD to the Owner and Cx Provider (CxP) for review at each milestone defined by the ~~OPR and Cx Plan~~ CFR and EBCx Plan.
8.2.3 The Owner and CxP shall evaluate each BoD submittal for the following:

a. Design and design assumptions in agreement with the OPR
b. Requirements for updating of the BoD
c. ~~Requirements for sustainable design goals and certification when required~~
d. Consideration of design alternatives at each phase
e. Requirements that systems, assemblies, and equipment be located and installed to be commissionable and maintainable
f. Opportunities for improved performance

8.2.4 The CxP shall document and track issues related to the BoD using the Cx issues and resolution log, including issues identified by the Owner and members of the Design Team.
8.2.5 The Design Team shall work with the Owner and CxP to resolve Cx issues.
8.3 Acceptance
8.3.1 Each submission of the BoD shall be formally reviewed and accepted by the Owner to facilitate the next step in the design process.

Informative: ASHRAE 202 Section 9 and ASHRAE SSPC 300 Informative Annex 07 concern the inclusion of requirements to cooperate with a Cx process in the contracts and specifications for Contractors, Suppliers, and Manufacturers. This is likely moot in the case that this standard is being enforced as a code. Otherwise, it might be appropriate to write such Cx specifications, referring to the process requirements of this standard, in the case of large or complex projects.

8.8.4 Design Review

Comply with ASHRAE Standard 202, Section 10 - Design Review, reproduced below.
Exceptions:

- Regarding clause 10.2.1 and 10.2.2, the review is conducted by the Authority instead of the Cxp.

- Regarding clause 10.2.2, the design review is considered a code or regulatory design review in the case that the standard is being used as a code.
- Regarding clause 10.2.3, the EBCx Team, including the Cxp, shall respond to the Cx Design Review Report.
- Regarding clause 10.3.1, the Owner and Authority shall approve the Cx Design Review Report and the Design Team's response before the start of construction.

[from 202]:
10. DESIGN REVIEW
10.1 Introduction. A Commissioning Process (Cx) Design Review shall be performed to evaluate compliance with the ~~Owner's Project Requirements (OPR)~~ CFR.
10.2 Requirements
10.2.1 The ~~CxP~~ Authority shall perform a review of the commissioned systems and assemblies in the design documents to evaluate compliance with the OPR. Cx Design Review shall be completed, and issues resolved, prior to the issuing of contract documents for systems being commissioned. The ~~OPR~~ CFR and the Cx Plan shall define any sampling strategies for Cx Design Review.
10.2.2 The ~~CxP~~ Authority shall conduct Cx Design Reviews, as contained in the Cx scope, and develop corresponding reports with comments, suggestions, clarifying questions, and observations in a Cx Progress Report to the Owner and Design Teams evaluating compliance with the ~~OPR~~ CFR. ~~This Cx Design Review shall not be considered a peer design review or a code or regulatory design review.~~
10.2.3 The ~~Design Team, Owner~~ EBCx Team, and/or other responsible party shall respond to the ~~CxP~~ Design Review report with necessary responses and agreed-to revisions to the project design documents. Revised documents shall be back-checked by the CxP. Any unresolved issues shall be reported to the Owner for direction to the design and Project Team on final disposition and direction.
10.2.4 A copy of the Cx Design Review reports and response shall be included in the final Cx Report.
10.3 Acceptance
10.3.1 The Owner and the Authority shall approve the ~~CxP~~ Design Review report and the Design Team's response before the start of construction.

8.8.5 Create Implementation Plan

For each measure, the Implementation Plan includes the following:

a. Participants in the implementation and their roles and responsibilities
b. Schedule of implementation coordinated with occupants, security, housekeeping, utilities, etc., for schedule impacts, outages and shutdowns, etc.
c. Scope of work with details of the work, including
    1. method of implementation,
    2. work required for enhancing persistence (maintenance) in support of the OCx, and
    3. verification procedures and responsibilities

8.8.5.1 Air-sealing

Air-sealing, to the level upon which compliance with the performance requirements of Section 5 and 6 is predicated, shall be included among the measures in the Implementation Plan.

8.8.5.2 Acceptance

The Owner's representative shall review and accept the Implementation Plan prior to implementation. [a la 0.2 8.6.2.2]

8.8.7 Implement selected measures

Implement each of the selected measures. Update the EBCx Report with the progress and results as they become available.

8.8.7.1 Commissioning Submittal Review

Comply with ASHRAE Standard 202 Section 11 - Commissioning Submittal Review, reproduced below. Exceptions:

- Read "OPR" therein as CFR in the context of this standard.

[from 202]:

11. COMMISSIONING SUBMITTAL REVIEW

11.1 Introduction. For construction or renovation projects requiring contractor or supplier submittals, a submittal documents review for commissioned systems and assemblies shall be performed to evaluate compliance with the ~~Owner's Project Requirements (OPR)~~ CFR. The commissioning submittal review does not replace the designer of record submittal review.

11.2 Requirements

11.2.1 A designated Project Team member shall review project submittals for systems and assemblies to be commissioned for compliance with the ~~OPR~~ CFR.

11.2.2 The Cx Provider (CxP) shall identify construction submittals to be provided by the contractor for the systems being commissioned.

11.2.3 The CxP shall review the construction submittals concurrently with the designers and provide comments to the designer.

11.2.4 The designer shall consider the CxP's comments and provide direction to the contractor in accordance with the designer's best professional judgment. A copy shall be provided to the CxP.

11.2.5 In the event that the Owner does not retain the designer for construction administration services, the Owner shall do the following:

a. Require the CxP to review the construction submittals for the systems being commissioned concurrently with the Owner or Owner's representative and provide comments to the Owner or Owner's representative.
b. Consider the CxP's comments and provide direction to the contractor in accordance with the Owner's best professional judgment. A copy shall be provided to the CxP.

11.2.6 The submittal review report shall include a listing of the submittals reviewed, the date reviewed, and a summary of the submitted equipment/material properties that appear not to

meet the ~~OPR~~ CFR. Any sampling review process used on the submittals shall conform to the ~~OPR and Cx Plan~~ CFR and EBCx Plan.
11.2.7 A copy of the submittal document review reports and response shall be included in the final Cx Report.
11.3 Acceptance
11.3.1 The CxP shall maintain a record of all Cx submittal reviews and shall submit a written report to the Owner and design authority. If it is determined that any reviewed submittals do not comply with the ~~OPR~~ CFR, that submittal shall be provided to the Owner to determine whether the system or equipment shall be accepted or rejected.

8.8.8 Implementation Observation and Testing

[a la 0.2 8.7, 202 12]
Comply with ASHRAE Standard 202 Section 12.1 and 12.2 in Construction Observation and Testing, reproduced below. Exceptions:

- Read OPR therein as CRF in the context of this standard, and Cx Plan as EBCx Plan.
- Regarding clause 12.1, the evaluation is to be done by the V&T Provider.
- Replace clause 12.2.4 with [a la 0.2 8.7.3]: Implementation Kick-off Meeting. The CxP shall coordinate Cx Activities at the beginning of the construction process and at other times as necessary. After updating and creating the EBCx Plan documents noted above, and prior to commencing actual implementation of the recommendations, the EBCx Team shall conduct a kick-off meeting with the Owner's representative and any selected outside providers and/or contractors. The purpose of the meeting is to review the roles of each party, resolve any misunderstandings, finalize the schedule, and ensure the updated EBCx Plan is as complete as needed by the Owner and the Authority. During the meeting the following shall take place:
    a. Review the updated EBCx Plan.
    b. Review the specific roles and responsibilities of contractors or consultants and the Owner's in-house staff to clarify who will implement and who will verify.
- Clause 12.2.6 b is the responsibility of the V&T Provider rather than the CxP.

[from 202]:
12. CONSTRUCTION OBSERVATION AND TESTING
12.1 Introduction. The proper installation, coordination, testing, and interaction among commissioned systems and assemblies shall be evaluated by the V&T Provider.
12.2 Requirements
12.2.1 The systems and assemblies to be commissioned, identified in the ~~Owner's Project Requirements (OPR) and Cx Plan~~ CFR and EBCx Plan, shall be confirmed to comply with the ~~OPR~~ CFR and with the contract documents.
12.2.2 Checklists and test procedures with necessary report forms shall be developed after submittal approval and used during equipment or assembly installation. All completed checklists and test reports shall be included in the final Cx Report.

a. Project-specific construction checklists and testing procedures shall be established for review by the Owner and appropriate team members.

b. The test procedures shall list the entities responsible for executing each of the tests.
c. Whenever a test data result is required for a specific system or assembly, there shall be an item in the associated construction checklist for the test data to be submitted to the Cx Provider (CxP).
d. Sampling procedures shall be used if required and defined in the Cx specifications.

12.2.3 There shall be a uniform and effective process for documentation of testing to provide Cx testing of, and interaction between, commissioned equipment, systems, and assemblies. The term Project Team shall refer to applicable Cx technical resources tailored to their specific projects.

12.2.4 ~~The CxP shall conduct a Cx kick-off and scoping meeting with the Project Team to explain Cx procedures, and shall coordinate Cx Activities at the beginning of the construction process and at other times as necessary.~~

Implementation Kick-off Meeting. The CxP shall coordinate Cx Activities at the beginning of the construction process and at other times as necessary. After updating and creating the EBCx Plan documents noted above, and prior to commencing actual implementation of the recommendations, the EBCx Team shall conduct a kick-off meeting with the Owner's representative and any selected outside providers and/or contractors. The purpose of the meeting is to review the roles of each party, resolve any misunderstandings, finalize the schedule, and ensure the updated EBCx Plan is as complete as needed by the Owner and the Authority. During the meeting the following shall take place:

a. Review the updated EBCx Plan.
b. Review the specific roles and responsibilities of contractors or consultants and the Owner's in-house staff to clarify who will implement and who will verify.

12.2.5 Evaluation of the systems and assemblies by the Project Team shall include the following:

a. Vital information on the equipment or materials being supplied. Information shall detail what equipment/material was specified and submitted. What was actually delivered on the site shall be documented and verified.
b. The condition of the equipment at the time it is delivered at the site and prior to its installation.
c. Proper installation of the systems and assemblies. Evaluation shall focus on the physical installation of the systems and assemblies, on their ability to meet the contract documents requirements, and on accessibility for Cx, testing, and maintenance operations.
d. Successful testing results of systems and assemblies.

Informative [a la 0.2 8.7.4]: Conducting site visits for verification. Periodically, appropriate EBCx Team members should visit the job site to verify installation of the selected measures. These visits provide an opportunity to identify issues early in the implementation that may not be able to be resolved later or cost more to resolve later.

12.2.6 Executing Test Procedures

a. Once construction checklists and test procedures are established, the responsible entities shall execute relevant test protocols and repeat testing as necessary until equipment, systems, or assemblies being tested pass all tests.
b. The ~~CxP~~ V&T Provider directs, witnesses, and documents the tests conducted by the Project Team as required by the Cx Plan.
c. Completed test reports shall be submitted to the Project Team for review and to the CxP for evaluation.

12.2.7 Any commissioned system or assembly that fails to meet requirements and that cannot be resolved in a timely manner shall be given an issue number and recorded in the issues and resolution log to facilitate follow-up.
12.2.8 All checklists and test procedure results shall be compiled into the final Cx Report.

8.8.8.1 Whole building air-tightness testing

The whole-building air-tightness called for in the Implementation Plan shall be verified by one of the following methods:
ANSI 380
ASTM E779
ASTM E3158
ASTM E741

8.8.9 Update the EBCx Documentation

[a la 0.2 8.9]

8.8.9.1 CFR

Update the CFR to include any changes that occurred during the Implementation Phase.

8.8.9.2 EBCx Plan

Update the EBCx Plan upon completion of deferred and seasonal tests (test procedures and results.)

8.8.9.2.1 Updated phase plan

List of measures to be implemented and CFR items to be addressed in later phases of the project.

8.8.9.2.2 M&V Documentation

Update the M&V Plan to point out which portions of the M&V requirements have been completed and what will be completed in the future.

8.8.9.2.3 Updated maintenance strategies

For each measure, include an updated strategy for persistence of the improvement (maintenance).

8.8.9.3 EBCx Report

Update the EBCx Report with the Implementation Report. Include the following:

8.8.9.3.0 Executive Summary

An executive summary of the measures implemented and those yet to be done in later phases of the retrofit project.

8.8.9.3.1 Updated list of findings and recommendations

Include an update to the performance analysis.
Informative: The final implemented recommendations may differ from the original recommendations due to conditions uncovered during the implementation process.

8.8.9.3.2 Reserved

8.8.9.3.3 New discovery

[a la 0.2 8.11.2]
If any new discoveries are made during Implementation activities, the Authority decides, based on EBCx Team recommendations, if additional investigation work is required. If a discovery during implementation requires additional investigation, the process for this specific discovery begins at the Investigation Phase. If the Authority chooses not to proceed with further investigation at this time, the item will be documented in the information transferred at hand-off.

8.8.9.3.4 Reserved

8.8.9.3.5 Test documentation

Test procedures, documentation, and results. This includes the original test procedures and data forms, plus data such as photos, computerized documentation, and other records of the tests. Both the final accepted test and earlier tests that failed to meet the specified criteria are to be included. Once deferred/seasonal testing is completed, the report shall be updated to include the deferred testing results.

8.8.9.3.6 Updated Issues and Resolution Log

The completed / updated issues and resolution log with all issues discovered and addressed.

8.8.9.3.7 Site Visit Records

Records of site visits and any significant reports and meeting minutes generated throughout the process.

8.8.9.3.8 Verification Documentation

Evaluations of the performance of the systems at the time of test completion and the ability of the system to meet the CFR.

8.8.9.3.10 Training Documentation

Provide information on any Owner training that occurred during implementation and verification, including who attended, dates, length of time, training subjects, training materials, and trainer, where applicable.

8.8.9.4 Owner Electives

In the EBCx Report, list the elective CFR items that were to be addressed through EBCx (from the EBCx Plan), and the level to which those CFR items were achieved by the end of the Implementation Phase. For any elective CFR items that were not fully achieved, describe why those items were not achieved and include recommended next steps.
Informative: This should supplement the verification documentation discussed in Section 8.8.9.3.8.

8.8.9.5 Updated systems manual materials

The systems manual is updated to include any new information for components, assemblies, and systems that have been modified or installed as part of the implementation process. Update the Facility Guide to include any changes to operating procedures that occurred during the Implementation Phase.

8.8.10 Implementation Phase Deliverables

[a la 0.2 8.10]

- Updated EBCx Plan
- Design Review Report and the Design Team's response
- Submittal Review Report
- Updated EBCx Report, including the addition of the Implementation Report
- Updated systems manual materials

8.8.11 Acceptance and Decision to Proceed

8.8.11.1 The Owner and Authority shall review the deliverables and unresolved issues from this phase and either accept them in total or make comments. The comments shall be addressed by the EBCx Team.
Informative: The resolution of the comments may result in changes to the EBCx Plan, CFR, scope, and budget of the work.

