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Engineering and Design
Design Requirements for Energy and Water Optimization

FOR THE COMMANDER:

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Purpose. This regulation provides direction and guidance for energy and water optimization, including the application of energy modeling and Life Cycle Cost Analysis, in design decisions and alternative analyses for buildings.

Applicability. All vertical (building) construction projects and programs when the United States Army Corps of Engineers is the design agent.

Distribution statement. Approved for public release; distribution is unlimited.

Proponent and exception authority. The proponent of this regulation is the Headquarters, United States Army Corps of Engineers, Engineering and Construction Division. The proponent has the authority to approve exceptions or waivers to this regulation that are consistent with controlling law and regulations. Only the proponent of a publication or form may modify it by officially revising or rescinding it.

*This regulation supersedes ER 1110-1-8173, dated 30 December 2017.

Summary of Change

ER 1110-1-8173
Design Requirements for Energy and Water Optimization

This major revision, dated 15 April 2025:

- Changes the title from Energy Modeling and Life Cycle Cost Analysis to Energy and Water Optimization.
- Accommodates future policy changes by generically addressing expectations and requirements for energy optimization, modeling, and life cycle cost analyses.
- Relates applicability to Unified Facilities Criteria 1-200-02 compliance tracking and reporting requirements.
- Expands applicability guidance for Civil Works and Interagency and International Services programs.
- Revises requirements and considerations for energy optimization and life cycle cost analysis processes.
- Provides a proposed methodology for optimization energy modeling and best practices for life-cycle cost analyses.
- Updates the list of references.

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Glossary of Terms

1. Purpose

This regulation provides direction and guidance for energy and water optimization, including the application of energy modeling and Life Cycle Cost Analysis (LCCA), in design decisions and alternative analyses for buildings.

2. Distribution statement

Approved for public release; distribution is unlimited.

3. References

See Appendix A.

4. Records management (recordkeeping) requirements

The records management requirement for all record numbers, associated forms, and reports required by this publication are addressed in the Army Records Retention Schedule. Detailed information for all related record numbers is located on the U.S. Army Corps of Engineers (USACE) Records Management Site https://usace.dps.mil/sites/INTRA-CIOG6/SitePages/Records-Management.aspx. If any record numbers, forms, and reports are not current, addressed, and/or published correctly, see DA Pam 25-403 for guidance.

5. Associated publications

This section contains no entries.

6. Applicability

a. This Engineer Regulation (ER) applies to all vertical (building) construction projects and programs when the USACE is the design agent. Energy modeling and LCCA (for both optimization and compliance modeling), including alternative water analysis, is required when projects meet the threshold for High Performance and Sustainable Building (HPSB) Guiding Principles Compliance Tracking and Reporting outlined in Unified Facilities Criteria (UFC) 1-200-02. Energy modeling and LCCA also apply to existing building large capital energy investments which are characterized in footnotes to Table 1-1 in UFC 1-200-02, Building Requirements and Thresholds.

b. Below thresholds, projects must comply with the building energy code defined by 10 CFR 433 or 10 CFR 435 to the extent applicable to the scope of the project and perform the energy modeling and LCCA required by UFC 1-200-02 for on-site renewable energy, solar domestic hot water, and alternative water systems. This ER also applies to Energy Resilience and Conservation Investment Program (ERCIP) projects to the extent practicable based on project scope. The following list elaborates on the requirements for specific programs:

(1) Department of Defense (DoD) projects are required to comply with UFC 1-200-02 and any applicable amendments, updates, revisions, or successors, to its criteria, to include any applicable Executive Orders.

(2) Civil Works projects, including rehabilitation or renovation projects, are required to meet federal high performance building requirements, and the Civil Works policy (USACE 2014) requires compliance through UFC 1-200-02. The Civil Works program includes industrial facilities. Some may have limited opportunity for energy or water reduction, and some may meet the definition of an unoccupied building per UFC 1-200-02. Additionally, the following Civil Works facilities do not require energy modeling and LCCA but must minimally comply with American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1:

(a) Storage buildings.

(b) Warehouses.

(c) Pole buildings.

(d) Outbuildings.

(e) Comfort stations.

(3) Vertical construction projects in the Interagency and International Services (IIS) program must also meet federal high performance building requirements (Energy Policy Act of 2005, 10 CFR 433, and 10 CFR 435). This ER applies to the IIS program. In the event of a conflict with the guidance of a particular agency, comply with the agency guidance.

7. Project development and delivery

This ER stresses adherence to the policies referenced in this document regarding energy and water efficient and resilient design. This ER also reinforces the steps necessary to comply with energy requirements, including the associated documentation, by setting forth the following common approach:

a. *Optimization – New and existing buildings* (regardless of funding source).

(1) Optimization determines the combination of siting, orientation, massing, building features, and systems that will provide the energy and water performance required by policy and regulations while meeting the associated requirements for life cycle cost (LCC) effectiveness. LCCA is required by 10 CFR 433 and 10 CFR 435. Methodology for LCCA is in 10 CFR 436. Modeling and analyses are based on conceptual design information. Success starts at inception, which means success begins at planning and programming.

(2) During concept or preliminary design phases (30 – 35% design phase), the Project Delivery Team (PDT) must determine the building orientation; massing;

envelope; lighting; resiliency features; heating, ventilation, and air conditioning (HVAC) systems; service water-heating systems; renewable energy systems; and alternative water systems. Project Managers are responsible for establishing an integrated team.

(3) The building site selection impacts opportunities for energy and water optimization. Examples include impacts to building orientation and massing or space for renewable energy or alternative water systems. The PDT should partner with stakeholders during project planning and site selection processes to the extent possible.

(4) The PDT must employ integrated design principles and have representation from all applicable design disciplines as well as owner and operator representatives (for example, the Directorate of Public Works, Base Civil Engineer, the Installation Energy Manager, the building tenant(s), utility representatives, and others) to identify opportunities to improve building performance and increase savings potential.

(5) The PDT must use a whole-building energy simulation program to facilitate building optimization (for example, EnergyPlus or a commercial off-the-shelf [COTS] product). LCCAs must use a National Institute of Standards and Technology (NIST) Handbook 135-compliant software. UFC 1-200-02 requires LCCAs to be performed using Building Life Cycle Cost (BLCC). BLCC is available via https://www.energy.gov/eere/femp/building-life-cycle-cost-programs.

(6) The PDT applies optimization to renovations of existing buildings based on the scope of the project. The team also evaluates the affected systems for optimization. The opportunity to optimize may be limited for existing buildings since the renovation scope may be narrow (for example, a project may consist only of replacing a building lighting system or repair by replacement). If the building is undergoing a full facility renovation, then multiple systems are affected that must be optimized.

