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CECW-EC Washington, D.C. 20314-1000

Regulation
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Engineering and Design
ENERGY MODELING AND LIFE CYCLE COST ANALYSIS

1. Purpose. The purpose of this Engineering Regulation (ER) is to provide direction and guidance for the application of energy modeling and Life Cycle Cost Analysis (LCCA) in design decisions and alternative analyses for buildings and structures. This ER is effective when issued.

2. Applicability. All projects and programs when USACE is the design agent and the vertical construction project includes over 5,000 gross square feet of interior space and the construction cost is greater than $3 million. Compliance with this ER will ensure energy modeling and LCCA activities for energy conservation alternatives are being performed and documented to comply with legislative mandates referenced by Unified Facilities Criteria 1-200-02, High Performance and Sustainable Building Requirements (Ref. d). Projects that do not meet these thresholds are not required to follow this ER. However, it may be beneficial to consider applying the methodology described below to make informed decisions.

3. Distribution Statement. Approved for public release; distribution is unlimited.

4. References.

a. Energy Policy Act of 2005 (EPAct 05), 8 Aug 2005, https://www.gpo.gov/fdsys/pkg/PLAW-109publ58/pdf/PLAW-109publ58.pdf

b. Executive Order (EO) 13693, Planning for Federal Sustainability in the Next Decade, 19 Mar 2015, https://www.gpo.gov/fdsys/pkg/FR-2015-03-25/pdf/2015-07016.pdf

c. CFR Title 10 Part 436, Subpart A and National Institute of Standards and Technology (NIST) Handbook 135, "Life-Cycle Costing Manual for the Federal Energy Management Program, Annual Supplement to NIST Handbook 135," http://fire.nist.gov/bfrlpubs/build96/PDF/b96121.pdf

d. Unified Facilities Criteria 1-200-02, subject: High Performance and Sustainable Building Requirements, http://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-1-200-02

e. Unified Facilities Criteria 3-401-01, subject: Mechanical Engineering, http://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-401-01

f. Unified Facilities Criteria 3-410-01, subject: Heating, Ventilating, and Air Conditioning

Systems, http://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-410-01

g. Memorandum, Office of the Assistant Chief of Staff for Installation Management, 18 December 2012, District and Islanded/Decentralized Heating Systems Selection Evaluation with Life Cycle Cost Analysis Guidance. usarmy.pentagon.hqda-acsim.mbx.oacsim@mail.mil

h. Engineer Regulation ER 1110-2-1150, Engineering and Design for Civil Works Projects, http://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1110-2-1150.pdf

i. Engineer Regulation ER-1110-345-700, Design Analysis, Drawings and Specifications, http://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1110-345-700.pdf

j. American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) Handbook, HVAC Applications, https://www.ashrae.org/resources--publications/handbook

k. ANSI/ASHRAE/IESNA Standard 90.1, Energy Standards for Buildings Except Low-Rise Residential Buildings. http://www.wbdg.org/ffc/dod/non-government-standards

l. Guiding Principles for Sustainable Federal Buildings & Associated Instructions, Feb 2016, https://sftool.gov/Content/attachments/guiding_principles_for_sustainable_federal_buildings_and_associated_instructions_february_2016.pdf

m. NISTIR 85-3273, "Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis," http://nvlpubs.nist.gov/nistpubs/ir/2017/NIST.IR.85-3273-32.pdf

n. OMB Circular A-94, Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs, https://www.whitehouse.gov/omb/circulars_a094

5. Background. The Energy Policy Act of 2005 (Ref. a) and Executive Order (EO) 13693 (Ref. b) mandate Federal agencies to lead by example by promoting sustainable Federal infrastructure through environmentally-sound, economically-sound and fiscally-sound design, construction and operating decisions. Uniform Facilities Criteria (UFC) 1-200-02 (Ref. d), integrates unique DOD requirements with Federal mandates and industry standards for high performance and sustainable buildings (HPSB). The Guiding Principles (Ref. l) of HPSB design are to employ integrated design principles, promote sustainable location and site development, optimize energy performance, protect and conserve water, enhance indoor environmental quality, reduce the environmental impact of materials and provide life-cycle cost effective solutions.