8.8.11.2 If the EBCx Plan and Implementation Report are acceptable to the Owner and the Authority then the team will continue the process as described in Section 9 - Hand-off. If either is unacceptable, the team shall discuss and, if possible, resolve the issues raised and resubmit the plan and report for review. Do not continue to the Hand-Off Phase until the Owner and the Authority have approved the Implementation work and its report along with the updated EBCx Plan. [a la 0.2 8.11.5]

Informative: The Owner and team should evaluate the process used. Changes that could improve the process may be added to the EBCx Plan. It is good to document issues, benefits, and process recommendations while the information is fresh in the minds of team members. [a la 0.2 8.11.6]

8.9 Hand-off

Informative: The Hand-Off Phase is the transition between the Existing-Building Commissioning (EBCx) Team and personnel responsible for operating and maintaining the facility until the next phase of the retrofit, or over the remainder of its life cycle.

The objectives of the Hand-Off Phase are to provide the completed documents from the EBCx to the Owner, provide training to the Owner's personnel, and to incorporate lessons learned from the Cx Process into the day-to-day O&M procedures in the facility.

The systems manual and the OCx Plan are used in conjunction with the training of facility operations and maintenance (O&M) personnel and occupants to ensure the persistence of the benefits.
[a la 0.2 9.1.1-2]

8.9.1 Roles and Responsibilities

[a la 230 9.2]

8.9.1.1 Owner's responsibilities

a. Ensure O&M entity participation in training and use of the Systems Manual.
b. Verify that records are being kept for future evaluation of building performance.
c. Review monitored data analysis at least annually, and provide direction to the O&M entity.

8.9.1.2 EBCx Team responsibilities

a. Deliver the Systems Manual, and conduct training. Training shall include avoiding operation mistakes, modifications implemented, and associated reasoning associated with the modifications.
b. Conduct lessons-learned workshop/meeting (per section 8.9.6, if elected per section 8.6.5.6.)

8.9.2 Develop OCx Plan

[a la 0.2 9.2]

The OCx Plan is the guiding document for how the facility's condition and performance will be monitored and evaluated, what systems or features will be included, what parameters will be tracked, and how deviations from the CFR will be corrected. [a la 0.2 10.3.1]

The OCx Plan shall address the following:
8.9.2.1 Establishing a scope of work that clearly defines the activities to be conducted, a schedule for when activities will take place, and what documentation will be provided.
8.9.2.2 Defining the roles and responsibilities of all team members and how communication will be routed.
8.9.2.3 reserved.
8.9.2.4 reserved.
8.9.2.5 Maintaining the Current Facility Requirements (CFR) to reflect changes in use and operation of the facility.
8.9.2.6 Maintaining the facility guide (FG) to reflect changes in systems and assemblies due to renovation or in response to changes in the CFR.
8.9.2.7 Maintaining the systems manual to reflect changes in the CFR, FG, and systems/assemblies.
8.9.2.8 Monitoring and evaluating system performance regularly to verify compliance with the CFR and against previously established benchmarks.
Informative: For example, through review of occupant satisfaction surveys, trend logs, complaint logs, service tickets, and utility use. ~~*See Section 7 for further guidance.*~~
8.9.2.9 Describing procedures necessary to maintain the ~~persistence of~~ building ~~performance~~.
8.9.2.10 Ongoing training of O&M personnel and occupants on the current CFR and the current systems/assemblies.
8.9.2.11 Defining the process and procedures necessary for satisfying the measurement and verification (M&V) requirements.

Informative: Guidance appropriate to single-family homes can be found in the Healthy Homes Maintenance Checklist from the National Center for Healthy Housing.

It has the following sections:

- *Yard and Exterior*
- *Garage*
- *Exterior Roof, Walls, and Windows*
- *Basement and Crawlspace*
- *Attic*
- *Interior Walls, Ceilings, Windows, and Doors*
- *HVAC Equipment filters*
- *Plumbing and Fixtures*
- *Appliances*
- *Electrical Equipment*

8.9.3 Assemble Systems Manual

Comply with Section 14 of ASHRAE Standard 202, as adapted below:

14.1 Introduction. The Systems Manual documentation shall be provided to the Owner for use in building operation and the training of personnel.

14.2 Requirements

14.2.1 The Systems Manual shall provide the information needed to understand, operate, and maintain the building's systems and assemblies.

14.2.2 The Systems Manual is the repository of design, construction, and testing information, including updates and corrections to systems and assemblies as they occur during construction. The Project Team shall be responsible for updating the Systems Manual during Cx, including design, construction, and operation as required in the OPR, Cx Plan, and contract documents.

14.2.3 The following shall be included in the Systems Manual: see Normative Appendix T-4.

14.3 Acceptance

14.3.1 The contents of the preliminary Systems Manual, Sections 2 through 4 of Appendix T-4, shall be reviewed and evaluated by the CxP prior to training of O&M personnel and occupants ~~in accordance with the OPR~~.

14.3.2 The Owner shall approve the final Systems Manual for use in building operations.

8.9.4 Train Facility Personnel

Comply with Section 15 of ASHRAE Standard 202, as adapted below:

15.1 Introduction. The operations and maintenance (O&M) personnel and occupants shall be trained on the systems being commissioned, in accordance with the ~~Owner's Project Requirements (OPR)~~ CFR, to operate and maintain the building systems and assemblies. The training plan is considered an essential element in designing, preparing, and delivering the training to the participants.

15.2 Requirements

15.2.1 The training plan shall include the following items:

a. Level of training for O&M staff, emergency response personnel, and occupants.
b. Outline of instructional topics related to the systems, subsystems, equipment, and assemblies. These topics shall address the design, construction, operation, and maintenance of specific systems, assemblies, and equipment.
c. Learning objectives and training delivery methods for each instructional topic.
d. The planned location of the training sessions (classroom, on site, and off site) and the minimum duration of each training session, in hours, to be completed as required in the OPR, Cx Plan, or contract documents.
e. Instructor's qualifications.
f. Training materials requirements to be employed during the instructional process.
g. Training report, records, and recording requirements.

15.2.2 Archival of instruction, delivery of instruction, and training materials shall be provided as specified in the contract documents and per the ~~OPR~~ CFR. A copy of the training plan, training materials, and records shall be included in the final Systems Manual as shown in Section 14 of ~~this standard~~ ASHRAE Standard 202.

15.3 Acceptance

15.3.1 The training plan, the execution of the training plan, and the delivery of instruction shall be reviewed for acceptance by the Cx Provider (CxP) and Owner. The training plan shall be submitted and accepted prior to the delivery of any instruction. Evaluation or survey of the participants shall be as defined in the ~~OPR~~ CFR and contract documents.

8.9.5 Reserved

8.9.6 Conduct Lessons-Learned Workshop

[a la 0.2 9.6]
If elected by the Owner per section 8.6.5.6, conduct a lessons-learned workshop after the completion of the training and the update of the systems manual.

Informative: The lessons-learned workshop typically includes all of the key participants and stakeholders of the Cx Process. The lessons-learned workshop provides a forum for the EBCx Team to discuss issues impacting the O&M of the facility and to discuss knowledge gained during the implementation of the measures. The discussion should examine both the execution of the Cx Process and the methods and issues found that affect facility operation. The intent of the discussion is to determine improvements in both the Cx Process and facility operations. Because the meeting includes all key stakeholders, the lessons-learned workshop can also be an opportunity to recognize the contributions of individual EBCx Team members to the success of the Cx Process.

See ASHRAE Guideline 0.2, Informative Annex L6, for suggested list of invitees, agenda, list of documents for distribution before the workshop, and outline of the workshop report.

8.9.6.1 Lessons-Learned Report

Document the results of the lessons-learned workshop in a Lessons-Learned Report, which will help to facilitate the transfer and retention of knowledge gained during the Cx Process. Make recommendations to support the OCx efforts of the facility, to update the EBCx Program and approach for a multiple-facility effort, and improve all future commissioning efforts at the facility.

8.9.7 Finalize EBCx Report

[a la 0.2 9.7]
8.9.7.1 Update the EBCx Report to include the final Lessons-Learned Report (if any) and to reflect any necessary changes to the EBCx Program Plan and OCx Plan.
8.9.7.2 Update the EBCx Report to include the final training documentation and verification.

8.9.8 Provide Project Documents to Owner

[a la 0.2 9.8]

8.9.8.1 Transfer the completed EBCx Report, the OCx Plan, and the systems manual to the Owner. Request the acceptance by the Owner of: these documents, and the improvements implemented.
8.9.8.2 Provide for distribution of the M&V Reports to be submitted for approval. The document shall be reviewed with the Owner and operations staff to ensure that the required instrumentation and data collection remain in place in accordance with the M&V Plan.

8.9.9 Hand-Off Phase Deliverables

- EBCx Report, including addition of the Lessons-Learned Report, if elected.
- Systems manual.
- OCx Plan.

8.9.10 Acceptance and Decision to Proceed

[a la 0.2 9.10]

8.9.10.1 The Owner and the Authority review the deliverables and any unresolved issues from this phase and either accept them in total or make comments.
8.9.10.2 If the EBCx Report, OCx Plan, and systems manual are acceptable, then the process will continue as described in Section 8.10.
8.9.10.3 If the EBCx Report, OCx Plan, or systems manual are unacceptable, assemble the Hand-Off Phase team to discuss and, if possible, resolve the issues raised and resubmit the plan for review by the Owner and the Authority.
8.9.10.4 If neither the Owner nor the Authority require proceeding with the OCx Phase for the specific facility just commissioned, the EBCx Report and all phase reports shall be filed for future reference and the process stopped for this facility.
8.9.10.5 For multiple facilities, refer to the EBCx Program Plan to determine the next facility to be assessed and begin the Assessment Phase on that facility if an EBCx Program Plan was developed for multiple facilities.

8.10 Ongoing Commissioning

[a la 0.2 10]

8.10.1 Introduction

The Ongoing Commissioning (OCx) Phase is a program that consists of Cx Process activities that repeat continuously throughout the life of the facility subsequent to the Hand-Off Phase.

The overall objective of the OCx Program is to ensure that the benefits obtained from the EBCx Plan and any other building improvements are sustained over time. OCx involves performing critical elements of the process repeatedly over a series of cycles with periods typically lasting from months to years. [a la 0.2 10.1.1, 10.1.2]

Informative:
For each facility, the capabilities of the internal facility staff, service contractors, and the nature of the relationship with external professionals, commissioning contractors, and Cx Process providers are unique. Further, over time, people move in and out of positions, and the structure of the organization changes. [a la 0.2 10.2.1]

8.10.2 Assemble the OCx Team

[a la 0.2 10.2]
8.10.2.1 Reserved

8.10.2.2 Assign responsibility for OCx activities in the initial OCx Plan. Establish a high-level executive responsible for overall management of the OCx Program. Include staff responsibility assignments for the initial cycle as well as when the organization's structure changes or as staff members' responsibilities change.

8.10.2.3 OCx is led by a Commissioning Authority (CxA). This phase shall be carried out by personnel acceptable to the Authority.

Informative: The CxA for OCx may be a different person than the CxP for the previous phases of the EBCx.

8.10.2.4 The OCx Team shall include, at a minimum, an Owner’s Representative and a CxA.

Informative: Consider including stakeholders from a variety of levels of responsibility in the organization or leased-property occupants. Increased participation increases the accuracy and scope of the guidance for the OCx Program.

8.10.3 Update the OCx Plan

[a la 0.2 10.3]
The OCx Team shall

- Review The scope of activities in the OCx Plan to determine whether assigned resources have the time and skills needed for each activity.
- Review and update the frequency of activities in the OCx Plan.

The OCx Plan shall clearly define the measures that remain to be implemented in later phases of the retrofit project.

8.10.4 Verify Achievement of CFR

[a la 0.2 10.4]
8.10.4.1 Reserved.

8.10.4.2 Monitor the actual condition or performance of the defined parameters during the OCx Program to provide feedback to the OCx Team of any deviations that may require action.

8.10.4.3 The tracked information shall be consistent with the requirements of the chosen or required M&V Plan.

8.10.4.4 Review the M&V Plan at regular intervals. If it is determined that certain key parameters necessary to properly monitor the condition or performance of the facility are missing from the M&V Plan, revise the M&V Plan accordingly.

8.10.5 Investigate Unacceptable Performance or Outcome

[a la 0.2 10.5]
8.10.5.1 Whenever there are significant deviations from the CFR baseline or parameters, identify the root cause of the unacceptable performance. Section 8.7 of this standard addresses the investigation methodology.

8.10.5.2 Reserved.

8.10.5.3 Maintain the issues and resolution log to track and record issues.
Informative: The issues and resolution log used during this phase can be similar to the issues and resolution log used in previous phases.

8.10.5.4 Once findings and recommendations are identified, they are listed on the issues and resolution log, including any estimated costs and associated benefits that the action will provide. Recommendations shall include methods to maintain the benefits of the performance and improvements made during the EBCx.

Informative: In cases where the corrective action is simple, the action should be taken immediately on clearance from responsible operations staff. For other, more complex issues, the nature of the problem and the recommendation may need to be reported to the Owner for approval.

8.10.6 Implement Recommendations

[a la 0.2 10.6]
8.10.6.1 Establish a plan for implementing the recommendations, including schedules and responsible parties. Implement the recommendations in accordance with that plan. Verify the action and its effect on the facility.

Informative: It is important that the recommendations are implemented carefully, understanding that actions can often interact with one another. If multiple recommendations are implemented at one time or in a close timeframe of one another, it may become difficult to distinguish the interrelation and interaction of one action and another.

8.10.6.2 Develop relevant documentation for the OCx Report once the recommendations have been implemented and verified. Include any lessons-learned discussion that may prevent a recurrence of the issue. This documentation shall include quantitative comparisons of the benefits tracked in comparison with those predicted and in comparison with the acceptable performance. Note any excess or shortfalls in benefits measured.

8.10.6.3 With the facility personnel, develop a plan for maintaining the persistence of benefits related to the implemented recommendations.

8.10.7 Update Systems Manual

[a la 0.2 10.7]
8.10.7.1 Review the facility Systems Manual at least annually to ensure all information is current.

Informative: The Facility Guide section of the systems manual should be updated with key performance parameters and facility operating procedures whenever they are changed.

8.10.7.2 Changes to the CFR will eventually arise due to changes in occupancy, use, or remodeling. Document the impact of these changes in the Systems Manual and Facility Guide.

8.10.8 Update Facility Personnel Training

[a la 0.2 10.8]
8.10.8.1 Introduction
Facility personnel training requirements will continue to evolve due to facility changes, operational changes, staff turnover, changes to regulatory factors, facility equipment, or overall facility function.

8.10.8.2 Make regular updates to any formal training program, and conduct training and retraining throughout the OCx Process, as needed to allow the CFR to be achieved.

8.10.8.3 Discuss with O&M Staff all operator-error items identified during fault correction, as lessons learned.

8.10.9 Write/Deliver OCx Report

[a la 0.2 10.9]
8.10.9.1 Introduction
The OCx Report is used to document at regular intervals the performance of the facility and success of the OCx Program. The report shall include the following:

a. Any recommendations that will assist the O&M staff in procedures that will maintain the persistence of building performance, particularly for improvements implemented during the OCx Process.
b. Measured verification results over the current OCx period.

c. Corrective actions taken and lessons learned.
d. Updates to facility training programs and training conducted based on changes to the facility, staff turnover, or lessons learned.
e. Any updated acceptable performance parameters from the Authority.
f. Any improvement recommendations accompanied by estimated costs.
g. The level to which the elective CFR items have been achieved.

8.10.9.2 The OCx Report shall include the current results of the M&V Plan. If the OCx Program requires compliance with an elective M&V protocol, the material in the OCx Report shall be consistent with the requirements of the M&V Plan and be produced and submitted under separate cover.