(7) Perform the energy and water optimization according to paragraph 8. Refer to Appendix B for best practices and resources.

b. Compliance modeling – New and existing buildings (regardless of funding source).

(1) The PDT uses compliance modeling to evaluate how well the proposed final design meets or exceeds energy and water conservation goals according to applicable policies and regulations, including third-party certification (TPC) requirements.

(2) The PDT develops compliance models based on the standards required in applicable policies and regulations. If project scope changes during design result in a significant impact to building energy performance (defined as 30% or greater energy cost savings), update the optimization LCCA and the design (including building envelope, lighting, HVAC, etc.) to achieve the required performance.

(3) Additionally, if the project exceeds the thresholds established in UFC 1-200-02 for TPC, then compliance modeling must be executed according to the TPC requirements.

(4) For Army and USACE Civil Works projects only, comply with the P2 Sustainability Reporting requirements in the Army Sustainability Implementation Guide. Similar reporting methods are encouraged for all other agency and stakeholder projects.

c. *Design-build* (regardless of funding source).

(1) The PDT must complete an energy optimization model and LCCA prior to advertisement. If the project requires a DD Form 1391 (FY_Military Construction Project Data) (DD Form 1391), the PDT must perform the optimization and LCCA prior to budget lock. The level of detail of the energy model must correspond with the level of detail in the design-build request for proposal. The resulting system and feature selections must be incorporated as requirements into the design-build request for proposal.

(2) Design-build selection criteria must require that betterments provided by the offeror that significantly affect energy efficiency be supported by an LCCA. Acceptance of such betterments must consider the life-cycle cost.

(3) Do not include LCCAs with the request for proposal. The files used in developing the LCCA can be shared with a contractor post-award, if requested.

(4) If the results of the optimization indicate the project will not meet policy and criteria, the PDT must obtain the necessary waiver(s) or exemption(s) prior to advertisement.

d. *Third-party certification*. Follow compliance energy modeling rules for the TPC system required by applicable policy, including interpretations and exceptions granted to the Government. Due to potential differences in energy modeling rules, two models may be necessary: one to show compliance with the requirements of applicable policy and regulations, and one to achieve certification in the TPC system.

e. *Quality management*. Incorporate quality management into the optimization according to ER 1165-2-217 for Civil Works projects or ER 1110-3-12 for all other projects. Include the statements outlined below as part of any required review documentation (including Biddability, Constructability, Operability, Environmental, and Sustainability (BCOES) reviews).

(1) *Proposed alternatives.* District architects and engineering subject matter experts (SMEs) must review and approve alternatives proposed for analysis before the optimization is started to confirm a sufficient number and variety of alternatives are analyzed for the project and that alternatives that are not acceptable are not included. Include a statement in the project design analysis, signed by the SME(s), that the proposed alternatives have been reviewed and approved.

(2) *Energy Optimization and LCCA Report.* The analysis results are used to establish features/systems for the project; therefore, District SMEs will review the submitted Energy Optimization and LCCA Report to ensure compliance with requirements prior to design progression. The District SMEs then sign and include a

statement in the project design analysis that the submittal has been reviewed for compliance with requirements.

8. Requirements of the energy and water optimization process

Energy and water optimization is the process of determining the combination of building systems and features that meet required performance levels in an economical way that minimizes total ownership costs. The specific energy performance, water performance, and economic requirements vary based on which regulations, policies, codes, and standards apply to the project. In one case, the requirement may be to meet a minimum performance level in the most economical way. In another case, the requirement may be to achieve the highest performance level possible without increasing total cost of ownership beyond a baseline metric. Regardless, the intent is to balance consideration of energy efficiency, utility costs, initial costs, and operation and maintenance (O&M) costs.

a. General.

(1) There may be instances where the PDT must accommodate multiple applicable requirements. For example, if policy requires using a TPC system, then that TPC system may require higher performance goals than those prescribed by regulation. The different requirements and goals influence the methodology used to optimize the design; however, some considerations and documentation requirements are common to any of the appropriate methodologies.

(2) Energy and water optimization must be completed early in the planning and design process prior to the prescribed milestones for the project according to design directives, instructions, and UFC 1-200-02. The analyses will be based on the best information available at the time the optimization is performed.

(3) Optimizations, or parts thereof, from previous projects may be reused if the building, climate, utility rates, costs, occupancy, and usage are sufficiently similar. Sensitivity analyses from past analyses may be used to determine the extent of change in the parameters that warrant an update. Where initial costs, O&M costs, and utility costs have changed by more than 10% since the previous analysis, update the associated data for the analysis. An example of this is when a new Company Operations Facility is being planned for an installation. If a compliant optimization analysis was performed for a previous Company Operations Facility in the prior year, then the results of the previous analysis may be used unless there were major changes in costs. Using previous analyses must be documented, and the previous analyses must be available in the project files.

(4) Any changes to the project scope (beyond completion of the project design milestone associated with the optimization) that impact energy cost (greater than 30% of building's total annual energy cost) or project construction cost (more than 30% of programmed amount) require an update to the energy optimization for the project.

b. Optimization energy model.

(1) The optimization energy model helps the PDT determine which building configurations, features, and systems will achieve the energy and water performance requirements while considering life-cycle cost according to applicable regulation and policy. The modeling occurs at a conceptual design stage with limited details available and should reflect anticipated operation to the maximum extent practical. The optimization energy models will be simpler than compliance energy models. While complying with the rules for energy modeling in governing standards to the extent practical, the optimization energy model may use simplifying assumptions and techniques. The emphasis is not on strict adherence to the standard energy modeling rules.

(2) In contrast, compliance energy modeling demonstrates full compliance with regulations and policies and must strictly adhere to the governing standards. The results from compliance energy modeling are used to report the energy performance of the project (for example, percent energy consumption or cost reduction from baseline).

c. Project team.

(1) The project Technical Lead is responsible for ensuring the energy and water optimization is performed and fully documented.

(2) The PDT, including the architect and the mechanical, electrical, and cost engineers, must employ integrated design principles according to UFC 1-200-02.

(3) One PDT member must take the lead in performing the optimization. This lead must understand and have experience in applying the optimization requirements and processes, including the individual analyses (energy modeling and LCCA).

(4) Comply with the integrated design requirements in UFC 1-200-02. The full PDT, including stakeholder representatives, participates in identifying systems and features to include in the optimization and in determining the design alternative selected for implementation. The Project Manager is responsible for establishing an integrated PDT.

d. Design alternatives.

(1) Analyze at least three feasible and substantially different whole-building, integrated design alternatives to determine the optimum energy and water performance strategy.

(2) Perform individual component or system analyses when necessary to support the optimization methodology.