a. The US Army Corps of Engineers (USACE) is a technical leader in engineering solutions worldwide and is committed to advancing the quality of our built environment while maximizing opportunities for our customers. To further the Corps' effectiveness in delivering sustainable and energy efficient solutions, USACE initiated the Regional Technical Centers of Expertise for

Energy, Sustainability and Life Cycle Cost Analysis (RECX). The technical centers determined the most effective advancement of HPSB is to incorporate fundamental requirements into the US Army Corps design & construction process. This ER is a step in the process to consistently deliver high performance sustainable buildings.

b. A whole-building energy model is one of the tools used to meet the high performing and sustainable building requirements. The energy modeling program uses inputs as key building performance indicators, including but not limited to solar heat gain, ambient temperatures, occupancy and lighting schedules, temperature and humidity set-points, and unit energy costs to simulate the performance of a building for an entire year. The resulting model outputs may include energy use and demand based on model inputs. Model outputs, which are dependent on inputs and limitations of the modeling methodology and software, are typically used for comparison purposes in evaluating energy conservation measures (ECM's, also referred to as energy efficiency measures). In the absence of other benchmarking tools, model outputs may also be used to approximate actual building performance and energy consumption trends for comparison purposes.

c. Life-Cycle Cost Analysis has been a legally mandated requirement of Federal building projects for many years. Subpart A of Title 10 Code of Federal Regulations (CFR) Part 436 (Ref. c) establishes Methodology and Procedures for Life Cycle Cost Analyses for determining energy and water conservation improvements (Ref. d) for Federal Buildings which is an administrative law and the authority for it rests in 42 U.S.C. 6361, 42 U.S.C. 8251-8263, 42 U.S.C. 828708287C. To date, there are many inconsistencies in the execution and application of LCCA in the design of buildings on USACE projects. As a result, this ER is intended to improve compliance, standardization and uniformity of LCCA requirements in the design of USACE building projects. It is also intended to improve the delivery of design decision documentation and operational information to designers, future occupants, building owners and operators.

d. An LCCA provides important information to influence design decisions and choices early in the design phase. The results of an LCCA can help prioritize energy efficiency and water conservation measures that demonstrate a strong return on investment, guard against future cost increases (such as fuel or electricity costs), and reduce the total ownership costs of the facility. The LCCA information can be used by the owner and design team to select building features that enhance facility performance and better quantify long-term investment decisions.

e. There is an important relationship between the energy model and Life Cycle Cost Analysis during the design process. An integrated team is also necessary to complete both the energy model and the LCCA. Project Delivery Team (PDT) members are required to communicate effectively to ensure an accurate product. Early in the design, the integrated team makes design assumptions based on scope and criteria requirements. These design features, which usually result in two or more alternative systems, or options are fed into the energy model. The energy consumption results, as well as other factors such as utility, maintenance, operation, replacement costs are then input into the LCCA to compare alternatives that will be reviewed for selection.

This process must be completed as early as possible in order to allow decisions to be made which meet all the requirements while remaining cost effective.