8.10.9.3 The report shall be submitted at least annually, accompanied by appropriate updates to the OCx Program Plan, CFR, systems manual, and issues and resolution log. Present any issues and recommendations requiring evaluation and selection by the Owner for implementation in the form of a list of findings and recommendations, as discussed in Section 8.7.

8.10.10 OCx Phase Deliverables

- Updated OCx Plan
- Updated systems manual
- OCx Report (made periodically)

8.10.11 Acceptance

If the OCx Report is acceptable to the Owner and the Authority, then the team shall continue the process into the next cycle.

If the OCx Report is unacceptable, determine what the issues are and take corrective action before resubmitting the OCx Report.

9. Referenced documents

9.1 Normative references

Annual CO2e emissions by country
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https://www.worldometers.info/co2-emissions/taiwan-co2-emissions/

Annual gross domestic product by country
https://data.worldbank.org/indicator/NY.GDP.MKTP.CD
https://www.statista.com/statistics/727589/gross-domestic-product-gdp-in-taiwan/

ASCE 7 - Minimum Design Loads for Buildings and Other Structures

ASCE 11-99 - Guideline For Structural Condition Assessment Of Existing Buildings

ANSI/RESNET/ICC 380-2019 - Standard for Testing Airtightness of Building, Dwelling Unit, and Sleeping Unit Enclosures; Airtightness of Heating and Cooling Air Distribution Systems; and Airflow of Mechanical Ventilation Systems

ASHRAE Climatic Design Conditions

ASHRAE Guideline 0.2-2015 - Commissioning Process for Existing Systems and Assemblies

ASHRAE RP-1199 - Updating the ASHRAE/ACCA residential heating and cooling load calculation

ASHRAE SSPC 300 INFORMATIVE ANNEX 11 – ISSUES AND RESOLUTION LOG

ASHRAE Standard 62.2-2022 Ventilation and Acceptable Indoor Air Quality in Residential Buildings

ASHRAE Standard 140 - Method of Test for Evaluating Building Performance Simulation Software

ASHRAE Standard 202-2018 - Commissioning Process for Buildings and Systems

ASHRAE Standard 227P - Passive Building Design, Advisory Public Review Draft

ASHRAE Standard 230-2022 - Commissioning Process for Existing Buildings and Systems

ASTM E779-19 - Standard Test Method for Determining Air Leakage Rate by Fan Pressurization

ASTM E741-23 - Standard Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution

ASTM E3158-18 - Standard Test Method for Measuring the Air Leakage Rate of a Large or Multizone Building

ATC Hazards by Location

Berkeley CoolClimate calculator

Commercial and Residential Hourly Load Profiles for all TMY3 Locations in the United States, OEDI

Connected Criteria, US EPA

Defensible Space & Home Hardening Self-Inspection Checklist, City of Berkeley Fire Department

Design Flow Rate model for infiltration

Earthquake Hazard Maps, US FEMA

EnergyPlus weather format

Energy Star for New Homes, US EPA - Program Requirements

Energy Star Portfolio Manager Technical Reference

EPA Energy Savings Plus Health: Indoor Air Quality Guidelines
    EPA 402K21001: IAQ Guidelines for Single-family Home Renovations
    EPA 402K21002: IAQ Guidelines for Multifamily Renovations

FEMA Flood Maps

FEMA P-50 Simplified Seismic Assessment of Detached, Single-Family,Wood-Frame Dwellings

FEMA P-50-1 Seismic Retrofit Guidelines for Detached, Single-Family, Wood-Frame Dwellings

FEMA P-154 Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook, Third Edition

FEMA P-348 - Protecting Building Utility Systems From Flood Damage

FEMA P-424 - Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds

FEMA P-804 - Wind Retrofit Guide for Residential Buildings

FEMA P-957 - Snow Load Safety Guidance

FEMA P-2062 - Guidelines for Wind Vulnerability Assessments of Existing Critical Facilities

Flow Coefficient model for infiltration

FM Approval Standard 4476

FM Approval Standard 4478

“Heat Index.” In *EnergyPlus Engineering Reference, Version 22.1.0, Build ed759b17ee, Section 23.5.1.1*. U.S. Department of Energy, 2022

HUD Permanent Foundations Guide for Manufactured Housing (4930.3G)

IBHS FORTIFIED Home 2020

IBHS FORTIFIED Commercial 2020

Indoor airPLUS, US EPA

International Residential Code

Kiva ground heat transfer calculation

Multifamily Building Efficiency Screening Tool (MBEST), US DOE

NREL Cambium workbook (LRMER) for GEA regions

Phius Certification Guidebook

Portfolio Manager, US EPA Energy Star

Residential Efficiency Measures Database, NREL

Top 15 US trading partners

Tsunami | FEMA National Risk Index

UL 1703 Flat-Plate Photovoltaic Modules and Panels

Wildfire - FEMA National Risk Index

White, Lisa M, and Graham S Wright. “Assessing Resiliency And Passive Survivability In Multifamily Buildings.” *Building Performance Analysis Conference and SimBuild*, no. August, 2020: 144–55. https://www.ashrae.org/file%20library/conferences/specialty%20conferences/2020%20building%20performance/papers/d-bsc20-c018.pdf.

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ASHRAE Guideline 1.4-2019 - Preparing Systems Manuals for Facilities

ASHRAE Standard 241-2023 - Control of Infectious Aerosols

ASHRAE SSPC 300 Informative Annex 05 - Commissioning Process Plan

ASHRAE SSPC 300 Informative Annex 06 - Basis of Design

ASTM E1827-22 - Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door

ASTM E1186-22 - Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems

Building 4 Health

Community Solar resource page, US DOE

EnergyPlus Engineering Reference - Infiltration/Ventilation

FEMA P-646 - Guidelines for Design of Structures for Vertical Evacuation from Tsunamis, Third Edition

FEMA P-737 - Home Builder's Guide to Construction in Wildfire Zones

FEMA P-957 Snow Load Safety Guide

FEMA Roof Snowdrift Design Guide

FEMA P-1000 - A Guide to Improving School Natural Hazard Safety

FEMA P-1037 - Reducing Flood Risk to Residential Buildings That Cannot be Elevated

Gagnon, Pieter; Frazier, Will; Hale, Elaine, Cole, Wesley (2022): Long-run Marginal Emission Rates for Electricity - Workbooks for 2021 Cambium Data. National Renewable Energy Laboratory, Golden, CO. https://data.nrel.gov/submissions/183

Guidance for Applying ASCE 24 Engineering Standards to HMA Flood Retrofitting and Reconstruction Projects

Healthy Homes Maintenance Checklist, NCHH

How to Identify a Lead Service Line
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https://www.ldh.la.gov/assets/oph/Center-EH/engineering/LCR/Lead_Pipe_Identification.pdf

How to read a flood map
https://www.floodsmart.gov/all-about-flood-maps
https://www.fema.gov/sites/default/files/documents/how-to-read-flood-insurance-rate-map-tutorial.pdf

International Building Code

IBHS Wildfire Prepared Home

ISO 9972:2015 - Determination of air permeability of buildings Fan pressurization method

LBNL Residential Diagnostics Database (ResDB)

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Normative Appendix A – ADORB Calculation method

Informative note: The convention in this section is that equals signs “=” indicate calculation formulas and the words “is / are” indicate definitions of the symbols in the formulas.

ADORB = PV/N, where
N is the analysis period [years].
PV is the overall present value [$].

PV = sum over i of PV_i,
where the cost component i is one of

{dirEnr, # direct energy cost
opCarb, # cost of carbon (operating)
dirMR, # direct maint/refit cost,
emCarb, # cost of carbon (embodied)
eTran} # cost of energy transition

PV_i = sum over y from 1 to N of C_i_y / (1+k_i)^y , where
C_i is the Cost of cost component i [$].
k_i is the discount rate for cost component i [fraction 0 to 1].
    k_dirEnr = 0.02
    k_opCarb = 0
    k_dirMR = 0.02
    k_emCarb = 0
    k_sysTran = 0.02
y is the year, counting from the current year = 1, that is, the future calendar year minus the previous calendar year.

And, for yearly time resolution:

C_dirEnr_y = Eg_y * Pg_y + Ee_y * Pe_y, where

Eg_y is the Annual gas energy use [therm/yr] in year y.
Ee_y is the Annual site electrical energy use [kWh/yr] in year y.
Pg_y is the Gas price [$/therm] in year y
Pe_y is the Electricity price [$/kWh] in year y

C_opCarb_y = Pc * M_op_y, where

Pc is the Carbon price [$/kg].
Pc = $0.25/kg # Direct air capture

M_op_y is the Annual operating emissions [kg] in year y.
M_op_y = Mg_op_y + Me_op_y
Mg_op_y is the gas emission [kg] in year y.
Me_op_y is the elec emission [kg] in year y.

Mg_op_y = Eg_y * Fg
Me_op_y = Ee_y * Fe_y
Eg_y is the gas energy consumption [therms] in year y.
Ee_y is the electrical energy consumption [kWh] in year y.

Fg is the gas emission factor, assumed to be constant (i.e., negligible fraction of green hydrogen in the future.)
Fg = 12.7 kg/therm # Energy Star Portfolio Manager Technical Reference

Fe_y is the electrical emission factor [kg/kWh] in year y.
For national average electrical emission factor:
if y=1 then
    Fe_1 = 0.433 kg/kWh # Energy Star Portfolio Manager Technical Reference
else # y>1
    Fe_y = max(0,Fe_(y-1) - Fe_1/(grid decarb year - this year)) # Linear glide path

For 8760 hourly time resolution:

Me_op_y = sum over the hour from 1 to 8760 of Ee_hour * Fe_hour_region_y

hour is the hour of the year.
region is the GEA region in which the building is located.
Ee_hour is the electrical energy consumption for the hour [kWh].

Fe_hour_region_y is a long-run marginal emission factor from the NREL Cambium workbook (LRMER) for GEA regions (Gagnon et al 2022), with the following settings:

Emission - CO2e
Emission stage - Combined
Start year - 2023+y
Evaluation period - 1 years
Discount rate (real) - 0
Scenario - 95% decarb by 2050
Global Warming Potentials - 100-year (AR5)
Location - End-use

(See Levelized LRMER tab, row 350+, check units and convert to kg/kWh if necessary.)

C_dirMR_y is the cost of all the maintenance or retrofit items occurring in year y.
C_dirMR_y = sum over individual cost items in these categories:

C_dirMR_y =
+ ENV_y # Envelope
+ HVAC_y # HVAC
+ DHW_y # Hot water
+ APL_y # Major appliances, builder-installed.
+ LITE_y # Lighting
+ … continues below

Alternate: It is recommended that the more detailed breakdown of the five hard costs above follows the structure of NREL's Residential Efficiency Measures Database. Its high-level categories are as follows:

AirLeakage

MechanicalVentilation
AppliancesFixtures
CeilingsRoofs
FoundationFloors
Lighting
SpaceConditioning
Walls
WaterHeating
WindowsDoorsSkylights

+ …
+ GEN_y # PV/Battery/Generation

+ CX_y # Commissioning, Testing, Inspection
+ PERF_y # Other performance-related
+ IAQ_y # Indoor air quality related
+ HAZ_y # Hazard mitigation related
+ IN_y # Other in-scope
+ OUT_y # Other out-of-scope

+ INC_y # Incentives
+ TAX_y # Tax credits

For items that do not have a replacement interval,

C_dirMR_item_y = Cinitial_item
Cinitial_item is the initial cost of the item [$].

For items that have a replacement interval,
C_dirMR_item_y = Cinitial_item*Flag, where
If (y + repIntv_item - remLife_item) modulo repIntv_item < 1 then
Flag = 1 else Flag = 0

repIntv_item is the replacement interval of the item [years].
remLife_item is the presently remaining life of the item [years].

Note: setting remLife_item to 1 (not zero) in this formula will make the cost happen in year 1.

For Level 1 embodied carbon calc (national emissions intensity based):

Right now there is no decarbonization glide path applied to embodied emissions (i.e. of recurring equipment replacements).

C_emCarb_y = (emMat_y + emLbr_y)*Pc

emMat_y is the embodied emissions due of the material items in year y [kg]
emLbr_y is the embodied emissions due to domestic / installation labor of the items in year y [kg]

emMat_y = sum, over the project retrofit and maintenance items, of emMat_item_y
emMat_item_y is the embodied emissions of the material item [kg].

emMat_item_y = C_dirMR_item_y * (1-LF_item_y) * EF(CoO_item_y)
LF_item_y is the fraction of install labor in C_dirMR_item_y [fraction 0 to 1].
EF(country) is the national emission factor of a country [kg/$].
CoO_item_y is the country of origin for the item occurring in year y.

EF(country) = CO2_country / GDP_country * 1000
CO2_country is the annual CO2e emissions from the country [Megatons].
GDP_country is the annual gross domestic product of the country [USD millions].

EF, CO2 and GDP data for the top 15 US trading partners is shown in Table 1.

emLbr_y = sum, over the project retrofit and maintenance items, of emLbr_item_y
emLbr_item_y is the embodied emissions due to labor, of the item occurring in year y.

emLbr_item_y = C_dirMR_item_y * LF_item_y * EF(COPL)
COPL is the country of the project location / building site.

Table 1. Annual CO2 emissions and GDP of US and top trading partners.

Country	US trading rank	GDP [USD millions]	CO2 [MT]	EF [kg/$]
USA	-	20,936,600.00	4900	0.234
Canada	3	1,643,407.98	565.2	0.344
China	1	14,722,730.70	9500	0.645
France	15	2,603,004.40	303.5	0.117
Germany	5	3,806,060.14	696.1	0.183
India	10	2,622,983.73	2300	0.877
Ireland	8	418,621.82	35.3	0.084
Italy	12	1,886,445.27	317.1	0.168
Japan	4	5,064,872.88	1100	0.217
Korea, South	7	1,630,525.01	605.8	0.372

Country	US trading rank	GDP [USD millions]	CO2 [MT]	EF [kg/$]
Malaysia	13	336,664.44	228	0.677
Mexico	2	1,076,163.32	448.5	0.417
Switzerland	11	747,968.64	35.7	0.048
Taiwan	9	668,510.00	276.7	0.414
United Kingdom	14	2,707,743.78	352.4	0.130
Vietnam	6	271,158.44	226.5	0.835

For level 2 embodied carbon calc (itemized carbon reduction credits)

The formula for C_emCarb changes to:
C_emCarb_y = (emMat_y + emLbr_y - L2mC_y)*Pc,
where L2mC_y is the Level 2 embodied carbon credits for year y [kg]. That is, the Level 2 calc is an adjustment to the Level 1 calc rather than a replacement for it.

L2mC_y = L2mCbizMat_y + L2mCperson_y
L2mCbizMat_y is the embodied carbon credit from Business Process and Materials choices in year y. [kg]
L2mCperson_y is the embodied carbon credit from Personal choices in year y. [kg]

L2mCbizMat_y = sum over g of the carbon credit items L2mCbizMat_g_y
L2mCperson_y = sum over persons p of the carbon credit items L2mCperson_p_y

L2mCbizmat_g_y is an embodied carbon credit item g in year y. [kg]
L2mCperson_p_y is an embodied carbon credit from person p in year y. [kg]

L2mCbizmat_g_y = BAUintens_g_y * BAUqty_g_y - PROJintens_g_y * PROJqty_g_y

BAUintens_g_y and PROJintens_g_y are the business-as-usual and project-chosen carbon intensities respectively, for item g. [units vary but are of the form kg per quantity].
BAUqty_g_y and PROJqty_g_y are the corresponding quantities. [units vary among the items g].