(3) Exercise good engineering judgment and use past experience in identifying the best alternatives for analysis. Give preference to systems and features with lower complexity and maintenance burdens, when possible.

(4) Do not include alternatives when it is clear, prior to LCCA, that the cost exceeds the potential savings based on historic information or engineering judgment. Historic information includes, but is not limited to, prior analyses at the same installation, for a similar building, with similar cost data (for example, utility costs); analyses performed by a Center of Standardization design if applicable to the installation/climate zone in which the design will be built; and analyses for system types that have been demonstrated to not be cost effective at the location (for example, solar hot water). Where such alternatives were considered but not analyzed, identify those alternatives and provide rationale for not including them.

(5) Include justification in the documentation where there are fewer than three feasible alternatives for the project. Document all alternatives considered, including those not analyzed and the reason they were not analyzed.

(6) Note that some stakeholders, such as military installations, have preferred systems or systems that they prohibit. Such preferences do not supersede UFCs, regulations, and/or policies of the stakeholder agency (examples: DoD or Army policies).

(7) Obtain an exemption or waiver from the appropriate stakeholder agency or Authority Having Jurisdiction when design requirements deviate from energy and water optimization requirements. Deviations from UFCs require an exemption or waiver from the cognizant Engineering Senior Executive Panel member.

(8) Alternative designs must comply with all applicable regulations, policies, codes, and standards. As an example, when a dedicated outdoor air system (DOAS) is required based on a UFC for a specific service component within the Department of Defense, every design alternative must include a DOAS.

(9) All alternative designs must be feasible. For an alternative to be considered feasible, it must meet the following criteria at a minimum:

(a) Achieve project functional requirements.

(b) Achieve project thermal comfort, indoor environmental quality, and ventilation requirements.

(c) Be reliable, locally serviceable, and safe.

(d) Not degrade overall building performance.

(10) Analyze an additional alternative if the optimization is performed before determining that one of the three required alternatives is infeasible.

(11) Where a project requires a DD Form 1391 and a line item requires a particular feature or system, include such feature or system in each of the whole-building design alternatives and must be included in the design. For example, if photovoltaics appear as a discrete line item on the DD Form 1391, then the photovoltaic system has been

programmed, must be included, and does not require the PDT to perform a separate LCCA of the photovoltaic system. The photovoltaic system is a part of each whole-building design alternative.

e. *Baselines*.

(1) Typically, as with 10 CFR 433, 10 CFR 435, and UFC 1-200-02, energy performance is determined relative to a baseline. In such cases, a performance baseline must be added to the analysis (in addition to the three alternatives).

(2) An economic baseline must be added to the analysis when applicable policy and regulations require comparing alternative life-cycle costs to the life-cycle cost of an established baseline. The economic baseline is based on the same design as the performance baseline.

(3) Baselines conform to the specific requirements of the regulation, policy, code, or standard applicable to the optimization. For example, projects that must use ASHRAE Standard 90.1 use a baseline that complies with the instructions in ASHRAE Standard 90.1 and the applicable regulations. Baselines are not required to comply with the other regulations, policies, codes, and standards that apply to the design and construction requirements for the project. For example, for a project that uses ASHRAE Standard 90.1, when a DOAS is required for the design/construction for a project based on UFC 3-410-01, the baseline would not include a DOAS unless the Performance Rating Method requirements specifically require such.

(4) The method for existing buildings varies based on the type of project. For example, if a project consists of improving an existing building's envelope systems, the LCCA baseline building's envelope should match the existing envelope to determine the cost effectiveness of improvements.

(5) HVAC replacement/improvement projects that do not involve modifying any other building system:

(a) The LCCA baseline building's HVAC system should be the existing system; the other systems can be modeled using the as-built conditions, or the ASHRAE Standard 90.1 minimally-compliant systems and components, since the comparison is focused on the relative energy performance of different HVAC systems. In other words, model the building envelope, fenestration, lighting, etc., to match the existing conditions (U-values, solar heat gain factors, luminaire types and power densities, etc.).

(b) Alternatively, the ASHRAE Standard 90.1 minimally-compliant systems can be used. For example, if the existing envelope is masonry, use the ASHRAE Standard 90.1 masonry wall type in the analysis; use the lighting power densities specified in the standard based on the space type; etc. Similar logic must be applied when using International Code Council, International Energy Conservation Code (IECC).

f. Selection and sensitivity.

(1) Select the design systems and features for the project based on the optimization to comply with the related regulations, policies, codes, and standards. The required energy and water performance and economic requirements must be met.

(2) Provide justification when sensitivity analyses or non-quantitative considerations (such as mission or resiliency requirements or non-quantified O&M considerations) impact alternative selection. For example, if considering two alternatives for which a sensitivity analysis shows that the differences in performance or costs are well within potential error of the optimization analysis, then the alternative with the lower performance or higher costs may be selected with a suitable justification.

g. Economic comparisons.

(1) The economic requirements associated with optimization can be confusing depending on the regulation, policy, or code that applies. Sometimes meeting a specified performance is required "if LCC effective." In other cases, achieving the "most or best performance that is LCC effective" is required. Still another requirement is to achieve a specified performance "in the Most LCC effective manner." Different regulations, service component policies, and TPC systems may have different requirements. Each of these is a different goal and influences the optimization methodology and system and feature selection differently.

(2) "If LCC Effective": When a specified performance is required "if LCC effective," it requires a comparison of alternative LCC to the specified baseline LCC. In this case, if achieving the specified performance is NOT LCC effective relative to the baseline, that specified performance is NOT required. As an example, 10 CFR 433 requires that a 30% energy reduction be achieved if LCC effective. If all the alternatives that meet the 30% energy reduction are not LCC effective, then 30% energy reduction is not required.

(3) "Most or Best Performance that is LCC Effective": When the requirement is to achieve the most or best performance that is LCC Effective, a comparison of alternative LCC to the specified baseline LCC is required. Of the set of strategies that are LCC effective relative to the baseline, the one with the best performance is the required alternative. As an example, 10 CFR 433 requires achieving the highest energy reduction that is LCC effective (if 30% is not LCC effective). In a project, of the three alternatives, two are LCC effective and one is not. Of the two LCC-effective alternatives, the one with the highest energy reduction sets the energy performance requirement.

(4) "In the Most LCC-Effective Manner": When the requirement is to achieve specified performance in the most LCC-effective manner, a specified baseline for LCC is not required. However, a performance baseline may be required solely to establish a performance target. The LCC of the alternatives are compared only to each other. As an example, a project may need 15% energy reduction to achieve some required number of points in a TPC system and do so in the most LCC-effective manner. In this case, a baseline energy performance is determined, but an LCC for the baseline is not

necessary. Of the three alternatives developed to achieve the 15% energy reduction, the one with the lowest LCC is required.