6. Energy Modeling.

a. Whole Building Energy Modeling. All climate controlled spaces that meet the requirements in section 2 Applicability, must include energy modeling as a reference for design decisions. The building energy modeling must be completed with an 8760 hour simulation that has hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat setpoints, and heating, ventilation and air-conditioning (HVAC) system operation, with daily schedules. The model is used to evaluate ECM's such as changes in building envelope insulation or alternative system types of HVAC equipment. Energy modeling should not be used as an absolute predictor of the energy consumption after occupancy. It is the only tool available at this time to reference real energy consumption to theoretical consumption. The level of detail and complexity of the energy model(s) must be appropriate for the analysis required. For example, the energy model for a project to partially renovate an existing office building, may include just the renovated area and respective climate controlled systems serving the renovated area. If the project includes full HVAC equipment replacement for the entire facility, the model should evaluate the entire facility. In addition, energy modeling must be accomplished by project delivery teams in order to demonstrate compliance with EPAct 2005 (Ref. a) energy reduction targets, Guiding Principles (Ref. l), and Third Party Certification (TPC) such as Leadership in Energy and Environmental Design (LEED) Energy and Atmosphere credit templates. It is possible this will result in two separate models if the versions of ASHRAE required under EPAct 2005 (Ref. a) do not match the ASHRAE version which the TPC is requiring. The energy model will also fulfill the design energy analysis requirements described in governing standards and publications that require production and documentation of energy analysis to ensure energy efficiency and conservation. These include ER 1110-345-700 (Ref. i) and UFC 3-401-01, Mechanical Engineering (Ref. e), and UFC 3-410-01, HVAC (Ref. f). A building energy model must be performed using approved computerized simulation software which meets ASHRAE 90.1 (Ref. k) Appendix G requirements including an 8760 hourly analysis. A simplified approach to the energy model can be used for projects which do not meet the thresholds stipulated. A simplified approach still requires use of the approved computerized simulation software; however, the number of inputs can be significantly reduced. For Army projects, plug and process loads must be included as part of the energy calculations.

(1) New Projects

(a) Planning and Programming Phase. Energy modeling must be completed to the level necessary for a PDT to identify energy optimization features and consider the features in their planning efforts. The energy model must be integrated in the planning and programming phase in proportion to the complexity of the project requirements. Energy optimization features may include structural shape, layout, and orientation, day lighting, HVAC system types, Installation energy Demand Side Management (to include energy curtailment) programs, building envelope design tradeoffs, and allocation of energy use (values and proportions) within the facility. Considerations may also include investigations into fossil fuel reduction, poly-generation, energy security (continuity of operations and management of future energy costs), resilience, and other strategies.

(b) Interim Design Phase Requirements. Update the concept model to include any changes that would affect the outcome on the energy model.

(c) Final Design Phase Requirements. Provide completed energy modeling calculations as part of the design analysis (DA). Include output report showing energy consumption for each energy source for each of the twelve months of the modeled year, and include the total cumulative annual energy consumption for each energy source.

(2) Sustainment, Restoration, and Modernization of Military Projects

(a) Sustainment. Energy modeling is not required for Sustainment projects.

(b) Restoration and Modernization (R&M). R&M projects involving a significant reconfiguration of interior spaces, change of Facility Category Code, changes to heating and cooling equipment, or modifications to insulation and/or building envelope must include energy modeling as if the project were new construction. Window, door, and/or lighting only replacement projects require LCCA's, but not energy modeling unless the projects are a part of overall R&M.

- 'Significant' is defined as any building over 5,000 square feet and receiving a project contracted value of 25% or more of its replacement value.

- Renovation areas within buildings that are less than 5,000 square feet may use simplified approaches for heating and cooling equipment replacement projects. Simplified analyses need to be documented and retained as required for full modeling efforts.

- Determination of energy modeling requirements must be based on the work classification of R&M work. Any modeling requirement applies even if the project is programmed with Sustainment funds.

(3) Rehabilitation of Civil Works. Rehabilitation projects involving a significant reconfiguration of interior spaces, changes to heating and cooling equipment, or modifications to insulation and/or building envelope must include energy modeling as if the project were new construction. Exception: Window, door, and/or lighting only replacement projects.

(a) Significant is defined as any building over 5,000 square feet and receiving a project contracted value of 25% or more of its replacement value.

(b) Buildings less than 5,000 square feet may use simplified approaches for sizing heating and cooling equipment replacement projects. Simplified analyses need to be documented and retained as required for full modeling efforts.

b. Energy Model Project Team Responsibilities. Performing an energy model requires an integrated team. A design team must have representation from all applicable disciplines, including owner operations, to identify all opportunities to improve building performance and increase savings potential. Project team roles and responsibilities for performing energy model are as follows:

(1) Project Managers are responsible for establishing an integrated team.

(2) Design Team Leads are responsible for ensuring that integrated design principles are being followed for energy model development.

(3) Architects, Mechanical Engineers and Structural Engineers are generally responsible for the building envelope passive features.