L2mCperson_p_y = IncomeFrac_p_y * Tons_p_y * 1000 * %better_p_y

IncomeFrac_p_y is the fraction of person p's annual income that comes from the project in year y.

Tons_p_y is the tons of CO2e per year, and %better_p_y is the percent better than average, for person p, according to the Berkeley CoolClimate calculator.

C_eTran_y = TCF_y * PkPwr_y * 1000, where
TCF_y is the transition cost factor for year y. [$/Watt.yr]
PkPwr_y is the peak electrical power used by the building in year y. [kVA]

if y > ytt, then
    TCF_y = 0
else
    TCF_y = NTCF / ytt   #linear transition

    ytt is the number of years to transition. #default 30 years
    NTCF is the national transition cost factor [$/W]

    NTCF = NTC / (NNCI * 1e9)

    NTC is the national transition cost [$].
    NNCI is the required national nameplate capacity increase (of carbon-free generation) [GW].

    For the US,
        NTC = $4.5e12
        NNCI = 1600 GW

pkPwr_y is calculated by detailed hourly simulation, or by the following simplified method:

    Simplified method for baseline cases:

    basePkPwr_y = Pavg * PAM_tmy3

    Pavg is the current average power consumption [kW].
    PAM_tmy3 is a peak over average multiplier for the TMY3 location appropriate for the project location, according to the Open Energy Data Initiative (OEDI).

    Simplified method for post retrofit cases:

    postPkPwr_y = basePkPwr_y * Elif
    Elif is an electrification multiplier [dimensionless]

    Elif = (oldCkts + newCkts)/oldCkts
    oldCkts is a power rating based on the existing electrical circuits in the building with diversity factors applied. [kVA]

newCkts is a power rating for new electrical circuits with diversity factors applied. [kVA]

oldCkts = sum over k of ckt_k
k is the number of existing circuits.
ckt_k = Voltage_k * Amperage_k * div_k / 1000
Voltage_k is the nominal circuit voltage e.g. 120, 240 [V].
Amperage_k is the circuit breaker / fuse rating of the circuit, e.g. 15, 30 [A].

div_k is the diversity factor according to circuit function, see Table 2. Set the factor to zero for any existing circuits that will be removed.

Table 2. Suggested load diversity factors by circuit function.

Circuit function	Diversity factor
Range	1
Dryer	1
Furnace	0, because removed
Kitchen	0.2
Lights	0.9
Plugs	0.2
Bath	0.2
Storage	0.01
Heat pump	0.8
Heat pump water heater	0.8

Informative Appendix E – Indoor air quality

According to the US EPA: “EPA's Energy Savings Plus Health: Indoor Air Quality Guidelines documents focus primarily on the health and safety of building occupants. The document identifies priority indoor environmental issues and includes

- Assessment Protocols to evaluate existing conditions,
- Minimum Actions to be taken during home energy upgrade activities, and
- Expanded Actions that provide opportunities to promote improved occupant health through home energy upgrades…”

The tables of contents reproduced below indicate the issues addressed.

Single-Family

Multi-family

Informative Appendix M – Multiple-Facility Planning

If there are multiple facilities and a need to decide the order in which they will be addressed, it is recommended to follow the guidance in ASHRAE Guideline 0.2, Chapter 5 and Annex H. Here is an abbreviated summary:

- Assemble EBCx Program Planning Team
- Conduct EBCx Program Planning Meeting
    - Discuss the metrics to be used to rank the facilities under consideration. Metrics may include
        - occupant density (staff and client/guest);
        - income or profit per unit area or facility;
        - environmental quality/satisfaction;
        - use effectiveness;
        - fire/life safety compliance with current codes;
        - maintenance/service needs or cost; annual net cost per unit area;
        - annual energy use per unit area, including demand charges;
        - intensity of contribution toward meeting the organization's mission.
        - It may be decided to focus on facilities built prior to a specific year.
    - Other possible methods for prioritizing the order in which buildings are scheduled for EBCx may include the following:
        - Highest return for the effort, such as a facility with high opportunity for reduction in energy or operational cost.
        - Highest productivity return to the organization, such as for a large data center.
        - Facilities most critical to the organization's mission.
        - Selecting less complicated candidates first to refine the process before undertaking more complicated projects.

- Assemble Information and Rank Facilities
    - Based on the ranking method established during the planning meeting, assemble the various types of information regarding the general performance, state, and condition of the facilities to be considered in the EBCx Program. Analyze data gathered and rank the facilities based on the criteria established during the planning meeting.
    - Develop an execution schedule showing the initial list of facilities and the order in which the EBCx will be applied. This is the prioritized list of facilities. Include the reasoning used to establish this prioritized list so that it may be referenced should the order need to be changed as the program progresses.

- Write the EBCx Program Plan
  The EBCx Program Plan should include the following:
    - a. EBCx Program mission statement
    - b. Program goals and objectives
    - c. Facility identification
    - d. Facility systems and assemblies included
    - e. Ranking metrics
    - f. Prioritized list of facilities
    - g. Measurement and verification requirements
    - h. Training approach
    - i. EBCx resources
    - j. Expected benefits
    - k. Budget and investment criteria
    - l. Execution schedule
    - m. EBCx Program Planning Team (name, affiliation,
    - and title)

- Obtain Owner Acceptance and Decision to Proceed

Normative Appendix MZ – single-zone approximation for multifamily / multizone buildings

MZ.1 With respect to Section 6.2 Winter Resilience, model the unit on the top floor at the northwest corner. (Southwest in the southern hemisphere.)

MZ.2 With respect to Section 6.3 Summer Resilience, model the unit on the top floor at the southwest corner. (Northwest in the southern hemisphere.)

MZ.3 With respect to Section 6.4.1 Life Cycle Cost limit, model the building as follows:

a. Ignore common spaces.
b. Group dwelling unit floor plans by number of bedrooms and identify the most common plan in each group as the representative.
c. Model each representative dwelling unit in its most common orientation, and also in other orientations if desired for greater accuracy.
d. Calculate the total ADORB cost as the weighted sum of the representative units and orientations.
e. Model individual mechanical systems for the units but adjust the initial / replacement costs to reflect the reality of any centralized systems.

Informative Appendix P – retrofit package tiers

Modeling for the selection of the final post-retrofit state of the building could begin with the evaluation of the following upgrade packages a la Munankarmi et al (2023).

All Equipment Swap-outs
+ Lite Envelope (includes H/ERV sometimes)
+ IECC Envelope
+ Phius New Construction Envelope (prescriptive)

Package 1: *All Equipment Swap-outs*

The *All Equipment Swap-outs* package includes upgrades that replace all major fossil fuel-using equipment with high-efficiency electric equipment counterparts, including equipment for space heating, water heating, cooking, and clothes drying. It also upgrades all lighting to 100% LED and upgrades all major appliances to ENERGY STAR® or ENERGY STAR Most Efficient® performance levels. Miscellaneous gas end uses such as pool heaters and gas fireplaces are not changed. The components of this package are listed in Table 1.

In this package, all water heaters are replaced with an 80-gallon heat pump water heater. For HVAC, homes with existing ducts receive a ducted air-source heat pump (ASHP) whereas homes without ducts receive an air-source mini-split heat pump (MSHP). All lighting is upgraded

to 83 lumens/watt LED lights. Ducts in unconditioned space are upgraded to 10% leakage, R-8 insulation.

Table 1. Details of *All Equipment Swap-outs* package

Package upgrades	Upgrade details	Upgrade condition
Heat pump water heater	80 gal; UEF around 2.4	All homes
Heat pump HVAC	ASHP, SEER 22, 10 HSPF	Homes with ducts
	MSHP, SEER 29.3, 14 HSPF	Homes without ducts
Duct sealing/insulation	All ducts in unconditioned space sealed to 10% leakage and insulated to R-8	All homes
Lighting	100% LED (83 lumens/watt)	All homes
Dryer	ENERGY STAR Most Efficient, Heat Pump, Ventless (CEF=5.2)	All homes
Refrigerator	ENERGY STAR (EF 21.9, 348 rated kWh/yr)	All homes
Clothes Washer	ENERGY STAR Most Efficient (IMEF=2.92)	All homes
Dishwasher	ENERGY STAR (144 Rated kWh/yr)	All homes
Cooking Range	Induction cooktop and electric resistance oven (Cooktop_ef = 0.84, Oven_ef = 0.11)	All homes

Package 2: *Lite Envelope*

This package includes all the upgrades in the *All Equipment Swap-outs* package plus additional envelope upgrades listed in Table 2. These *Lite Envelope* upgrades include attic air-sealing and attic insulation, R-6.5 wall insulation, and low-e storm windows. Each of the upgrades have necessary existing conditions in order to be applied, and thus not all the upgrades are necessarily applied in every home.

Table 2. Details of *Lite Envelope* package

Package upgrades	Upgrade details	Upgrade condition

Attic floor air-sealing and insulation	R-values follow 2021 IECC	Homes with vented attic and attic R-value less than 2021 IECC
R-6.5 wall insulation with re-siding	R-6.5 of continuous wall insulation, e.g., 1” of rigid polyisocyanurate board installed under new siding	Homes older than 1990 with less than R-19 wall insulation
Low-e storm window	Exterior low-e storm windows	Homes with single and double pane windows

Homes with vented attics and attic floor R-values less than specified those in 2021 IECC code receive the attic air sealing and insulation upgrade. Because attic floor insulation often cannot be applied at full thickness near eaves, as shown in Figure 1 [6], a derate is applied to determine the effective attic insulation level used in modeling the packages for each climate zone (see Table 3). The derate was calculated using attic perimeter insulation calculations in BEopt [7] based on average attic perimeters from ResStock.

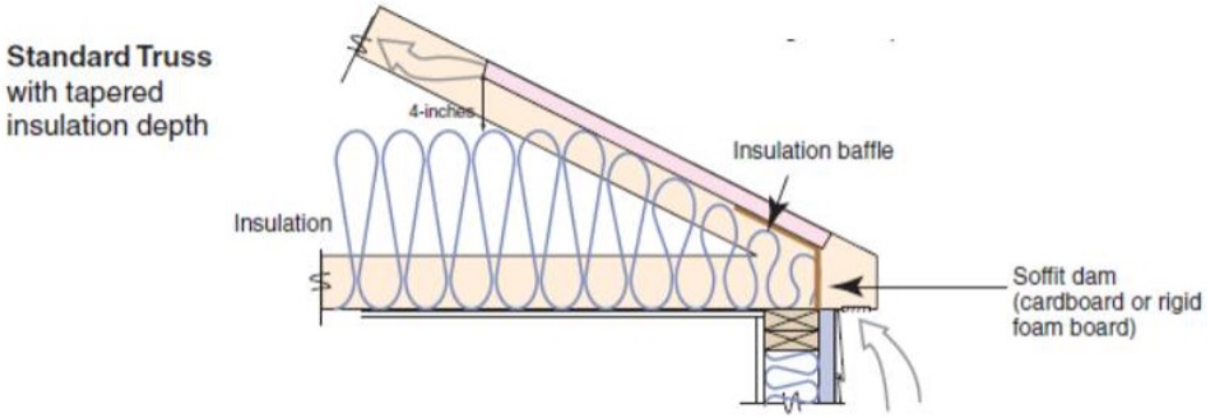


Figure 1. Standard roof trusses are narrow at the eaves, preventing full insulation thickness over the top plate of the exterior walls. Image source: Building America Solution Center [6]

The attic insulation level for each climate zone is specified in Table 3.

Table 3 Attic insulation for *Market-Ready Envelope* upgrade

Climate Zone	Attic Floor R-value, Nominal	Attic Floor R-value, Effective
1	30	29

2-3	49	44
4-7	60	51

Similarly, exterior low-emissivity (low-e) storm windows are added to the homes with pre-existing single and double pane windows. These exterior storm windows can reduce the air infiltration and conductive heat transfer associated with the window. The U-value and SHGC value for windows with and without low-e storm window is shown in Table 4.

Table 4 Window Properties with and without addition of low-e windows

Primary Window Type	Without Storm Window		With Low-E Storm Window	
	U-Value	SHGC	U-Value	SHGC
Single-Pane, Clear, Metal Frame	1.16	0.76	0.69	0.59
Single-Pane, Clear, Non-Metal Frame	0.84	0.63	0.40	0.48
Double-Pane, Clear, Metal Frame	0.76	0.67	0.38	0.51
Double-Pane, Clear, Non-Metal Frame	0.49	0.56	0.29	0.42

R-6.5 continuous wall insulation with re-siding is added in homes meeting two conditions. First, the vintage of the homes should be earlier than 1990 so that the siding is at least 30 years old and, second, the wall insulation of the home should be less than R-19. This upgrade is a generic performance level that can be achieved with currently available or emerging insulation materials, but agnostic of the specific technology used. Rigid polyisocyanurate insulation board (1” thickness) would be a typical example of a product achieving this performance level.

All three upgrades in the *Lite Envelope* package have associated reductions in air infiltration. The air leakage reduction from each upgrade of *Lite Envelope* is provided in Table 5 [8] [9]. The whole-home air leakage reduction due to the upgrades is calculated using Equation 1:

$$(1 - (1 - r1)*(1 - r2)*(1 - r3)) \quad (1)$$

Where r1, r2, r3 represent the air leakage reduction from each package upgrade.

For instance, let us consider a home with single pane windows and no storm windows and a vented crawlspace where all three of these upgrades apply. In this case, the air leakage reduction from attic air sealing is 8%, R-6.5 wall insulation upgrade is 13%, and low-e storm window upgrade is 21%. Thus, the whole-home air leakage reduction is calculated to be 37%.

Table 5. Air Leakage Reduction

Package upgrades	Vented crawlspace	Other than Vented crawlspace
Attic air-sealing and insulation	8%	13%
R-6.5 wall insulation with re-siding	13%	19%
Window upgrade for single pane without storm window	21%	30%
Window upgrade for double pane or single pane with storm window	7%	10%

Energy recovery ventilators (ERV) or heat recovery ventilators (HRV) are provided in homes with post-retrofit air infiltration rates less than 7 ACH_{50}. The efficiency of ERV and HRV upgrades are provided in Table 6, ~~based on the forthcoming PHIUS Ventilator Product Certification.~~

Table 6 Efficiency of ventilation system by climate zone

Climate Zone	Ventilation System	Sensible Recovery Efficiency	Total Recovery Efficiency
1A	ERV	NR	60%
2A	ERV	60%	60%
2B	ERV	50%	60%
3A	ERV	70%	60%
3B	HRV	70%	NR

3C	HRV	60%	NR
4A	ERV	80%	50%
4B	HRV	75%	NR
4C	HRV	70%	NR
5A	HRV	85%	NR
5B	HRV	80%	NR
6 (6A and 6B)	HRV	85%	NR
7 (7A and 7B)	HRV	85%	NR

NR = not reported (total recovery efficiency is not reported for HRVs). Values are based on calculation of the recovery efficiency needed to deliver 60 ºF air with outside air at the coldest average month temperature. Using calculations from 1,000 climate locations, the table values are halfway between the maximum and the mean value for locations in each zone, rounded to the nearest 5%. Source: Phius Ventilator Product Certification (forthcoming).