(5) It is common for more than one of these goals to apply to a project at the same time. In such cases, all the goals must be satisfied by the methodology and the selected design.

9. Documentation requirements

Documentation must be detailed enough to provide sufficient information for the analysis to be auditable or repeatable by a third party.

a. Energy optimization and LCCA report. At a minimum, the document must include the following, to the extent applicable.

(1) Narrative.

(a) Identify applicable criteria.

(b) Document any exemptions approved by higher headquarters.

(c) Identify the proposed design resulting from the analysis and include thorough descriptions of processes/reasoning for selection. If the alternative selected does not comply with the requirements for performance and life-cycle cost, provide justification (maintainability, initial cost, etc.).

(d) Provide a summary description of each analyzed alternative, including assumptions and references used to determine each parameter. Include a summary of the baseline.

(e) List any alternatives considered but not selected for analysis and the associated reasoning. Include descriptions of installation/stakeholder preferences and restrictions or DD Form 1391 requirements, if applicable, that influenced alternative selection.

(f) Provide a table comparing alternatives that shows initial cost, annual energy consumption, annual energy cost, maintenance/replacement costs, other operating costs (if applicable), salvage/residual costs, and present-value life-cycle cost.

(g) Provide a table comparing alternatives for each feature/system (wall-to-wall, roof-to-roof, HVAC-to-HVAC) if component/system level analyses were performed while developing whole-building analyses. Provide the same information for renewable energy, waste heat recovery, and alternative water system analyses.

(h) Describe sensitivity analysis results and any impact on selection for proposed design.

(i) Identify software used for energy modeling and LCCA, including the vendor and version.

(j) Identify information sources for initial costs, maintenance/removal costs, service life, residual/salvage value, energy/water utility data, and the others.

(k) List utility rate data and explain how utility rate structure was applied.

(l) Confirm/identify source of discount and escalation rates for the LCCA.

(m) Include a statement, signed by the reviewing SME(s), that alternatives proposed for analysis were reviewed and approved prior to beginning LCCA.

(2) Analysis documentation.

(a) Provide cost analysis for initial costs and maintenance/operational costs.

(b) Provide input/output reports from software (BLCC) for the LCCA for each whole-building alternative. If component/system level analyses were performed to support the whole-building analyses, include the input/output reports for each component/system.

(c) Provide input/output reports from energy modeling software for each alternative included in the LCCA.

(d) Bookmark locations in the electronic submission (PDF) for energy analysis, cost analysis, and LCCA separately. Subdivide by alternative/baseline and bookmark so the reviewer can quickly find the modeling, cost, or LCCA information relevant to a particular alternative or the baseline.

b. Energy Compliance Analysis. Refer to Energy Compliance Analysis (ECA) and ECA narrative requirements in UFC 1-200-02. The Energy Optimization and LCCA Report is a separable component of the ECA. The balance of the ECA includes the compliance modeling documentation and reflects the final design of the project. At a minimum, the document must include the following.

(1) Narrative.

(a) List the energy and water efficiency and resiliency criteria that applies to the project.

(b) Identify the software used for the compliance energy model, including the vendor and version.

(c) Describe each energy efficiency and resiliency feature and strategy for the project.

(2) Analysis documentation.

(a) Provide the performance calculation to show compliance with the applicable regulations and policy. Example: For 10 CFR 433 and UFC 1-200-02 compliance,

calculate the percentage energy cost reduction based on energy modeling software outputs.

(b) Provide a completed compliance form for the applicable energy standard (for example, ASHRAE Standard 90.1 or IECC)

(c) Include a chart demonstrating, for the as-designed building, the annual energy consumption and cost attributed to each energy end use including, but not limited to, lighting, space cooling, space heating, ventilation, receptacle/process loads, and service water heating.

(d) Provide a report showing, for the as-designed building, the monthly fuel consumption for 12 consecutive months (electricity, natural gas, propane, etc.)

(e) Provide the input/output reports from the energy modeling software for the building as designed (proposed building performance) and the baseline. Include inputs/outputs for all spaces, systems, plants, and schedules. Include reports showing how ventilation was handled in the simulation.

(f) Provide calculations and explanations for any applied exceptional calculation methods performed.

(g) Include any additional documentation necessary to achieve TPC as required by applicable regulations or policy.

Appendix A
References

Section I

Required Publications

Unless otherwise indicated, Code of Federal Regulations (CFR) publications are available at https://www.ecfr.gov. Army publications are available at https://armypubs.army.mil/. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards are available at http://www.wbdg.org/ffc/dod/non-government-standards. USACE publications are available at https://www.publications.usace.army.mil.

10 CFR 433
Code of Federal Regulations Title 10 Part 433, Energy Efficiency Standards for the Design and Construction of New Federal Commercial and Multi-Family High-Rise Residential Buildings

10 CFR 435
Code of Federal Regulations Title 10 Part 435, Energy Efficiency Standards for the Design and Construction of New Federal Low-Rise Residential Buildings

10 CFR 436
Code of Federal Regulations Title 10 Part 436, Subpart A Methodology and Procedures for Life Cycle Cost Analyses

AR 420-1
Army Facilities Management

Army Sustainability Implementation Guide
(Available at https://rfpwizard.mrsi.erdc.dren.mil/MRSI/content/sustain/Library/Policy%20and%20Guidance/Army%20Sustainability%20Implementation%20Guide.pdf)

ASHRAE Standard 90.1
Energy Standards for Buildings Except Low-Rise Residential Buildings

ASHRAE Standard 209
Energy Simulation Aided Design for Buildings Except Low-Rise Residential Buildings

DA PAM 25-403
Army Guide to Recordkeeping

Energy Policy Act of 2005
Public Law 109-58. 2005. *Energy Policy Act of 2005*. (Available at https://www.gpo.gov/fdsys/pkg/PLAW-109publ58/pdf/PLAW-109publ58.pdf)

ER 1110-3-12
Quality Management

ER 1165-2-217
Civil Works Review Policy, Water Resource Policies and Authorities

International Code Council, International Energy Conservation Code (IECC)
(Available at https://codes.iccsafe.org/)

National Institute of Standards and Technology (NIST) Handbook 135
Life-Cycle Costing Manual for the Federal Energy Management Program. (Available at https://www.wbdg.org/nist/criteria/nist-handbook-135)

Unified Facilities Criteria (UFC) 1-200-02
High Performance and Sustainable Building Requirements. (Available at https://www.wbdg.org/dod/ufc/ufc-1-200-02)

UFC 3-410-01
Heating, Ventilating, and Air Conditioning Systems. (Available at https://www.wbdg.org/dod/ufc/ufc-3-410-01)

USACE 2014
"Sustainable Buildings Policy for Civil Works and United States Army Corps of Engineers (USACE)-Owned and In-leased Buildings." USACE Memorandum. October 2014. (Available under Policy and Guidance at https://mrsi.erdc.dren.mil/sustain/)

Section II

Prescribed Forms

DD Form 1391 FY__ Military Construction Project Data
Processor System

Appendix B
Optimization Modeling Process and Life Cycle Cost Analysis Best Practices

B–1. Optimization modeling process

The process described in this appendix is not mandatory; it simply aids the project team in approaching optimization energy modeling.

a. ASHRAE Standard 209.