(4) Mechanical and Electrical Engineers are responsible for the active mechanical and electrical systems.

(5) The Energy Model Regional Technical Center of Expertise (RECX) may provide assistance in the development of the energy model on a reimbursable, project funded basis. The Energy Model RECX point of contact can be found at the following website: https://mrsi.erdc.dren.mil/sustain/cx/energy-modeling.

(6) Teams are encouraged to review the Department of Energy's, Energy Modeling website which includes a comprehensive list of software and select the most applicable software for their specific project: https://energy.gov/eere/buildings/building-energy-modeling-0.

7. Life Cycle Cost Analysis.

a. Minimum LCCA Requirements. Projects must meet the minimum energy and sustainability requirements described in UFC 1-200-02 (Ref. d) including all applicable referenced UFCs therein. A life-cycle cost analysis (LCCA) is required for each project whether it meets, exceeds or falls below the applicable target as compared to a baseline building that meets the minimum requirements of ASHRAE 90.1 (Ref. k). An LCCA requires a systematic evaluation of alternatives according to the energy requirements stated in this ER.

(1) An LCCA provides the decision maker a full, unbiased presentation of candidate

alternatives, including the costs for maintaining viable alternatives. The decision maker may select an alternative based on operational considerations, customer requirements, and project budget. In this case, the justification for selecting an alternative that does not achieve the highest energy savings must be included in the final LCCA document.

(2) Good engineering judgment must be exercised in the analysis of at least three alternatives (one alternative is the baseline) for each system (where available, e.g. walls, roof, glazing, lighting, HVAC, etc.) that meet the requirements defined in this section. Where it is clear that the cost of an alternative exceeds the potential savings, do not perform the analysis; rather, use judgment and experience to select cost effective features. Document in the Design Analysis any systems or features considered but removed due to them not being cost effective. Where similar performance is achieved by alternatives with substantial cost differences, select the alternatives that are the most economical. Renewable energy and/or energized systems such as PV, solar hot water, CHP must also be evaluated and considered for each project.

(3) All project delivery teams must follow the methodology in Subpart A of Title 10 of CFR Part 436 (Ref. l) to perform the LCCA for each building. It is important that there is one person in charge of performing the LCCA that receives inputs from PDT members including design details and costs. The responsible individual should have experience preforming economic analysis and using LCCA programs or spreadsheets. The Building Life-Cycle Cost (BLCC) program, developed by the National Institute of Standards and Technology (NIST), complies with 10 CFR Part 436 (Ref. c) and may be used to perform the analysis. However, it is important to note there are some limitations using BLCC such as not allowing different rates for natural gas between interruptible and non-interruptible supplies within an analysis. A spreadsheet with economic formulas or using other economic analysis programs are also acceptable methods to perform the analysis, as long as they meet the requirements of Subpart A of Title 10 of CFR Part 436 (Ref. c). The following link is provided that includes instructions on how to download the BLCC program for free: https://energy.gov/eere/femp/building-life-cycle-cost-programs.

(4) Whole Building LCCA. An LCCA for a facility as a whole must be completed for efficiency or conservation features provided in excess of the baseline to ensure the discounted payback period is no greater than 40 years or the projected life of the facility, if shorter than 40 years. This is not the same as evaluating separate sub systems (i.e., HVAC, lighting, etc.) that have a shorter individual system life than the facility as a whole. As stated previously, UFC 1-200-02 (Ref. d), including all referenced UFCs therein, define the minimum building requirements and will be used as the project baseline for life-cycle cost comparisons. Subsystem equipment and material capital costs, labor, water, fuel, maintenance, repair, replacement, tangible external costs, and any other quantifiable benefits and costs are to be included in an LCCA. Fuel cost escalation factors must be taken from the DOE Energy Information Administration NIST Handbook and supplements embedded within the BLCC program. Paragraphs 6 d. and e. below provide additional guidance on factors that must be considered and included in an LCCA.

(5) An LCCA will be a separate document that is included as part of the design analysis and/or basis of design. LCCAs will be conducted as prescribed in the references in paragraph 7.a(3) above.