Package 3: *IECC Envelope*

This package includes all the upgrades in *All Equipment Swap-outs* plus envelope upgrades achieving performance levels consistent with the 2021 IECC Residential prescriptive path [10], [11], including the insulation of wall, floor, foundation wall, and window U-values and SHGCs (Table 7). *IECC Envelope* upgrades are applied to all the residential buildings with lower efficiency envelopes than *IECC Envelope* specifications, and are also applied to mobile homes and multifamily buildings with more than three stories. We recognize that there may not yet exist easy or practical methods to achieve these performance levels via retrofit at scale; the purpose of this analysis is to explore the hypothetical savings that could be achieved from a package such as this. [add sentence here to explain and communicate intent]

Table 7 Details of *IECC Envelope* package upgrade, based on 2021 IECC prescriptive path specifications

Climate Zone	Window U-factor	Window SHGC	Ceiling R-value	Wall R-value	Floor R-value	Foundation Wall R-value	Slab Edge R-value
1	0.40	0.25	30	13	13	0	0
2	0.40	0.25	49	13	13	0	0

3	0.30	0.25	49	20	19	5	2 ft R-10
4 except Marine	0.30	0.40	60	20	19	10	4 ft R-10
5 and Marine 4	0.30	0.40	60	20	30	15	4 ft R-10
6	0.30	0.40	60	30	30	15	4 ft R-10
7 and 8	0.30	0.40	60	30	30	15	4 ft R-10

In this package, envelope air leakage is reduced to 3 ACH_{50} for homes with a leakage rate greater than 3 ACH_{50}. ERV and HRV upgrades are included as detailed in the *Market-Ready Envelope* upgrade package.

Package 4: *Phius New Construction Envelope*

This package includes all the upgrades in package 1 (*All Equipment Swap-outs*) with the addition of the *Phius Envelope* upgrades (Table 8). The building envelope in this package is aligned with the 2021 Phius prescriptive specification [12]. This package is applied to all residential buildings with lower efficiency envelopes than what is specified in Phius, includes mid- and high-rise residential buildings. The air leakage rate is reduced to 1 ACH_{50}, and it is assumed that there are no duct losses in crawlspaces or attics as these spaces are fully brought within the thermal envelope. As with the *IECC Envelope* package, we recognize that there may not yet exist easy or practical methods to achieve these performance levels via retrofit at scale; the purpose of this analysis is to explore the hypothetical savings that could be achieved from a package such as this.

Table 8. Details of *Phius New Construction Envelope* package

Climate Zone	Window U-factor	Window SGHC	Ceiling R-value	Wall and Floor R-value	Foundation Wall R-value	Slab Edge R-value
1A	0.5	0.25	R-51	R-22	R-7	2ft R-7
2A	0.28	0.25	R-56	R-27	R-10	2ft R-10
2B	0.29	0.25	R-56	R-27	R-13	2ft R-13

3A	0.23	0.25	R-61	R-31	R-13	2ft R-13
3B	0.28	0.25	R-60	R-30	R-14	2ft R-14
3C	0.32	0.25	R-59	R-30	R-10	2ft R-10
4A	0.19	0.25	R-66	R-36	R-17	2ft R-17
4B	0.18	0.25	R-67	R-37	R-17	2ft R-17
4C	0.24	0.4	R-65	R-35	R-16	2ft R-16
5A	0.16	0.4	R-72	R-42	R-21	2ft R-21
5B	0.17	0.4	R-69	R-39	R-19	2ft R-19
6A	0.13	0.4	R-77	R-46	R-24	2ft R-24
6B	0.14	0.4	R-75	R-44	R-23	2ft R-23
7A	0.12	0.4	R-82	R-51	R-30	2ft R-30
7B	0.12	0.4	R-82	R-51	R-30	2ft R-30

Informative Appendix S – Seismic assessment & evaluation resources

Investigation Phase Resources from FEMA P-154:

“ASCE/SEI 41-13 provides both procedures to evaluate the seismic force- resisting capacity of buildings and recommended procedures for the seismic retrofitting of buildings with inadequate seismic capacity. The ASCE/SEI 41-13 procedure includes three tiers of evaluation and is ideal for those buildings that require a Detailed Structural Evaluation. Previously, evaluation was covered by ASCE/SEI 31-03, Seismic Evaluation of Existing Buildings (ASCE, 2003), and recommended retrofitting procedures, along with more in-depth evaluation procedures were contained in the separate ASCE/SEI 41-06 standard, Seismic Evaluation and Retrofit of Existing Buildings (ASCE, 2007). ASCE/SEI 31 was an updated version of FEMA 310, Handbook for Seismic Evaluation of Buildings - A Prestandard (FEMA, 1998), which in turn was an update of the original FEMA 178 report, NEHRP Handbook for the Seismic Evaluation of Existing Buildings (FEMA, 1992). ASCE/SEI 41 began as an updated version of FEMA 356, Prestandard

and Commentary for the Seismic Retrofit of Buildings (FEMA, 2000b), which was in turn an update of FEMA 273, NEHRP Guidelines for the Seismic Rehabilitation of Buildings (FEMA, 1997a).

FEMA P-58-1, Seismic Performance Assessment of Buildings, Volume 1 – The Methodology (FEMA, 2012d), is the initial volume in a series of publications that document a sophisticated "methodology for seismic performance assessment of individual buildings that properly accounts for uncertainty in accurately predicting response, and communicates performance in ways that better relate to the decision-making needs of stakeholders. The procedures are probabilistic, uncertainties are explicitly considered, and performance is expressed as the probable consequences, in terms of human losses (deaths and serious injuries), direct economic losses (building repair or replacement costs), and indirect losses (repair time and unsafe placarding) resulting from building damage due to earthquake shaking."

HAZUS-MH is FEMA's nationally applicable software program that estimates potential building and infrastructure losses from earthquakes, riverine and coastal floods, and hurricane winds using methodology documented in the Multi-Hazard Loss Estimation Methodology, Earthquake Model, HAZUS-MH MR4 Technical Manual (FEMA, 2009a). HAZUS can be used to inform decision-making at all levels of government by providing a reasonable basis for developing mitigation, emergency preparedness, and response and recovery plans and policies.

FEMA 547 report, Techniques for the Seismic Rehabilitation of Existing Buildings (FEMA, 2006), provides a comprehensive discussion of common techniques for seismic retrofitting, with extensive figures and advice on detailing.

FEMA P-807 report, Seismic Evaluation and Retrofit of Multi-Unit Wood-Frame Buildings with Weak First Stories (FEMA, 2012c), provides guidance for evaluation and cost-effective retrofit procedures for wood buildings with weak ground stories.

FEMA E-74 explains the sources of nonstructural earthquake damage in simple terms and provides methods for reducing potential risks. FEMA E-74 is ideal where a Detailed Nonstructural Evaluation is recommended based on the results of the rapid visual screening."

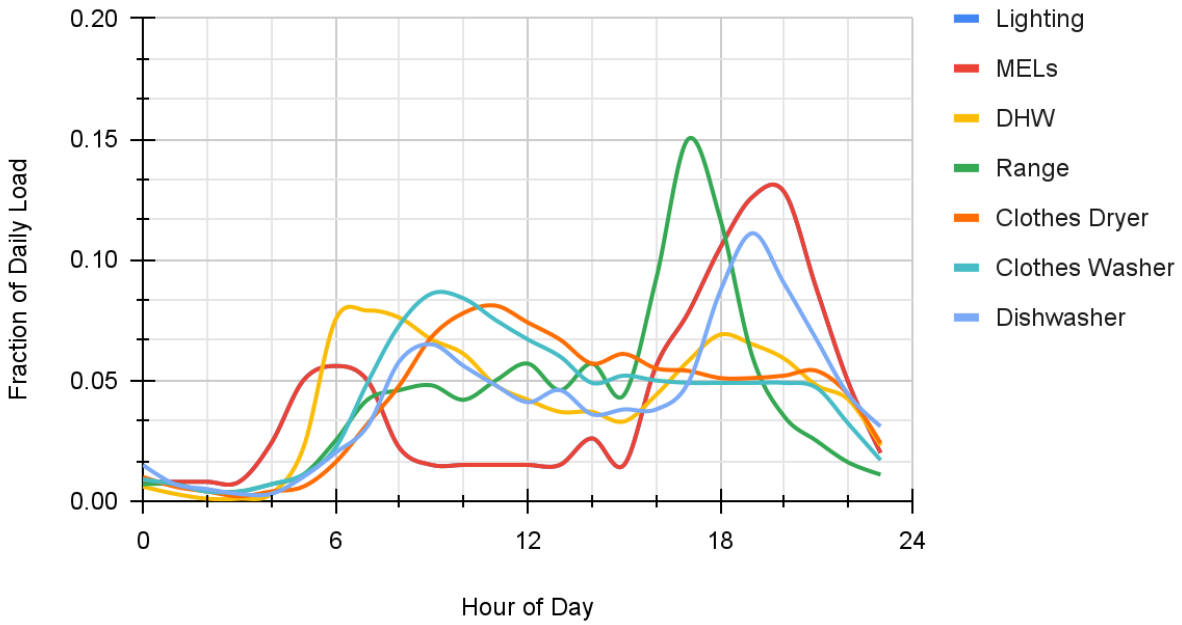
Normative Appendix SC – Schedules

Informative: The schedules used in this section are from the Building America House Simulation Protocol, but simplified into a daily schedule rather than using a seasonal adjustment.

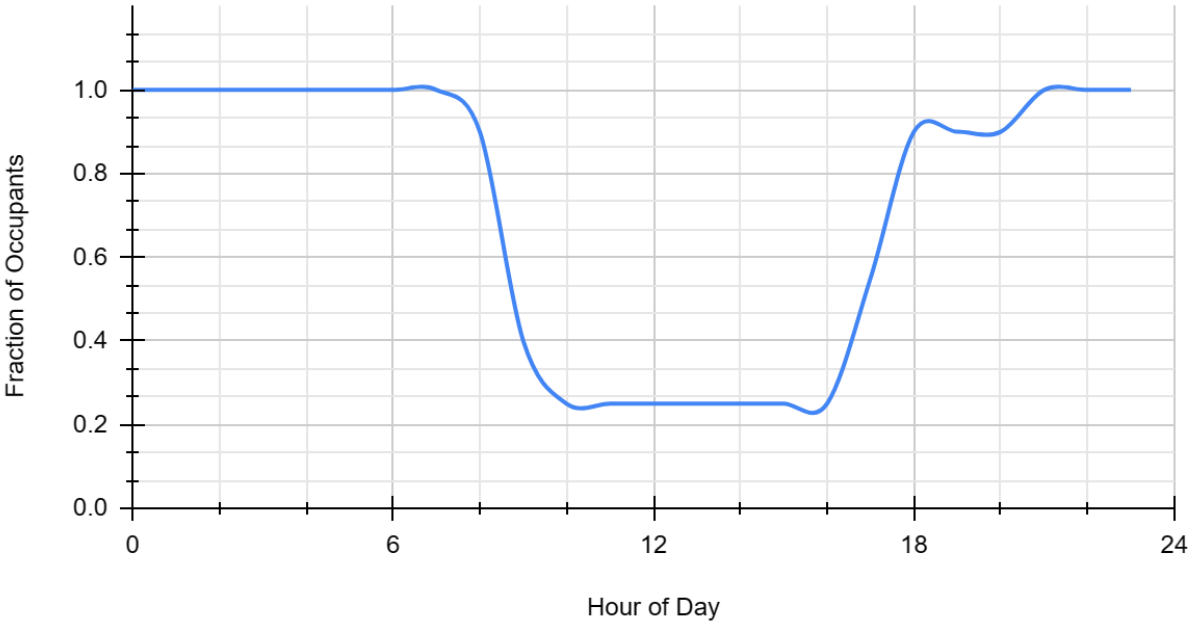
Hour of Day	Lighting Schedule	MELs Schedule	Whole House DHW Schedule	Range Schedule	Clothes Dryer Schedule	Clothes Washer Schedule	Dishwasher Schedule	Occupant Schedule
1	0.008	0.008	0.006	0.007	0.01	0.009	0.015	1
2	0.008	0.008	0.003	0.007	0.006	0.007	0.007	1
3	0.008	0.008	0.001	0.004	0.004	0.004	0.005	1
4	0.008	0.008	0.001	0.004	0.002	0.004	0.003	1

5	0.024	0.024	0.003	0.007	0.004	0.007	0.003	1
6	0.05	0.05	0.022	0.011	0.006	0.011	0.01	1
7	0.056	0.056	0.075	0.025	0.016	0.022	0.02	1
8	0.05	0.05	0.079	0.042	0.032	0.049	0.031	1
9	0.022	0.022	0.076	0.046	0.048	0.073	0.058	0.9
10	0.015	0.015	0.067	0.048	0.068	0.086	0.065	0.4
11	0.015	0.015	0.061	0.042	0.078	0.084	0.056	0.25
12	0.015	0.015	0.048	0.05	0.081	0.075	0.048	0.25
13	0.015	0.015	0.042	0.057	0.074	0.067	0.041	0.25
14	0.015	0.015	0.037	0.046	0.067	0.06	0.046	0.25
15	0.026	0.026	0.037	0.057	0.057	0.049	0.036	0.25
16	0.015	0.015	0.033	0.044	0.061	0.052	0.038	0.25
17	0.056	0.056	0.044	0.092	0.055	0.05	0.038	0.25
18	0.078	0.078	0.058	0.15	0.054	0.049	0.049	0.55
19	0.105	0.105	0.069	0.117	0.051	0.049	0.087	0.9
20	0.126	0.126	0.065	0.06	0.051	0.049	0.111	0.9
21	0.128	0.128	0.059	0.035	0.052	0.049	0.09	0.9
22	0.088	0.088	0.048	0.025	0.054	0.047	0.067	1
23	0.049	0.049	0.042	0.016	0.044	0.032	0.044	1
24	0.02	0.02	0.023	0.011	0.024	0.017	0.031	1

Hourly Load Schedules



Occupant Schedule



Normative Appendix T-0 – Program Plan Outline

In the case of multiple facilities, assemble a Program Plan document containing the following:

a. Facility identification
b. Ranking metrics
c. Prioritized list of facilities
d. Phase plan or execution schedule
e. Program planning team (names, affiliation, and title)

For each building, collect narrative answers to the questions posed in sections 4.5.1.1-3 into a rationale to retrofit.

Normative Appendix T-1 – CFR/OPR Outline

Facility Summary

A narrative describing facility location, size, occupancy type, construction, systems, and facility usage.

General Requirement

“The retrofitted building shall meet the requirements of Phius Standard EB1-2023.”

The retrofitted building shall also meet the owner-directed and owner-elected requirements listed below:

Facility requirements

Facility requirements per section 8.6.4.1.

Regulatory
Financial
Functional uses
Space needs
Indoor Environment
Preferred vendors

Nonresidential critical electrical and process loads
Nonresidential outage occupancy schedule
Nonresidential heat exposure criteria for unoccupied zones

Indoor air quality electives

See sections 5.1 and 8.6.4.3.

1 Asbestos
2 Below ground contaminants (except radon)
3 Building products
4 Carbon Monoxide
5 Environmental tobacco smoke
6 Garage air pollutants
7 Lead
8 Moisture / mold
9 Pests
10 PCBs
11 Radon
12 Wood smoke
13 HVAC equipment
14 Vented combustion appliances
15 Unvented combustion appliances
16 Local exhaust ventilation
17 Whole dwelling ventilation
18 Safety
19 Protecting IAQ during construction
20 Jobsite safety

Defer discussion - not a CFR issue but an EBCx Plan issue.