(1) ASHRAE Standard 209 provides a methodology to develop energy models from planning phase through project completion to make design decisions using “design modeling cycles.” ASHRAE has granted permission to include some of the standard in this document, including Informative Appendix C Simple Box Modeling in its entirely (Figure B–1). However, using direct quotes or modified content from ASHRAE 209 does not constitute endorsement by ASHRAE nor does ASHRAE waive any copyright protection or other rights entitled by its intellectual property.

(2) References in this appendix to a “baseline” is defined in ASHRAE Standard 209 as, “the building design or level of energy performance used as the basis of comparison against other project alternatives, usually based on a hypothetical design defined by building standards or based on the currently proposed building design at the time of modeling cycle analysis.” For this analysis, the baseline is a facility that meets the requirements of the applicable model energy code.

b. Modeling cycles.

(1) The following descriptions explain when and how the modeling cycles can be used in building systems optimization and provide a real-world example; however, use judgment regarding the necessity or practicality of a particular modeling cycle. To emphasize what is stated above, this appendix does not imply that the design team is required to perform these modeling cycles, but it does present a process that will help the design team succeed. The modeling cycles can succeed only with an integrated design team.

(2) The examples are oversimplified for clarity. Also, the “design modeling cycles” and their application to the planning, programming, and design phases should be used as an example and not as a rule. The example describes an ideal process and follows Army Military Construction (MILCON) design codes; however, the modeling cycles can be adapted to the type of project as needed.

(3) Referenced design codes are taken from AR 420-1 (refer to paragraph “Design directives” for definitions). Use engineering judgment in relating those definitions to Civil Works projects. For example, Design Codes 1 and 3 may relate best to the Feasibility Study phase of a Civil Works project while Design Codes 2 and 6 may be appropriate for the Preconstruction, Engineering and Design (PED) phase of the project.

c. *Simple box modeling* (Modeling Cycle #1).

(1) Ideally, execute this modeling cycle during programming and planning. This cycle should be applied as early as possible in the project to maximize the energy saved by optimizing the passive systems. The following language is taken from ASHRAE Standard 209.

(2) Identify the distribution of energy by end use. Evaluate energy end uses and demand characteristics that affect building conceptual design.

(3) Apply this modeling cycle before the building's geometry and site orientation have been set in the design process.

(4) Create energy models to calculate annual building energy by end use and peak heating and cooling loads with identical HVAC systems. Perform a sensitivity analysis by varying the following building characteristics:

(a) Building geometry.

(b) Window-to-wall ratio, by orientation, and shading options (if applicable).

(c) Orientation.

(d) Thermal performance of the envelope and structure.

d. *Design* (Modeling Cycle #2).

(1) Evaluate energy improvements that are tied to the form and architecture of the building.

(2) Apply this modeling cycle to projects where the form and architecture of the building are still subject to design changes before parametric design begins. This modeling cycle applies to buildings with internal equipment/process loads less than 75% of overall energy breakdown.

(3) Create energy models based on architectural conceptual designs to calculate annual building energy by end use and peak heating and cooling loads with identical HVAC systems.

(a) Perform comparative analyses of the conceptual designs.

(b) Provide recommendations to improve the energy performance of each conceptual design.

e. *Load reduction modeling* (Modeling Cycle #3).

(1) Perform the load reduction modeling during the Code 2 or Code 3 process. The following language is taken from ASHRAE Standard 209 with slight modifications.

(2) Identify the distribution of energy by end use. Evaluate strategies that will reduce annual energy use and heating and cooling peak loads.

(3) Complete this modeling cycle prior to the final selection of HVAC system type and prior to the end of the concept or preliminary design phase (30 – 35% design phase).

(4) Create an energy model based on the baseline design and calculate the annual energy end uses and heating and cooling peak loads. Develop a list of at least three peak load reduction strategies selected from one or more of the following categories:

(a) Building envelope (including, but not limited to, insulation level, window-to-wall ratio, glazing performance, shading, infiltration, phase change materials, and thermal mass).

(b) Lighting and daylighting.

(c) Internal equipment loads.

(d) Outdoor air (including, but not limited to, outdoor air flow, exhaust air, and energy recovery).

(e) Passive conditioning and natural ventilation.

(5) Select at least two of the strategies from the internal equipment loads category when internal equipment loads exceed 60% of the building energy end use.

(6) Use energy modeling to evaluate each load reduction strategy compared to the baseline design using identical HVAC system types.

f. *HVAC system selection modeling* (Modeling Cycle #4).

(1) Conduct this phase of the modeling before the end of the concept or preliminary design phase (30 – 35% design phase).

(2) Estimate the annual energy and demand impacts of HVAC system options.

(3) Apply this modeling cycle prior to HVAC system selection. When this modeling cycle is used to show compliance with the standard, start it after Modeling Cycle #3 is complete.

(4) Use energy modeling to evaluate a minimum of two alternate HVAC systems.

This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.