(6) Alternative or Sub Systems LCCA. LCCA's should be performed on separate sub systems and individual features as needed to ensure they are life-cycle cost effective (LCCE). UFC 1-200-02 (Ref. d) states systems and features to be analyzed for cost effectiveness to include passive features (envelope components, etc.,), active systems (HVAC and lighting, etc.), water systems (rainwater harvesting, life safety systems (fire sprinkler/suppression systems), greywater systems, etc.), renewable energy features (solar PV, solar thermal, wind, etc.), and material selections (recycled content, biobased materials, etc.). UFC 1-200-02 states, "LCCAs comparing individual component or system alternatives must use the estimated life of the mutually exclusive alternative having the longest life, not to exceed 40 years from the beginning of beneficial use or the lowest common multiple of the expected lives of the alternatives. Include the appropriate replacement and salvage values for each of the other alternatives."

b. Standard Designs. In general, standard design facilities which have had an LCCA completed based on design parameters set by the Centers of Standardization do not require an LCCA. Standard design projects will be required to provide an updated LCCA when major changes proposed by the PDT to the standard result in an increase to the project cost and/or energy and water consumption. Major changes can include but is not limited to utility rates, maintenance cost used, or other factors. When there is a standard design that has used a previous LCCA, the LCCA must be reviewed to ensure that the data used in the original analysis match the actual project location and current conditions. If not, then the LCCA must be updated to match the conditions (e.g. utility rates, labor costs, etc.) of the actual project location. Standard design facilities that do not have a regional model, or features that have not been pre-determined, require an LCCA.

c. LCCA Schedule Requirements.

(1) General. The LCCA must be initiated to validate the cost effectiveness of the highest energy efficiency feasible within the Programmed Amount (PA) or Project Budget Amount. The project scope and cost must be shown to support a cost effective project. The final LCCA is to be started and completed no later than the parametric design phase, normally (5-35%). The LCCA must validate a cost effective project and be made part of the Design Analysis and available for review upon request. Any subsequent changes in project scope beyond the initial design that impact energy savings or project cost require an update to the LCCA. Prior to the start of the design phase, the building site, orientation and configuration must be determined.

(2) Design Phase. Early in the design phase, the building envelope passive design features and components (i.e. roofs, walls, windows/fenestrations, day lighting) need to be selected and analyzed for life-cycle cost effectiveness. Selection of passive (non-mechanical) features will help minimize energy demands for the active systems. After the passive building envelope

strategies are determined, the active and mechanical systems (e.g. HVAC, plumbing, water heating systems, lighting systems, control systems, elevators, and fire protection systems) are selected, analyzed, designed and integrated into the overall design. The active and mechanical systems are the largest building energy consumers. It is critical that design teams use LCCA information to optimize selection of these systems including accounting for the capacity and cost to maintain the systems. All of these features will need to be coordinated with the PDT and included in the energy model analysis.

(a) Once the most cost effective and energy reducing active systems have been selected, other sustainability features such as renewable energy systems and water conservation strategies can be added to the whole building LCCA. This is an iterative process to determine which sustainability features can be included within the PA.

(b) For projects with scope variations impacting energy savings following the initial design, the final LCCA document must be completed and incorporated into the Design Analysis no later than the second design submittal (i.e. 65%).

d. Critical LCCA Factors. The following factors have significant influence in LCCA outcomes and must be included in calculations for analysis. All calculations and assumptions must be clearly documented in the LCCA document that is required to accompany the design analysis and/or basis of design.

(1) First Costs.

(a) Capital Cost of New Equipment. Pricing should be based on quotations or budgetary information received from manufacturers when possible. Where quotations from manufacturers are not available, pricing will be based on RSMeans or Tri-Services Automated Cost Engineering Systems (TRACES) costbook data. Costs must include all components required for a complete and usable system to include distribution network costs. Costs per square foot from other similar projects or parametric cost software are acceptable methods to develop these costs.

(b) Labor for Installation Priced per Location. If available, pricing may be based on data from recent projects of comparable scope and scale at or in close proximity to the installation. Where such data does not exist, pricing will be based on the most accurate data available. RS Means or TRACES costbook data is acceptable for this. Pricing data should include consideration for Davis Bacon wage rates from Department of Labor.