Hazard mitigation electives

See sections 5.2 and 8.6.4.4.
Seismic
Flood, Tsunami
Hail
Wind
Snow load
Wildfire

Decarbonization pathways

Operational decarbonization pathway chosen per section 6.4.2.1.
Embodied decarbonization pathway chosen per section 6.4.2.2.

Monitoring / Measurement and Verification electives

See sections 7 and 8.6.4.2.

Normative Appendix T-2 – EBCx Plan Outline

Assessment Phase Planning

Facility requirements assessment plan

Occupant concerns related assessment plan

List of concerns from the occupant survey to be assessed in the walkthrough.

IAQ Assessment site visit plan

Per section 8.6.5.1

With respect to the EPA energy savings plus health documents, list the assessment protocol items that could be accomplished in a walkthrough.

Informative: A suggested list is as follows:

2 Below ground contaminants (except radon)
- *AP 2.1 Evaluate Sources*
  - *-Take note of any odors on site/indoors*
  - *-Visually inspect any drain/waste/vent piping if easily accessible*

3 Building products
- *AP 3.2-3.3 - Building Products/Material Emissions*
  - *-Discuss importance of safe product choices and avoiding VOCs*
  - *-Identify carpet prone to moisture/wetting problems*
  - *-Assess existing ventilation strategies*

4 Carbon Monoxide
- *AP 4.1 Assessment of CO Sources*
  - *-Document all existing combustion equipment*

5 Environmental tobacco smoke
- *AP 5.1 Look for Signs of Smoking Indoors*

6 Garage air pollutants
- *AP 6.1-6.5 Garage Air Pollutants*
  - *-Assess existing garage configuration and characteristics*

7 Lead
- *AP 7.1 Assess Paint Conditions*
  - *-Document peeling, bubbled, or worn paint that may contain lead*

8 Moisture / mold
- *AP 8.1-8.4 - Mold/Moisture Assessment*
  - *-Document all areas where moisture/mold issues are currently present or suspected*

-Discuss containment of mold and remediation plan/strategies

Note: ANSI IICRC S520-2015 Standard for Professional Mold Remediation, Section 10.4, addresses building inspection. It suggests looking for water intrusion or condensation, water stains, odors, structural defects and damage, previous repairs and remodeling, among other things, as well as attempting to identify pathways of water intrusion so as to predict where there might be hidden mold.

Intrusive inspections should be deferred to the Investigation Phase, and are preferably conducted and documented according to ANSI/IICRC S500, Standard and Reference Guide for Professional Water Damage Restoration.

9 Pests

AP 9.1-9.2 Pests

-Check for evidence of pests/rodents

10 PCBs

AP 10.1 Assess Light Ballasts

-Document any fluorescent light fixtures

11 Radon

AP 11.3 Determine if Active or Passive Radon Mitigation System

-Document current mitigation system, if applicable

13 HVAC equipment

AP 13.1-13.2 HVAC Equipment

-Document existing equipment functionality

-Document existing equipment information (mfr, model #, etc.) if easily accessible

-Note specific areas of occupant discomfort/concern

16 Local exhaust ventilation

AP 16.1-16.2 Source/Local Exhaust Ventilation

-Document existing ventilation strategies for kitchen/baths

-Document existing dryer exhaust

18 Safety

AP 18.1 Assess Conditions

-Check if existing wood stove vent is sealed (stove not used)

-Replace batteries/supply CO and smoke alarms

-Identify harmful chemicals on-site

-Inspect existing fire extinguisher, if any

-Check DHW temp. Adjust to align with state/local code if needed

-Document any and all additional hazards/occupant concerns

List of locations to be inspected on site.

Initial retrofit phase plan for performance-related measures

Initial M&V approach

Initial approach to maintenance and persistence of benefits

Investigation Plan

Facility requirements related investigation

Occupant concerns related investigation

IAQ and moisture risk related investigation

1 Asbestos
2 Below ground contaminants (except radon)
3 Building products
4 Carbon Monoxide
5 Environmental tobacco smoke
6 Garage air pollutants
7 Lead
    How to identify a Lead Water Water Service Line
8 Moisture / mold
9 Pests
10 PCBs
11 Radon
12 Wood smoke
13 HVAC equipment
14 Vented combustion appliances
15 Unvented combustion appliances
16 Local exhaust ventilation
17 Whole dwelling ventilation -> refers in turn to ASHRAE 62.2-2019
18 Safety
19 IAQ during construction
20 Jobsite safety

Site hazards investigation

Seismic
Flood, Tsunami
Hail
Wind
    FORTIFIED Roof requirements summary:

3.1 roof sheathing thickness
3.2 sealing and strengthening under roof deck
3.3 attic vents and covers (hurricane only)
3.4 engineered attachments for roof PV

Snow Load
Wildfire

Winter Resilience related investigation

Summer Resilience related investigation

ADORB cost reduction related investigation

Additional decarbonization related investigation

M&V related investigation

Schedule of investigation activities

[a la 230 6.2.1.2.3.1 h]
Any system testing that may require interruptions of facility operations. [a la 0.2 6.5.1 e ii]

Pre-site visit tests, potential disruptions

Per section 8.7.5.2

Stakeholder interviews

Per section 8.7.5.3

Test procedures

Per section 8.7.5.6
Informative Appendix T-2.1 has forms for documenting the condition of equipment, and for writing test procedures.

Updated retrofit phase plan for performance-related measures

Updated M&V plan

Updated approach to maintenance and persistence of benefits

Implementation Plan

Measures by requirements category

Facility Requirements & Occupant concerns

Moisture and IAQ Risk Mitigation Requirements

Site Hazard Mitigation Requirements

Winter Resilience Requirements

Summer Resilience Requirements

ADORB Cost Requirement

Additional Decarbonization Requirements

M&V Requirements

Measures by building component category

Air Leakage

Ceilings Roofs

Foundation Floors

Windows Doors Skylights

Walls

Mechanical Ventilation

Appliances Fixtures

Lighting

Space Conditioning Equipment

Water Heating

Sampling strategies for Cx Design Review

(per section 8.8.4)

Sampling review process for submittals

(per section 4.8.7)

Training Plan

[a la 0.2 8.6.1 c.]
[0.2 mentions training plan as early as Assessment Phase and as late as Hand-off]

Hand-Off Plan

Per section 8.6.5.6, will a lessons-learned workshop be conducted?

Lessons-learned workshop plan

Informative: See ASHRAE Guideline 0.2, Informative Annex L6, for suggested list of invitees, agenda, list of documents for distribution before the workshop, and outline of the workshop report.

Informative Appendix T-2.1 – EBCx Plan Outline ideas

Additional ideas about the content of EBCx Plans can be found in the references listed below:

ASHRAE Standard 230 Section 6.2.1.2.3.1
Note there is no Implementation section in this outline.

ASHRAE Guideline 0.2 Informative Annex G

ASHRAE Guideline 0.2 Section 6.5.1
Note there is no Implementation section in this outline, but Guideline 0.2 Section 8.6.2 and 8.6.3 do cover Implementation Plan and Implementation Verification Plan respectively.

ASHRAE SSPC 300 Informative Annex 05 - Commissioning Process Plan

ASHRAE Guideline 0.2 Section 7.5.1.6.3 and 7.5.1.6.4 contain the following templates for Investigation-Phase test procedures for equipment, and recording the condition of equipment:

Document test procedures in forms that include the following:
a. Purpose of the test
b. Participants required for the test
c. Schedule for testing
d. Precautions, including potential risks and disruptions
e. List of tools and/or equipment (ladders, test meters, gauges, sensors) required, means of access (keys, security codes), safety procedures (asbestos, specialty gases), and site protocols (sign-in, gowning, ID checks)
f. Accuracy and calibration of instrumentation
g. Prerequisites for the test
h. Step-by-step instructions for conducting the test. For each step of the test, include the following:
    1. Parameters and physical quantities to be measured
    2. Baseline information and measurements that need to be recorded for the M&V approach
    3. Expected performance and range of acceptable results
    4. Observed performance and if it is acceptable or not (pass/fail). (This information is recorded during the test.)
    5. Back-out and return to normal procedures

Make forms for documenting the installed characteristics and condition of equipment (heating, ventilation, air conditioning, refrigeration, service hot water, laundry, dishwashers, and cooking appliances) including the following:
a. Make and model
b. Location
c. Quantity
d. Age
e. Size
f. Capacity
g. Condition

Informative Appendix T-3 – Basis of Design Outline

When design work is required, e.g. for additions or major renovation, ASHRAE SSPC 300 Informative Annex 06 might be useful in developing the Basis of Design document.

Normative Appendix T-4 – Systems Manual Outline

Use the outline in ASHRAE 202-2018 section 14.2.3 (reproduced below) to develop the Systems Manual.

Section 1—Executive Summary
Section 2—Facility Design and Construction
- 2.1 Copy of OPR document
- 2.2 Copy of BoD document
- 2.3 Copy of building/project design and record documents

Section 3—Building, Systems, and Assemblies Information for Commissioned Systems and Assemblies
- 3.1 Copy of building and equipment specifications
- 3.2 Copy of approved submittals including final controls sequences of operation
- 3.3 Copy of manufacturer's operations and maintenance (O&M) data
- 3.4 Copy of warranties
- 3.5 Contractor and supplier listing and contact information

Section 4—Facility Operations
- 4.1 Facility Guide, including operating plan; building and equipment operating schedules, set points, ranges, and limitations; commissioned systems control sequences of operation; and emergency procedures. The Facility Guide shall contain operating instructions, which are the facility's operating criteria and procedures, for systems controls (HVAC&R, lighting), security, fire, safety, emergencies, and maintenance programs, including the assemblies commissioned.

Section 5—Training
- 5.1 Copy of training plan and materials
- 5.2 Training records

Section 6—Cx Progress Reports
- 6.1 Copy of final Cx Plans
- 6.2 Copy of Cx design and submittal review reports
- 6.3 Copy of test reports, construction checklists, and test procedures used for evaluation completed for commissioned systems and assemblies
- 6.4 Copy of all Cx Progress Reports
- 6.5 Copy of issues and resolution logs
- 6.6 Item resolution plan for open items
- 6.7 Preliminary Cx Report prior to issue of certificate of occupancy
- 6.8 Final Cx Report at the completion of the Cx

Informative Appendix T-5 – Facility Guide Outline

ASHRAE Guideline 0.2, Informative Annex M1 (reproduced below) might be useful in developing the Facility Guide.

Executive Summary
The executive summary contains an explanation of the source and use of the guide and an overview of the building design, construction, and operational requirements. The information is intended to provide general guidance on the intended operation of the building in conformance with the Current Facility Requirements (CFR).

Facility Operations Instructions

a. **Operating Plan**. Insert a copy of the completed facility operating plan with explanations of the intended use and operation of the facility.
b. **Building and Equipment Operating Schedules, Setpoints, and Ranges**. Insert a copy of setpoints of all equipment with normal operational adjustments. Include the setpoint normal intended ranges and limitations.
c. **Sequences of Operation and Limitations**. Insert a copy of the sequences of operation for appropriate operating equipment in language and a format that is understandable to the property managers or to other groups using the guide. This would not be the controls submittal drawings but a written description of the sequences and the intent of each sequence. It should include relevant sequence/system interaction as well as graphics or schematics.
d. **Start-Up and Shutdown Actions**. Insert a copy of routine system start-up and shutdown procedures and locations of applicable controls and shutoffs.

Ongoing Commissioning (OCx) Operational and Maintenance Record Keeping
Include OCx and optimization procedures and documentation to monitor and improve the performance of facility systems. These instructions should also be used as the basis for periodic Cx of operations or for contracts for this process.

The following sections can be added to the FG and systems manual when required … or when these items are available.

Maintenance Procedures, Checklists, and Records
Insert procedures, forms, and checklists for facility operation and their maintenance functions. Include updating requirements. Describe inspections and testing required on a routine basis and standard forms required.

a. **Maintenance Schedules**. Include recommended maintenance schedules for systems and equipment along with update requirements. The intent here is to provide guidance for the facility manager on when to order routine heavy maintenance functions such as annual testing.

Utility Measurement and Reporting

Include a description of utility metering and monitoring systems. If included in the property management functions, provide document formats and procedures for tracking utility use and reporting this information to meet the Owner's and jurisdictional requirements.

Janitorial and Cleaning Plans and Procedures
Insert a copy of facility cleaning and janitorial plan with procedures and intended chemicals and equipment if this is a function of the building property management. These janitorial plans could also be used to contract for those services.

_Normative Appendix T-6 – EBCx Report Outline

Assessment Report

[0.2 6.1.3.7, 6.8.1, 6.9.3]

Facility Information

Facility Summary. A narrative describing facility location, size, occupancy type, construction, systems, and facility usage. Reiterate the summary in the CFR.

General facility information

[mostly a la hespro.gov, first two tabs]
Project Name
Occupancy type

- ☐ single-family detached,
- ☐ single-family attached,
- ☐ multifamily,
- ☐ nonresidential, or
- ☐ mixed use.

For nonresidential and mixed-use, specify facility usage.

Contact information for EBCx Team members.

- Owner
- CxP Team
- V&T providers
- Design Professionals

Project Address
City with most similar climate to the project location
Year(s) built
Number of occupants by age

- 0 to 5 years

6 to 13 years
14 to 64 years
65 years and older

Energy Prices - Utility names and rate plans for applicable fuels, meter and submeter locations, data availability (hard copy or electronic)

Electricity [$/kilowatt-hour]
Piped Natural Gas [$/therm or $/100 cubic feet]
Liquid Propane Gas (LPG) [$/gallon]
Fuel Oil [$/gallon]

List of additional documents

Per section 8.6.1

Occupant Survey Results

Per section 8.6.2

Additional facility information

per section 8.6.1

a. Construction documents (drawings; specifications; submittals, especially HVAC controls; as-builts; previous modifications to the facility).
b. Utility usage/bills (energy and water).
c. Scheduled maintenance worksheets and work order history for systems included in the EBCx scope.
d. Previous new-construction commissioning Systems Manual, including its final commissioning report, or previous EBCx systems and facility manuals (as applicable, from previous projects).
e. Any previous consultant reports for systems included in the EBCx scope (as applicable).
f.
g. Operations and maintenance (O&M) plan.
h. O&M report of operating problems, malfunctioning equipment, maintenance costs, and revisions to O&M procedures pertaining to systems included in Cx scope.
i. Annual maintenance cost breakdown of interior building costs, building enclosure maintenance cost, and repair budget.
j. Onsite energy production (as applicable).
k.
l. A budget for low-cost repairs to be performed within the operations and maintenance (O&M) budget for the facility, where such a budget exists. If no budget exists, the Owner shall develop a budget for low-cost repairs. (for safety, security, health, or operational issues that can be easily remedied, do not require further investigation, and thus can be immediately implemented as the team develops the initial information on the facility. [a la 0.2 6.7.6.1]

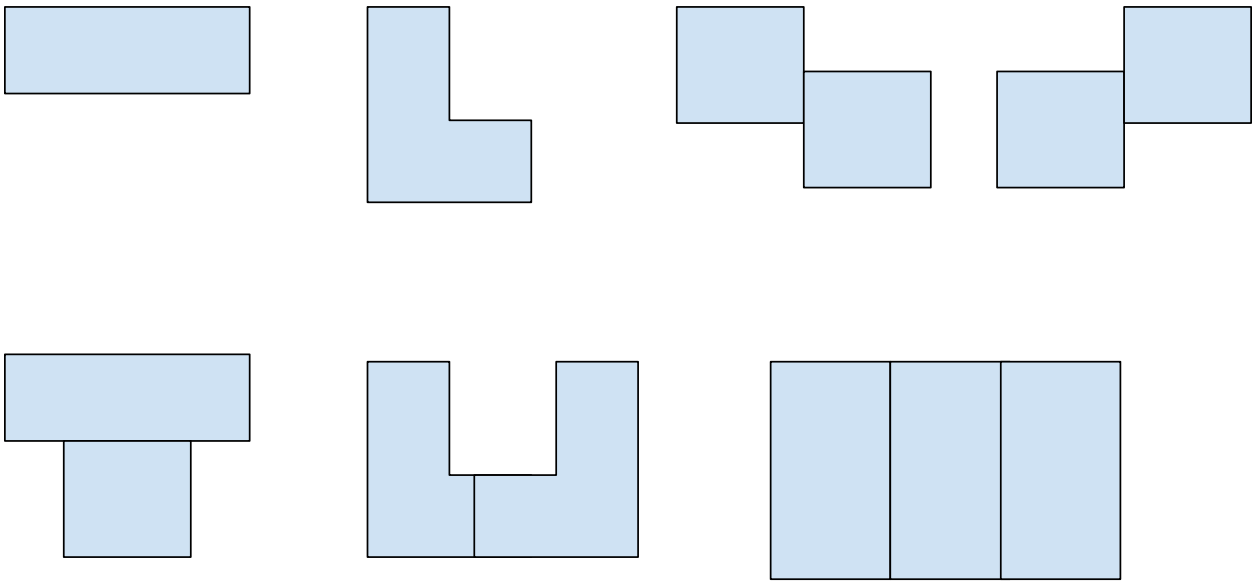
For Single-Family Residential

Direction faced by front door
Stories above ground level
Interior floor-to-ceiling height

Shape / Size / Orientation

Determine the shape below that most closely matches the shape of the house, and record the exterior dimensions of that simplified shape.