INFORMATIVE APPENDIX C
SIMPLE BOX MODELING

1. Create a *simple box model* using an energy *simulation program*. Some programs use preprocessor or expert ("wizard") systems to help create these models. The *simple box model* energy *simulation program* may use monthly design day hourly information (288 hour in lieu of 8760 hour simulation).
2. Initial input parameters
   - 2.1 Where design parameters are known, those should be used; otherwise, the following should be used to set input parameters.
   - 2.2 **Building type** (e.g., assembly, healthcare, hotel/motel, light manufacturing, office, restaurant, retail, school, warehouse, laboratory, etc.). The building type infers information about building program area allocations and locations (core or perimeter space) as well as occupancy and internal load information by program area.
   - 2.3 **Building form.** If the rough building form has not been otherwise prescribed, follow the parameters given in Table 13 of NREL/TP-5500-46861 "U.S. Department of Energy Commercial Reference Building Models of the National Building Stock." Aspect ratio is defined as the overall length in the east-west direction divided by the overall length in the north-south direction. If the building type is not one given in Table 13, and no other information is known, use a rectangle with an aspect ratio of 1.62, floor-to-floor height 12.5 ft (3.81 m), flat roof, glazing fraction 30%.
   - 2.4 **Site location by weather file location.** See Section 5.6 for types and sources of weather files.
   - 2.5 **Total conditioned square footage.** The accuracy of this parameter should be order of magnitude.
   - 2.6 **Number of floors, if known.** If not known, use the number of floors given in Table 13 of NREL/TP-5500-46861 referenced above. Unless known otherwise, each of multiple floors shall have the same footprint.
   - 2.7 **Fenestration amount.** Use Table 13 of NREL/TP-5500-46861 or the applicable local energy code or ASHRAE/IES Standard 90.1, Table G3.1.1-1, to define default WWR percent for various building types if actual WWR is not known. Allocate percent window-to-wall ratio, by orientation if known, evenly distributed if not.
   - 2.8 **Internal loads (people, equipment, and lighting).** If known, allocate by program area. If unknown, distribute evenly over the conditioned area. Lighting power densities should be the maximum allowed by applicable local energy code. If unknown, use applicable local energy code or Standard 90.1 User's Manual, Appendix G tables, for schedules, equipment power, and occupant densities. Additional information on internal loads and schedules may be found in NREL/TP-5500-46861 Appendices A and B.
   - 2.9 Ventilation shall be in accordance with applicable local building codes, ASHRAE Standard 62.1, outside air rate per occupant, or ASHRAE/ASHE Standard 170 air change rate by usage, whichever is largest.
   - 2.10 **Perimeter/core zoning.** Perimeter zone depth shall be no greater than 1.5 times floor to floor height.
   - 2.11 Building envelope assemblies shall be in accordance with the applicable local building codes or the *baseline* performance of ASHRAE/IES Standard 90.1, Table G3.1.5.
   - 2.12 ASHRAE/IES Standard 90.1, Appendix G, *baseline HVAC system* type is only to be used when sufficient information on the *HVAC system* has not been provided to the *energy modeler*. Refer to Appendix C, Section 2.1.

Table 13 Reference Building Form Assignments

Building Type	Floor Area		Aspect Ratio	No. of Floors	Floor-to-Floor Height		Floor-to-Ceiling Height		Glazing Fraction
	ft^2	m^2			ft	m	ft	m	
Small Office	5,500	511	1.5	1	10	3.05	10	3.05	0.21
Medium Office	53,628	4,982	1.5	3	13	3.96	9	2.74	0.33
Large Office	498,588	46,320	1.5	12*	13	3.96	9	2.74	0.38
Primary School	73,960	6,871	E-Shape	1	13	3.96	13	3.96	0.35
Secondary School	210,887	19,592	E-Shape	2	13	3.96	13	3.96	0.33
Stand-Alone Retail	24,962	2,294	1.3	1	20	6.10	20	6.10	0.07
Strip Mall	22,500	2,090	4.0	1	17	5.18	17	5.18	0.11
Supermarket	45,000	4,181	1.5	1	20	6.10	20	6.10	0.11
Quick Service Restaurant	2,500	232	1.0	1	10	3.05	10	3.05	0.14
Full Service Restaurant	5,500	511	1.0	1	10	3.05	10	3.05	0.17
Small Hotel	43,200	4,013	3.0	4	11** 9	3.35** 2.74	11** 9	3.35** 2.74	0.11
Large Hotel	122,120	11,345	3.8** 5.1	6	13** 10	3.96** 3.05	13** 10	3.96** 3.05	0.27
Hospital	241,351	22,422	1.3	5*	14	4.27	14	4.27	0.15
Outpatient Healthcare	40,946	3,804	1.4	3	10	3.05	10	3.05	0.19
Warehouse	52,045	4,835	2.2	1	28	8.53	28	8.53	0.006
Midrise Apartment	33,740	3,135	2.7	4	10	3.05	10	3.05	0.15

* Plus basement (not included in the table number)

** First floor

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Figure B–1. Simple box modeling excerpt (from ASHRAE Standard 209)

B–2. Example project –Test Range Late Add Fiscal Year 2025

a. The test range requires upgrades and expansion to meet future mission requirements. The project requires constructing a new pad, site improvements, and expanding their control building.

b. The PDT performed a DD Form 1391 validation charrette. The PDT consisted of stakeholder engineering staff, USACE resident engineer's office staff, District architect and engineering staff, and the customer. The PDT met over 3 days to discuss the DD Form 1391 and modify it as needed.

c. The process required the PDT to perform energy optimization.

d. During the charrette, the District architect drafted the additions to the building while the District mechanical engineer quickly produced an energy model of the existing facility using Trace 3D Plus. The optimization will be used for this illustration.

(1) Create the building model (see Figure B–2).

(2) Create the building addition based on programming requirements (square footage, space types, etc.) (see Figure B–3).