(2) Maintenance Costs.

(a) Required Maintenance. Hours must be based on manufacturer provided component and system maintenance requirements or the best available estimates. These costs are also available from the end user or owner such as a Department of Public Works (DPW), Base Civil Engineer (BCE), or Business Operations and Integration Division (BOID). For example, the BOID will have the records of labor and supply costs applied for each maintenance instance. The use of RS Means or TRACES costbook is an acceptable alternative if this data is not available, complete, or provided in a timely fashion. The LCCA must account for all associated costs for components and/or systems that are recommended to be replaced within the 40-year study period. The ASHRAE HVAC Applications Handbook (Ref. j) should be used for estimated service life and has a table containing median service life. The Handbook also includes information and a link to an online database which has up-to-date information from 300 buildings. The database can be sorted by region and building/system type for a more accurate service life. In addition, include costs of component replacement such as filters, belts or other components.

(b) Labor Rates. Pricing must be based on data from existing Installation or similar nearby installation maintenance contracts or prevailing wages (Davis Bacon rates). Where such contracts do not exist, pricing must be based on RS Means or TRACES costbook data.

(3) Operations Costs. Energy and fuel usage data, including impacts on demand charges, for new construction or renovations will be based on measured use or obtained from utility bills for similar existing buildings, when available. If measured data does not exist, usage will be estimated using engineering analysis, including taking the energy and fuel usage directly from the energy model.

e. Additional Factors.

(1) End-of-Life Removal. Pricing will be based on escalated demolition costs, as appropriate; to include any surcharge for material recycling, reuse, and special disposal costs (e.g. photovoltaic panels).

(2) Salvage Value at End of Useful Life. Pricing will be based on data from recent projects at or in close proximity the Army Installation on projects of comparable scope and scale. Where such data or projects do not exist pricing will be based on RS Means or TRACES costbook data.

(3) Discount and Escalation Rates. Data will come from the most current edition of Appendix C of OMB Circular A-94 (Ref. n).

(4) Differential Escalation Rate for Energy. As instructed in NIST Handbook and supplements (Ref. m), the differential escalation rates must be obtained from the Department of Energy Energy Information Administration (EIA).

f. LCCA Project Team Responsibilities. Performing a building level LCCA requires an integrated team. A design team must have representation from all applicable disciplines, including owner operations, to identify all opportunities to improve building performance and increase savings potential. Project team roles and responsibilities for performing LCCA are as follows:

(1) Project Managers are responsible for establishing an integrated team.

(2) Design Team Leads are responsible for employing integrated design principles to develop the energy and cost input data for implementation of the system-level LCCA.

(3) Personnel responsible for conducting the LCCA is recommended to have formal education in engineering economics.

(4) The PDT Technical Lead is responsible for assuring execution of the LCCA, including quality assurance for A-E designs.

(5) For Design Build contracts, the preparer of the contract documents must perform the required LCCA and include the documentation during each technical review period prior to issuing the Design contract drawings and specifications for design and construction. The Design Build selection criteria must require that proposals that offer betterments to the requirements defined by the Request for Proposal be supported by an LCCA.

(6) Architects, Mechanical Engineers, and Structural Engineers are generally responsible for the building envelope passive features.

(7) Mechanical and Electrical Engineers are responsible for the active mechanical and electrical systems.

(8) Construction Representatives/Project Engineers are responsible for providing input related to construction execution that may affect an LCCA.

(9) Cost Engineering or other qualified PDT member is responsible for cost input data for all LCCAs.

(10) Owner/Operator (i.e. DPW, BCE) have valuable information for operations and maintenance practices, evaluating options for space management and workplace alternatives, establishing energy and water operational performance goals, participating in development of Owner Project Requirements, and providing historical and empirical operating and maintenance cost data.