- ☐ Rectangle
- ☐ L-Shape
- ☐ Front S-Shape
- ☐ Back S-Shape
- ☐ T-Shape
- ☐ U-Shape
- ☐ Townhouse



Floor area info
- Above grade
- Below grade
- Unconditioned attached spaces (garage etc.)

For Multifamily Residential

Per section 8.6.1, attach MBEST workbook.

For Nonresidential and Mixed-Use

Narrative or graphics describing size and shape, including floor area and number of stories.

List of immediate improvements made

[a la 0.2 6.7.6.1]

Facility requirements related assessment

List of equipment not in service. [a la 230 6.2.1.2.1]
Findings related to occupant concerns.

IAQ and moisture risk assessment

1 Asbestos

2 Below ground contaminants (except radon)

3 Building products

Informative re: AP 3.1 new materials - See minimum action MA 3.3 - that actually covers requirements on new materials.

4 Carbon Monoxide

5 Environmental tobacco smoke

6 Garage air pollutants

7 Lead

8 Moisture / mold

9 Pests

10 PCBs

11 Radon

12 Wood smoke

13 HVAC equipment

14 Vented combustion appliances

15 Unvented combustion appliances

16 Local exhaust ventilation

17 Whole dwelling ventilation

18 Safety

19 IAQ during construction

20 Jobsite safety

Informative: This is mostly an EBCx Plan issue.

Site hazards assessment

Seismic

Seismic design category

Flood, Tsunami

Hail

Wind

Ice dams / snow load

Wildfire

Initial Performance modeling report

Baseline case

- Outage resilience performance
- Normal-operation energy end-use breakdown
- ADORB cost breakdown
- Direct cost breakdown for performance-related upgrades

Post-retrofit cases

- Outage resilience performance
- Normal-operation energy end-use breakdown
- ADORB cost breakdown
- Direct cost breakdown for performance-related upgrades

Budget categories for performance-related upgrades

Envelope

- Air leakage / sealing / tightness
- Ceilings, Roofs
- Walls
- Foundation, Floors

HVAC

- Mechanical ventilation
- Space Conditioning

Hot Water (DHW, SHW)

Major appliances

Lighting

PV / Battery / Generation

Other performance-related

Budget for Commissioning, Testing, Inspection

Additional decarbonization assessment

Investigation Report

[a Ia 230 7.2.1.2.2 a, 0.2 7.8.1]

Executive Summary

Documentation of changes implemented during the Assessment and Investigation Phases

List of findings and recommendations

Calculations and supporting documentation for Resilience performance and ADORB cost

Rationale for the selection or rejection of approaches

Documentation of observations and data gathered in the field

Informative: This information demonstrates the findings that led to development of the related recommendations.

List of immediate improvements made

Facility requirements related investigation

IAQ and moisture risk investigation

Site hazards and structural investigation

Winter Resilience related investigation

Summer Resilience related investigation

ADORB cost reduction related investigation

Additional decarbonization related investigation

M&V related investigation

List of deferred testing, if any

_Implementation Progress Reports

[0.2 8.7.1, 8.9.3, 8.10.2]

_Training documentation

[0.2 9.4.5, 9.7.2]

_Lessons Learned Report

[0.2 9.7.1, 9.9.1, Annex L6]

_Appendix T-7 – OCx Plan Outline

Per section 8.9.2.

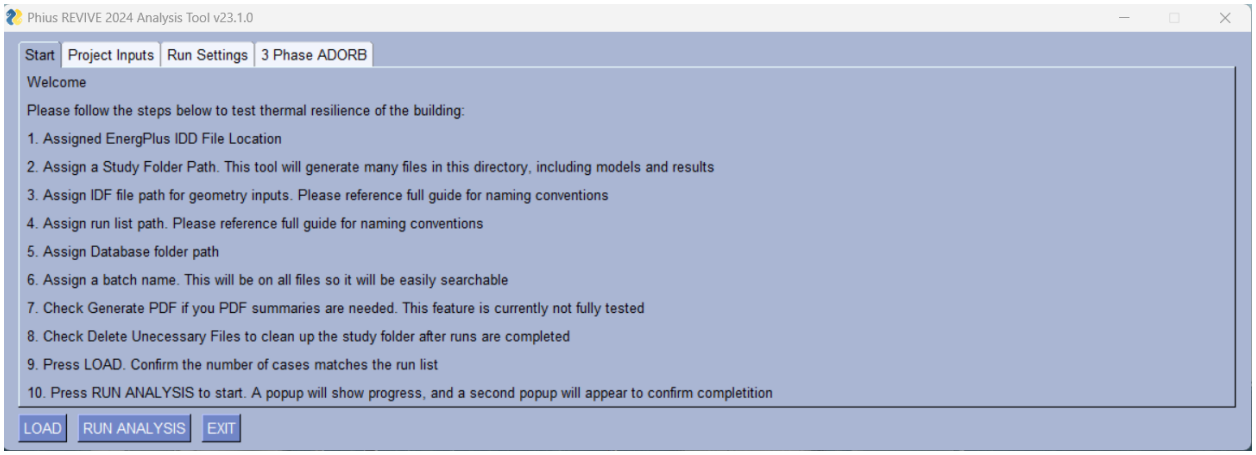
_Appendix T-8 – OCx Report Outline

_Informative Appendix U – Calculation engine user manual

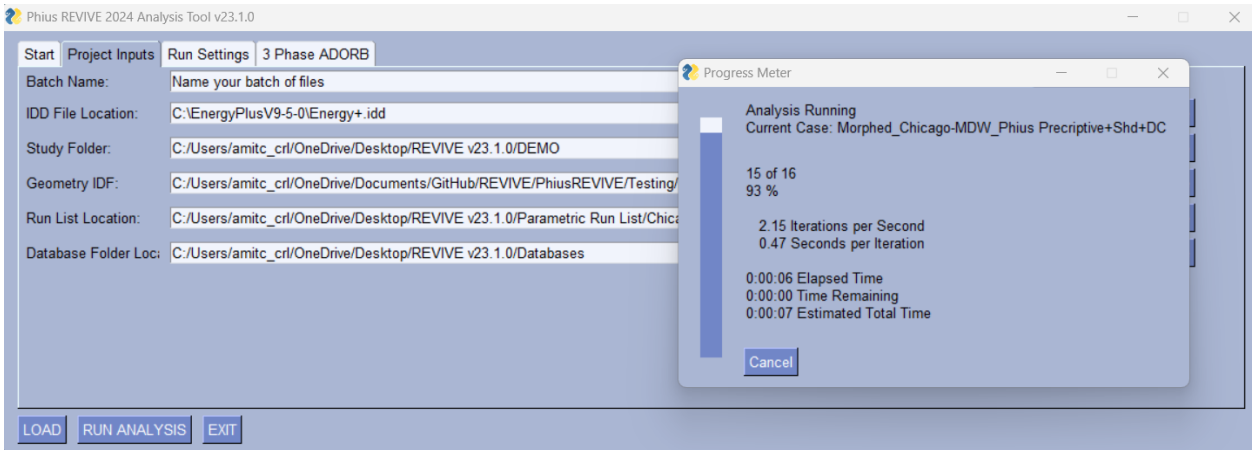
This appendix describes the inputs, outputs and function of the software tool that was developed to comply with the performative aspects of this standard. The tool is open source and based on the EnergyPlus simulation engine. Additional training videos as well as software download may be found on the Github Repository here.

U.1 - Workflow Description

The tool is a graphical user interface that serves as a simulation launcher platform. The first tab of the tool provides a simplified set of instructions for the user. At the top are the tabs that separate the tools functions into different inputs for each step of the analysis. At the bottom of the tool are the buttons that load in the **Run List**, run the analysis and exit the launcher.

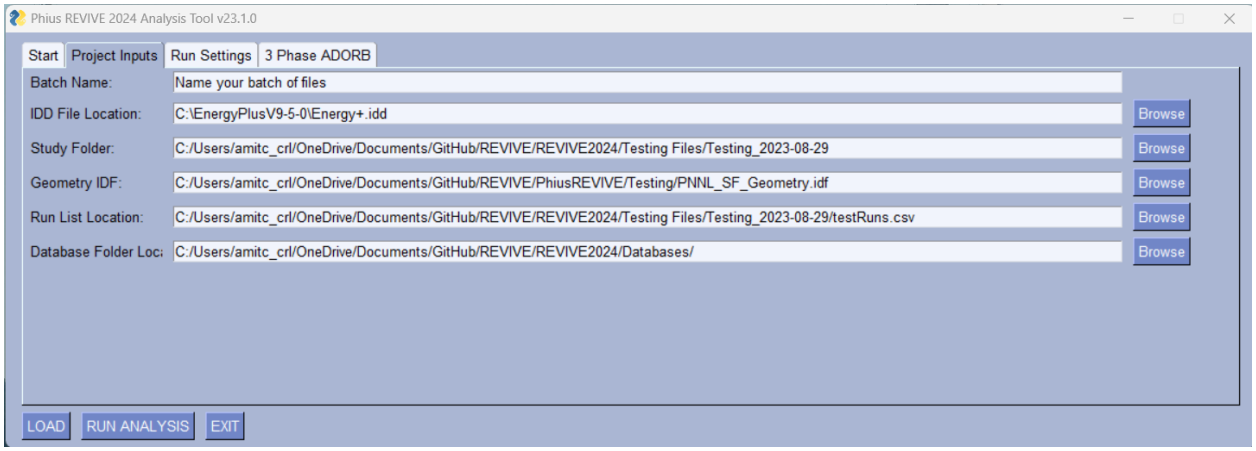


The **Project Inputs** tab has most of the normally used settings for the usage of the tool. Aside from the **Batch File Name**, all of the inputs are file paths to the files that are needed for simulation. Please fill out this entire tab of the tool in order to run an analysis. After filling out this tab, press **Load** to load in the **Run List** and a pop up window will appear confirming the number of cases identified in the **Run List.** When ready to perform the analysis, press the **Run Analysis** button at the bottom of the screen. While running a progress meter will pop up to display the elapsed time and time remaining. When fully complete a second popup window will appear.



Definitions of inputs:

- **Batch Name:** This text input will apply the batch name to all of the files created from the current run. This will make the files identifiable when running multiple scenarios.
- **IDD File Location:** This input is the path to the EnergyPlus Input Data Dictionary (IDD) file. This is needed to run write and run the energy simulation files. Please note that v23.1.0 of the tool runs on EnergyPlus 9.5.0 only.
- **Study Folder:** Provide a path to a folder where all of the output files and energy models should be saved. Each case can create multiple files while running, so ensure that there is adequate space in this folder.
- **Geometry IDF:** This path input is to the EnergyPlus Input Data File (IDF) that contains all of the geometry inputs for the model. Please ensure that the naming conventions for the constructions in the IDF are followed as described in U.2.
- **Run List Location:** This path is to the **Run List,** the .csv file that contains all of the inputs for the building other than the geometry.
- **Database Folder Location:** This path input is to the database folder which can be downloaded from the Github Repository. The database files contained within this folder are all user editable, and will be described in U.3.



The **Run Settings** tab has inputs that work as global settings for each run of the cases.

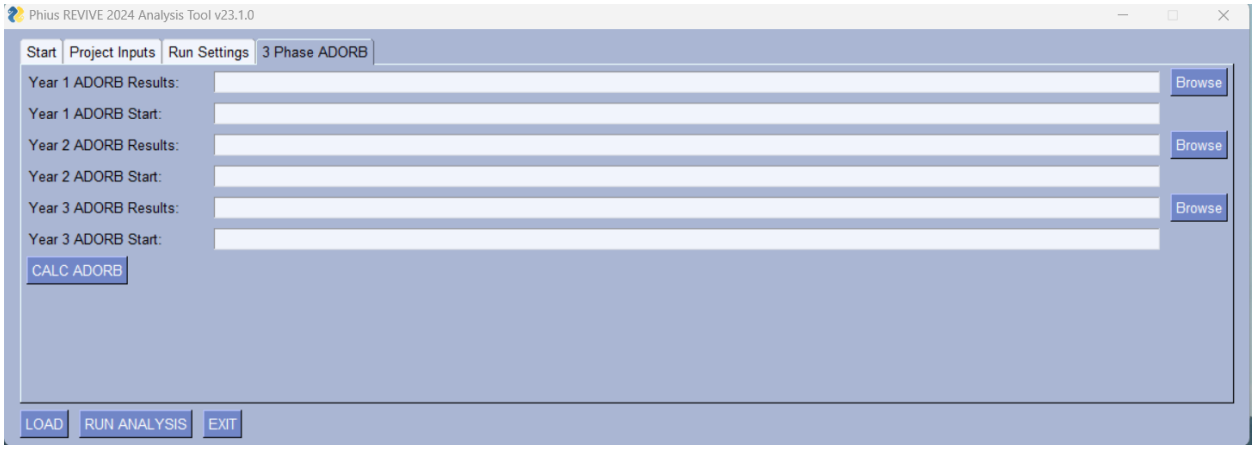
Definition of inputs:

- **Generate PDF?:** This beta feature will develop a PDF output with the graphs for the case included, as well as some additional information. This setting requires a Latex compiler to be installed, please see the Github Release for more information about this dependency. The default input is unchecked.
- **Delete Unnecessary Files:** Check this box to remove the files associated with EnergyPlus and the Latex PDF processing that are not needed for the end user. Default is checked.