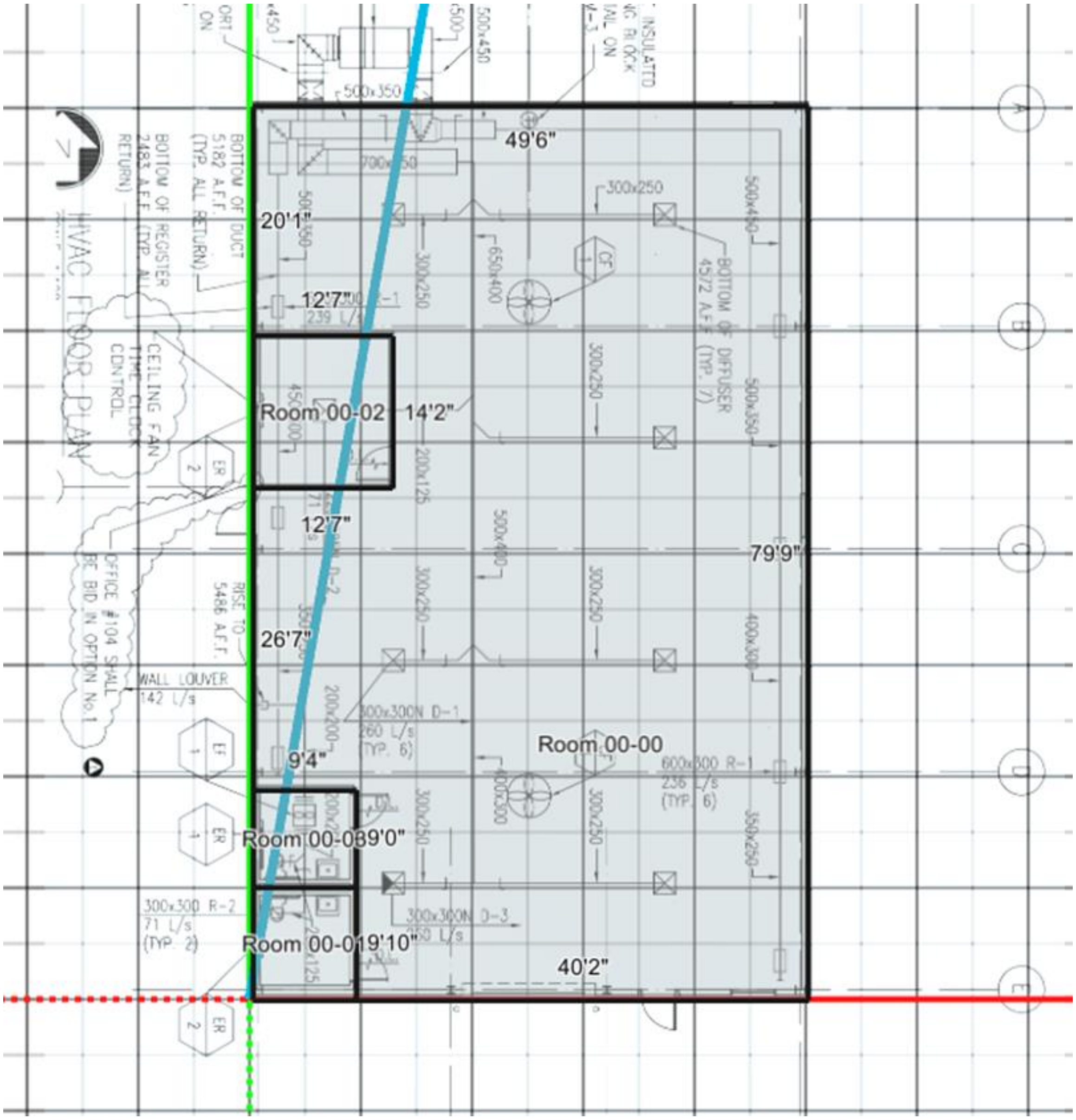

Figure B–2. Example building project layout in climate zone 5A

Figure B–3. Example building project layout with addition

e. At this point, Modeling Cycles 1 and 2 can be used to create alternatives that vary the location of the addition, its aspect ratio, glazing ratios, etc. (see Figure B–4).

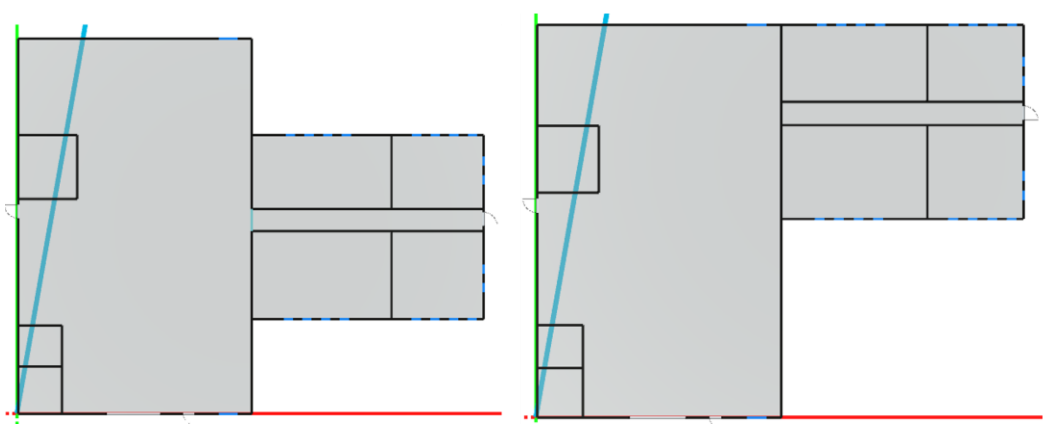

Figure B–4. Evaluation of addition position

f. In the above images, the addition was moved to align with the north wall of the existing building. All other inputs remained equal. The result of the energy analysis yielded the results provided in Table B–1.

Table B–1
Results of addition position comparison

		Baseline		**Comparison 1**	
		Primary		Addition Alt 1	
		Energy (kBTU)	**% of Total**	**Energy (kBTU)**	**% Improve**
Heating	*Natural Gas*	76,944	43%	77,001	0%
Cooling	*Electricity*	6,767	4%	6,853	-1%
Interior Lighting	*Electricity*	36,633	20%	36,747	0%
Exterior Lighting	–	–	–	–	–
Interior Equipment	*Electricity*	39,420	22%	39,514	0%
Exterior Equipment	–	–	–	–	–
Fans	*Electricity*	20,141	11%	20,255	-1%
Pumps	–	–	–	–	–
Heat Rejection	–	–	–	–	–
Humidification	–	–	–	–	–
Air-Side Heat Recovery	–	–	–	–	–
Refrigeration	–	–	–	–	–
Generators	–	–	–	–	–
Summary	*Electricity*	102,961	57%	103,369	0%
	Natural Gas	76,944	43%	77,001	0%
	Total	179,905	100%	180,370	0%

g. The results indicate that the alternative location of the addition does not significantly impact the energy use. For this illustration, the team ran two more alternatives for comparison: one that includes improved glazing performance, and one that includes the improved glazing as well as improved skins for the addition (see Table B–2).

Table B–2
Results of fenestration and envelope alternatives

		Baseline		**Comparison 1**		**Comparison 2**		**Comparison 3**	
		Primary		Addition Alt 1		Alt 1 w/ Improved glazing		Alt 3 w/ Improved envelope	
		Energy (kBTU)	**% of Total**	**Energy (kBTU)**	**% Improve**	**Energy (kBTU)**	**% of Total**	**Energy (kBTU)**	**% Improve**
Heating	*Natural Gas*	76,944	43%	77,001	0%	75,588	2%	49,239	36%
Cooling	*Electricity*	6,767	4%	6,853	-1%	7,298	-8%	6,057	11%
Interior Lighting	*Electricity*	36,633	20%	36,747	0%	36,633	0%	36,633	0%
Exterior Lighting	–	–	–	–	–	–	–	–	–
Interior Equipment	*Electricity*	39,420	22%	39,514	0%	39,420	0%	39,420	0%
Exterior Equipment	–	–	–	–	–	–	–	–	–
Fans	*Electricity*	20,141	11%	20,255	-1%	18,881	6%	13,857	31%
Pumps	–	–	–	–	–	–	–	–	–
Heat Rejection	–	–	–	–	–	–	–	–	–
Humidification	–	–	–	–	–	–	–	–	–
Air-Side Heat Recovery	–	–	–	–	–	–	–	–	–
Refrigeration	–	–	–	–	–	–	–	–	–
Generators	–	–	–	–	–	–	–	–	–
Summary	*Natural Gas*	76,944	43%	77,001	0%	75,588	2%	49,239	36%
	Electricity	102,961	57%	103,369	0%	102,232	1%	95,967	7%
	Total	179,905	100%	180,370	0%	177,820	1%	145,206	19%

h. Comparison 3 shows the most improvement compared to the baseline case. At this point, the team may decide to move to Modeling Cycle 3, load reduction modeling (see Table B–2).

i. The team created alternatives to reduce the loads for the facility while keeping the HVAC system constant between the alternatives. Based on the details provided in Table B–3 and Table B–4, it appears that interior lighting may be an area that could yield improvement. In this case, daylighting could be modeled to reduce the interior lighting power. Additional lighting controls could also be added to reduce the lighting power.