(11) The LCCA Regional Technical Center of Expertise (RECX) may provide assistance in the development of the LCCA and review of typical considerations on a reimbursable, project funded basis. The LCCA RECX point of contact can be found at the following website, https://mrsi.erdc.dren.mil/sustain/cx/lcca.

g. LCCA for District and Central Plant Heating Systems. Initial technical guidance on "district and islanded/decentralized" heating systems selection is available in Reference g. The guidance will help bring consistency and alignment for facilities on Army installations with central heating plants.

h. Sensitivity Analysis. Sensitivity analysis is required on all LCCAs to show how significantly the results change due to potential variations in key input data parameters. If a change in a variable causes a change in the ranking of alternatives, the LCCA is "sensitive" to that variable. Good engineering judgment should be used in selecting the most important input variables that will be included in the sensitivity analysis. The results of the sensitivity analysis are required to be included in the Executive Summary of the LCCA document. Performing a sensitivity analysis and including its results in the report, assures the decision maker that uncertainties in the LCCA have been tested and the results documented. At a minimum, sensitivity analysis should be considered as part of the analysis of benefits and costs; the discount rate; and potential variations in energy and water costs.

i. Exemption. A request for an exemption through Headquarters, U.S. Army Corps of Engineers, Engineering & Construction Division (HQUSACE CECW-CE) may be made for any specific LCCA requirement in this ER. Any approved exemptions to this policy must be documented with reference to the specific requirement in conflict and included in the project documentation.

8. Documentation Requirements. Design decisions and modifications to scope of work must be documented in the DA per ER 1110-345-700 (Ref. i) or the Design Documentation Report (DDR) per ER 1110-2-1150 (Ref. h).

a. Energy Modeling. An energy model must be completed and/or updated for the different phases as described in section 5. Each iteration of the modeling will be included in the DA or DDR along with any design assumptions and decisions made during the design process. In the DA or DDR, state whether the discrete energy conservation strategies listed in the project programming or budget documents were included in the energy model development and analysis. Design Analysis should include statements of compliance with EPAct 2005 (Ref. a), Guiding Principles (Ref. l), any relevant energy reduction goals, and if applicable, TPC cost energy reduction calculations.

b. LCCA. Final LCCA documentation, within the DA, must include a comprehensive summary that defines each alternative considered, including assumptions and references provided for each parameter. The assumptions must be clear, documented and of a level of detail sufficient to be used by a third party or audit team to duplicate the results of the LCCA. LCCAs must be completed using the same matrix of baseline information consistently across alternatives to ensure a fair comparison is made between alternatives. If the most energy efficient alternative that is LCCE is not selected, justification must be documented in the DA.

An LCCA must include documentation of the thought process used to support the selection of a specific alternative. The LCCA document should summarize why the selected alternative is the best alternative for the project. Include the sensitivity analysis as described in paragraph 6.h., in the LCCA section of the Design Analysis.

FOR THE COMMANDER:

1 Appendix
Appendix A Quality Control
Review of Energy Models

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APPENDIX A

Quality Control Review of Energy Models

1. General. Quality assurance reviews of energy models can be intimidating as literally 100's of pages of reports can be produced. For this reason, this appendix was developed to help simplify or highlight important areas to focus on. This appendix is intended to provide guidance and advice to the mechanical engineer with the responsibility to perform quality assurance for energy models. Energy reduction for Federal facilities is mandated by public law, so it is important to ensure that the models are reasonably accurate, and that facilities will meet the required reductions from the prescribed baseline facility.

2. Some Key Points to Keep in Mind When Reviewing Energy Models.

a. No two energy modelers will get the exact same results as they build an energy model using any given simulation program.

b. Various programs used to conduct 8760 hour modeling invariably end up giving some odd, or even bad results from time to time as the programs are imperfect.

c. Contacting the help desk for various software program glitches is always a good idea; however, one will not always receive a satisfactory answer, or outcome.

d. When the simulation program does not provide a result that is within reasonable expectations, don't be afraid to allow the modeler, or yourself, to use the exceptional calculation method as outlined in ASHRAE 90.1.

e. There are many variables and often multiple modeling scenarios included within any given simulation package. This makes it a challenge for even the most experienced modeler to get it just right.