The **3 Phase ADORB** tab is designed to support a phased project, where there are different states of completion the project will reach over the years. This tab will stitch together the yearly ADORB calculation results from the simulation and calculated an ADORB Cost for a 3 phase retrofit. A popup window will appear with the final result.

Definition of inputs:

- **Year X ADORB Results:** Path to the **XXXX_ADORBresults.csv** output of the tool. Select them in sequential order for the retrofit phases.
- **Year X ADORB Start:** Input the year in which the case starts. The first input should be 1, and the other two in sequential order, for example 5 and 10 for a retrofit that case a second phase in year 5 and third phase in year 10.



U.2 - Run List Input Description

The primary input for the tool is the **Run List.** This .csv file contains all of the information needed to apply the design parameters to the geometry model and run the analysis, aside from the information contained in the databases. That being said, there are many inputs in the **Run List** that reference the database inputs, and congruence in naming conventions and formatting is critical. It is best practice to keep a copy of these inputs in a standard Excel workbook and copy those into the .csv version of the **Run List** as needed. This way colors, formatting and any formulas are saved in a working version, and the inputs can be easily copied into a .csv file for the software to read. All inputs are case and format sensitive.

Definition of inputs:

- **CASE_NAME:** A unique text name for the case being run. If the case name contains 'BASE' in it, it will be considered a baseline case and will be used to compare against the other ADORB results in a bar graph. It is best practice to not include any spaces in the **CASE_NAME**, but rather use underscores, dashes, or camel lettering to differentiate words.

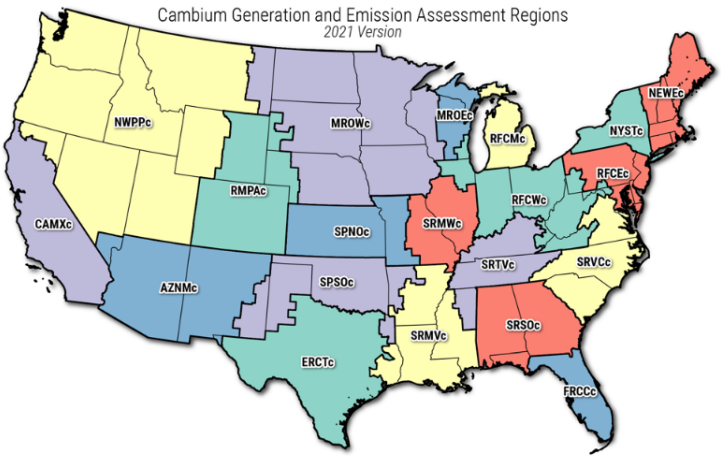


Figure 6. Cambium's generation and emission assessment (GEA) regions

- **EPW:** Provide the name of the .epw file for the case. These must be located in Databases/Weather Data/. EPW files are the EnergyPlus weather format. Example input: 'USA_TX_El.Paso.Intl.AP.722700_TMY3.epw'
- **DDY:** Provide the name of the .ddy file for the case. These must be located in Databases/Weather Data/. These are the EnergyPlus sizing weather data. When downloaded from the internet, most of these files will have 18 design days, adding runtime to the simulation. Phius recommends and supplies .ddy files with four sizing days, a 99.6%, 99%, 1%, and 0.4%. Example input: 'USA_TX_El.Paso.Intl.AP.722700_TMY3.ddy'
- **ELEC_PRICE_[$/kWh]:** Input the local marginal electrical price in dollars per kilowatt hour.
- **GAS_PRICE_[$/THERM]:** Input the local natural gas or propane price in dollars per Therm.
- **GRID_REGION:** Input the identifier for the grid region to be used in the hour operational emissions calculation. Please reference the Cambium map to confirm your grid region.
- **MorphFactors:** The four morphing factors will make the extreme period of the weather file during the outage shift to historic extremes. Use excel calculator to determine

morphing factors for the selected climate.
    - **MorphFactorDB1**
    - **MorphFactorDP1**
    - **MorphFactorDB2**
    - **MorphFactorDP2**
- **ICFA:** Input the total ICFA of the simulated zone in square feet.
- **NATURAL_GAS:** Boolean input as to whether or not natural gas is present in the case.
-

Informative Appendix V – V&T Provider Credentials

Any of the following credentials might suffice for V&T providers (aligns with Energy Star credentials list).

Licensed Professional Mechanical Engineer

Representative of the Original Equipment Manufacturer

EPA Energy Star Credentialed HVAC Contractor

AABC Commissioning Group (ACG)
- Certified Commissioning Authority (CxA)
- Certified Commissioning Technician (CxT)

ASHRAE
- Building Commissioning Professional (BCxP, formerly the Commissioning Process Management Professional (CPMP))

Association of Energy Engineers (AEE)
- Certified Building Commissioning Processional (CBCP)
- Existing Building Commissioning Professional

Building Commissioning Certification Board
- Certified Commissioning Professional

National Comfort Institute (NCI)
- Refrigerant Side Performance and: an Air-Side Certification or National Balancing Council Large Commercial Balancing Certification

National Environmental Balancing Bureau (NEBB)
- Building System Commissioning Certified Professional (BSC BP)
- Building System Commissioning Certified Technician (BSC CxCT)
- Commissioning Process Professional (CxPP)

University of Wisconsin (UW)
- Qualified Commissioning Process Provider (QCxP)
- Commissioning Process Authority Professional (CxAP)
- Commissioning Process Manager (CxM)
- Commissioning Process Technical Service Provider (CxTS)
- Green Commissioning Process Provider (GCxP)

Informative Appendix W – Wind retrofit structural code compliance checks

FEMA P-804, Second Edition, Table 7: Building Code Compliance Checks

Note: SI means Substantial Improvement, SD means Substantial Damage, as defined by the I-codes and the National Flood Insurance Program (NFIP).

Code Check	2021 IEBC[1]	7th Edition 2020 FBC: Existing[2]	Comments
Flood Hazard Areas	104.2.1, 401.3, 405.2.6, 502.3, 503.2, 701.3, 1103.3, 1301.3.3: Where work constitutes SI/SD, the building shall comply with flood-resistant requirements for new construction.	401.3, 406.2.4, 502.2,503.2, 701.3, 1103.5, 1401.3.3: Where work constitutes SI/SD, the building shall comply with flood-resistant requirements for new construction	SI/SD is a minimum requirement of floodplain management ordinances in communities that participate in the NFIP, regardless of whether a building code is adopted. All Mitigation Packages: Applicable if done simultaneously with SI/SD and located in a flood hazard area.
Existing Structural Elements Carrying Gravity Load	503.3: Any existing gravity load-carrying structural element, for which an alteration causes an increase in design load of more than 5%, shall be strengthened, supplemented, replaced, or otherwise altered to carry the increased load.	807.4: “Alterations shall not reduce the capacity of existing gravity load-carrying structural elements unless the elements demonstrate the capacity to carry the applicable design gravity loads required by the Florida Building Code, Building. Existing structural elements supporting any additional gravity loads as a result of the alterations, including the effects of snow drift, shall comply with the Florida Building Code, Building. Exceptions: 1. Structural elements whose stress is not increased by more than 5 percent. 2. Buildings of Group R occupancy with not more than five dwelling or sleeping units used solely for residential purposes where the existing building and its alteration comply with the conventional light-frame construction methods of the Florida Building Code,	Basic Mitigation Package: New roof covering may weigh more than the previous roof covering (or greater than 5% of the previous in the case of the FBC). IEBC: Existing load-carrying structural elements should not require strengthening to carry increased gravity loads from retrofits. FBC: Selection of a roof covering product less than 5% heavier than the existing roof

		Building or the provisions of the Florida Building Code, Residential."	covering is recommended.

Code Check	2021 IEBC[1]	7th Edition 2020 FBC: Existing[2]	Comments
Wall Anchors for Concrete and Masonry Buildings	706.3.1: If re-roofing more than 25% of the roof area of an unreinforced masonry building in seismic design category D, E, or F, work shall include installation of wall anchors to resist IBC seismic forces.		Basic Mitigation Package: Applicable if re-roofing in an area that is both hurricane- and earthquake-prone (e.g., Charleston, SC) with concrete and masonry construction.
Voluntary Lateral-Force Resisting System Alterations	503.13: Structural alterations of existing and new structural elements intended to increase the lateral force-resisting strength need not be designed for the IBC forces if all the following conditions apply: the capacity of the existing system isn't reduced, new or relocated elements are detailed and connected to existing or new structural elements according to IBC for new construction, and the alteration doesn't create a structural irregularity per ASCE 7 or make a structural irregularity more severe.	807.6: "Structural alterations that are intended exclusively to improve the lateral force-resisting system and are not required by other sections of this code shall not be required to meet the requirements of Section 1609 or Section 1613 of the Florida Building Code, Building, provided that all of the following apply: 1. The capacity of existing structural systems to resist forces is not reduced. 2. New structural elements are detailed and connected to the existing or new structural elements as required by the Florida Building Code, Building for new construction. 3. New or relocated nonstructural elements are detailed and connected to existing or new structural elements as required by the Florida Building Code, Building for new construction. 4. The alterations do not create a structural irregularity as defined in ASCE 7 or make an existing structural irregularity more severe."	All Mitigation Packages: Applicable if wind retrofit project qualifies as a Level 2 alteration;[3] an engineer may be needed to conduct an analysis. Wind retrofit projects should not qualify as a Level 2 alteration unless additional work is being done to the house.

Code Check	2021 IEBC[1]	7th Edition 2020 FBC: Existing[2]	Comments
Structural Alterations	906.1: If a Level 3 alteration results, all structural elements of the lateral force-resisting system in the building shall comply with 906.2 (next row of this table). Additional structural provisions may apply to buildings based on seismic provisions of Section 906.		All Mitigation Packages: Applicable if the wind retrofit project results in a Level 3 alteration. Wind retrofit projects should not qualify as a Level 3 alteration unless additional work is being done to the house.
Level 3, Substantial Structural Alterations	906.2: For a Level 3 alteration where more than 30% of the total floor and roof areas of the building have been proposed to be involved in a structural alteration in a 1-year period, an analysis must show the altered building complies with the IBC for wind loading and reduced seismic forces.		All Mitigation Packages: Applicable if the wind retrofit project results in Level 3 alterations. Wind retrofit projects should not qualify as a Level 3 alteration unless additional work is being done to the house. NOTE: 30% of the total floor and roof area includes tributary areas to vertical load-carrying components.

Code Check	2021 IEBC[1]	7th Edition 2020 FBC: Existing[2]	Comments
Roof Diaphragm	706.3.2: Where roofing materials are removed from more than 50% of the roof diaphragm or if the building is located where the ultimate wind speed is greater than 130 mph, the integrity of the roof diaphragm shall be evaluated, and connections must be provided or replaced to meet IBC requirements. There is an exception for buildings that comply with the wind load provisions of ASCE 7-88 or later editions.	707.3.2: "Where the structural roof deck is removed from more than 30 percent of the structural diaphragm of a building or section of a building located where the ultimate design wind speed, Vult, determined in accordance with Figure 1609.3(1) of the Florida Building Code, Building, is greater than 115 mph (51 m/s), as defined in Section 1609 (the High-Velocity Hurricane Zone shall comply with Section 1620) of the Florida Building Code, Building, roof diaphragms, connections of the roof diaphragm to roof framing members, and roof-to-wall connections shall be evaluated for the wind loads specified in the Florida Building Code, Building, including wind uplift. If the diaphragms and connections in their current condition are not capable of resisting at least 75 percent of those wind loads, they shall be replaced or strengthened in accordance with the loads specified in the Florida Building Code, Building. Exception: This section does not apply to buildings permitted subject to the Florida Building Code."	Basic Mitigation Package: Applicable only if the house has "defective" roof sheathing, and, therefore, is not generally considered a good candidate for a retrofit project. Wind speed triggers differ for the IEBC and the FBC. IEBC: Provision applies only if roof structure and not roof covering is at least 50% replaced. This condition should not occur for eligible candidates. FBC: Provision applies when the roof deck is removed from more than 30% of the roof diaphragm. An exception may apply to some buildings based on permitting dates and applicable codes

Code Check	2021 IEBC[1]	7th Edition 2020 FBC: Existing[2]	Comments
Roof Covering		706.1.1: “Not more than 25 percent of the total roof area or roof section of any existing building or structure shall be repaired, replaced or recovered in any 12-month period unless the entire existing roofing system or roof section is replaced to conform to requirements of this code. Exception: If an existing roofing system or roof section was built, repaired, or replaced in compliance with the requirements of the 2007 Florida Building Code, or any subsequent editions of the Florida Building Code, and 25 percent or more of such roofing system or roof section is being repaired, replaced, or recovered, only the repaired, replaced, or recovered portion is required to be constructed in accordance with the Florida Building Code in effect, as applicable. Pursuant to s. 553.844(5), Florida Statutes, a local government may not adopt by ordinance an administrative or technical amendment to this exception.”	Basic Mitigation Package: Applicable when reroofing. The entire roof system and section must conform to the FBC when more than 25% of the roof covering is replaced within a 12-month period. Some exceptions apply to roof systems built to the 2007 or later editions of the FBC.

Code Check	2021 IEBC[1]	7th Edition 2020 FBC: Existing[2]	Comments
Roof-to-Wall Connections		706.8: “When a roof covering on an existing structure with a sawn lumber, wood plank or wood structural panel roof deck is removed and replaced on a building that is located in the wind-borne debris region as defined in the Florida Building Code, Building and that has an insured value of $300,000 or more or, if the building is uninsured or for which documentation of insured value is not presented, has a just valuation for the structure for purposes of ad valorem taxation of $300,000 or more: Roof to wall connections shall be improved as required by Section 706.8.1. Mandated retrofits of the roof-to-wall connection shall not be required beyond a 15 percent increase in the cost of reroofing. Exception: Structures permitted subject to the Florida Building Code are not required to comply with this section.” 706.8.1: “Where required by Section 706.8, the intersection of roof framing with the wall below shall provide sufficient resistance to meet the uplift loads specified in Table 706.8.1 either because of existing conditions or through retrofit measures. As an alternative to an engineered design, the prescriptive retrofit solutions provided in Sections 706.8.1.1 through 706.8.1.7 shall be accepted as meeting the mandated roof-to-wall retrofit requirements. Exceptions: Where it can be demonstrated (by code adoption date documentation and permit issuance date) that roof-to-wall connections and/or roof-to-foundation continuous load path requirements were required at	Basic Mitigation Package: These provisions are applicable when reroofing a house unless the gable-end work costs less than 15% of the roof replacement work. There may be an exception applicable to the building based on the permitting date and the applicable code adoption date. If these provisions are triggered, some roof-towall connections may have to be installed, even for the Basic Mitigation Package.

		the time of original construction. Roof-to-wall connections shall not be required unless evaluation and installation of connections at gable ends or all corners can be completed for 15 percent of the cost of roof replacement.”	

[1] The IBC states that there is an alternative compliance with the IEBC in place of the IBC for existing structures (any retrofit projects would fall into this category). Most of the provisions of the IBC are similar to the IEBC, but the IBC is not as stringent in its requirements.
[2] 7th Edition 2020 FBC: Existing Building – Additionally, Chapter 17 – Retrofitting should also be consulted during wind retrofits.
[3] Levels of alteration correspond to the three levels defined in the IEBC, IBC, and FBC: Existing Building