Table B–3
Electric consumption and demand for chosen alternative

	Alt 3 w/ improved envelope	
	Energy (kWh)	Demand (kW)
Cooling	1,774.49	4.50
Exterior Lighting	0.00	0.00
Exterior Receptacles	0.00	0.00
Fans	4,061.40	0.84
Heat Recovery	0.00	0.00
Heat Rejection	0.00	0.00
Heating	0.00	0.00
Humidification	0.00	0.00
Interior Lighting	10,734.84	3.59
Interior Receptacles	11,553.33	2.54
Pumps	0.00	0.00
Refrigeration	0.00	0.00
Service Water Heating	0.00	0.00
Grand Total	**28,124.05**	**11.47**

Table B–4
Comparison showing lighting power improvements

		Baseline		Comparison 1	
		Alt 3 w/Improved envelope		Addition Alt 1	
		Energy (kBTU)	% of Total	Energy (kBTU)	% Improve
Heating	*Natural Gas*	49,239	34%	51,817	-5%
Cooling	*Electricity*	6,057	4%	5,403	11%
Interior Lighting	*Electricity*	36,633	25%	32,150	12%
Exterior Lighting	–	–	–	–	–
Interior Equipment	*Electricity*	39,420	27%	29,420	0%
Exterior Equipment	–	–	–	–	–
Fans	*Electricity*	13,857	10%	13,459	3%
Pumps	–	–	–	–	–
Heat Rejection	–	–	–	–	–
Humidification	–	–	–	–	–
Air-Side Heat Recovery	–	–	–	–	–
Refrigeration	–	–	–	–	–
Generators	–	–	–	–	–
Summary	*Electricity*	95,966	66%	90,431	6%
	Natural Gas	49,239	34%	51,817	-5%
	Total	145,206	100%	142,248	2%

j. After the team completes Modeling Cycle 3, they can move into Modeling Cycle 4, which evaluates different HVAC systems. Following this process can help the PDT choose the best combination of systems for a facility that meets and/or exceeds policy and criteria requirements.

B–3. Life cycle cost analysis best practices

a. Create energy modeling software utility rate structures that match the local utilities' tariffs. BLCC does not have input fields for complex rate structures; thus, creating the rate structures in the energy modeling software helps to normalize/average the price for demand charges, customer charges, generation, distribution, consumption charges, etc.

b. Obtain the first cost and replacement cost data from RSMeans Books, RSMeans Online, CBRE Cost Library, or other industry-recognized source. Cost estimators may also be consulted for historical information or for data from the Micro-Computer Aided Cost Estimating System (MCACES).

c. In performing LCCAs, compare only the differences between alternatives. For example, in determining if a magnetic-bearing chiller is more cost effective during its life cycle than a conventional-bearing chiller, the first cost, replacement cost, and O&M costs for the distribution pumps do not need to be included in the analysis since those costs would be incurred in either scenario.

d. Obtain the O&M costs from the stakeholder (where available) in a usable format and apply the data fairly to all alternatives. Otherwise, obtain data from a COTS product and/or manufacturer data. Examples of COTS products that provide life-cycle cost data are RSMeans Online (full package) and CBRE's Cost Library.

e. Obtain replacement frequency for equipment from ASHRAE, CBRE, or historic data.

f. Cite sources for future reference in the analysis or in a companion report. Note the source, the year of publication (if available), and the CSI number (RSMeans) or Work Breakdown Structure (WBS) number (CBRE).

g. Use straight-line depreciation.

h. Determine the salvage (residual) value of a piece of equipment by the end of the study period using straight-line depreciation. For example, in a 40-year study where one of the alternatives includes a piece of equipment that has a 15-year life expectancy, that piece of equipment will have been replaced twice. By the end of the study period, there will be five years of value remaining in the equipment (based on straight-line depreciation).

i. Often, the salvage or residual value of equipment replaced during the 40-year study period is offset by the demolition or removal costs. Unless it can be determined that the salvage value is significantly greater than the demolition cost, assume the salvage value during the study period is $0. Significant means that the cost would affect the outcome of the study. The sensitivity analysis may be helpful in determining the cost that would be significant. An example of a building component that may have significant salvage value is mass timber.

j. Use the following websites as additional resources:

(1) BLCC: https://www.energy.gov/eere/femp/building-life-cycle-cost-programs.

(2) Energy Escalation Rate Calculator: https://pages.nist.gov/eerc/.

(3) Annual Supplement to Handbook 135: https://www.nist.gov/publications/energy-price-indices-and-discount-factors-life-cycle-cost-analysis-2022-annual.

(4) Background information on LCCAs, links to O&M cost resources, and more. https://www.wbdg.org/resources/life-cycle-cost-analysis-lcca.

Glossary of Terms

Term	Definition
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BCOES	Biddability, Constructability, Operability, Environmental, and Sustainability
BLCC	Building Life Cycle Cost
COTS	Commercial off-the-shelf
DOAS	Dedicated outdoor air system
DoD	Department of Defense
ECA	Energy Conservation Analysis
ER	Engineering Regulation
ERCIP	Energy Resilience and Conservation Investment Program
HPSB	High Performance and Sustainable Building
HVAC	Heating, ventilating, and air-conditioning
IECC	International Energy Conservation Code
IIS	Interagency and International Services
LCC	Life cycle cost
LCCA	Life cycle cost analysis
MCACES	Micro-Computer Aided Cost Estimating System
MILCON	Military Construction
NIST	National Institute of Standards and Technology
O&M	Operations and maintenance
PDT	Project Delivery Team
PED	Preconstruction, Engineering and Design
SMEs	Subject matter experts
TPC	Third-party certification
UFC	United Facilities Criteria
USACE	U.S. Army Corps of Engineers
WBS	Work Breakdown Structure