f. Recognize that there may be a financial motivation for some parties to determine/claim, that a proposed building meets an energy reduction goal, even if it does not. The great many variables make it relatively easy for a modeler to skew the results, i.e. make the baseline use more energy that it really does, and similarly, make the proposed facility use less energy than it would. ASHRAE 90.1-2010 User's Guide mentions the term "gamesmanship" in this context and explains that this is one of the reasons that rules are in place for determining energy efficiency reductions. For this reason, it is not necessarily easy to detect faulty inputs to a program if you do not have all of the model input files. This appendix will attempt to help identify where there may be areas to focus on to ensure the model is as accurate as possible.

3. Preparation for How to Review an Energy Model.

a. The first thing you must have is a clear expectation of what the approximate Energy Use Intensity (EUI) should be for the facility type that you are reviewing in the climate zone of interest.

b. Where Do I Find Reasonably Reliable Data for EUI's?

(1) Design Guides for Military Buildings to Meet EPACT 2005 Energy Reduction Requirements, produced by the USACE Engineer Research and Development Center.

(2) Memorandum, Subject: Sustainable Design and Development Policy Update, dated Jan 17, 2017, Enclosure 1, Tables 1 and 2.

c. Have a reasonable expectation of what the energy use should be by "End Use" category. While the references in 2 above do not break out the EUI's by end use, you can find pie charts for office buildings, and other facility types on the web. The following website, https://www.mge.com/images/PDF/Brochures/business/ManagingEnergyCostsInOfficeBuildings.pdf, gives one example of "End-use" consumption.

(1) End use categories are:

(a) Space Heating (electricity) – Electric resistance very limited per Table G3.1.1-2.

(b) Space Cooling – Relatively low value in cool climates; increasing impact in warm and humid climates.

(c) Pumps – Generally low for most facilities.

(d) Heat of Rejection – Nearly inconsequential.

(e) Fans Interior – Generally 12 to 15% of total.

(f) Receptacle - Approximately 10% of total.

(g) Interior Lighting – 15 to 20% of total.

(h) Exterior Lighting (parking lot) – Usually minor.

(i) Building Exterior Lighting – Almost always minor.

(j) Space Heating (gas) – Substantial in cool climates, decreasing in warm/humid climates.

(k) Domestic Water (electricity) – Limited facility types per Table G3.1.1-2 for baseline service hot water.

(l) Domestic Water (gas) – Most facilities per Table G3.1.1-2, Min. EUI in offices, substantial EUI in dorms.

(2) As an example, a Battalion Headquarters project in Climate zone 4C using the 2007 version of 90.1 ended up with the following baseline and proposed facility End Use Energy Use Intensities.

Table A-1: Example Battalion Headquarters in Climate Zone 4C

	Baseline EUI (BTU/sq ft yr)	Proposed EUI (BTU/sq ft yr)	Reduction by End Use	Reduction by End Use of Total	Baseline % of Total Energy
Space Heating (elect)	0	2,111			
Space Cooling	2,871	2,892	-0.007	0.000	0.053
Pumps	978	944	0.035	0.001	0.018
Heat Rejection	226	208	0.080	0.000	0.004
Fans – Interior	6,885	2,210	0.679	0.086	0.126
Receptacle	5,942	6,029	-0.015	-0.002	0.109
Interior Lighting	8,813	6,037	0.315	0.051	0.162
Exterior Lighting	351	192	0.453	0.003	0.006
Building Ext Lighting	763	198	0.740	0.010	0.014
Space Heating Gas	23,733	9,382	0.516	0.225	0.435
Domestic Water (gas)	3,943	2,077	0.473	0.034	0.072
	54,505	32,280	0.408	Overall reduction with receptacle load	
			0.458	Overall reduction without receptacle load	

(a) In this example, the space heating was reduced by 51.6% which represents a 22.5% reduction in the total energy use (including plug energy), and a 25.2% reduction (not including plug energy). For the baseline building, the heating energy represented 43.5% of the total energy use, making the heating system a prime target to apply energy reduction measures to. Baseline building did not include electrical space heating.

(b) The proposed facilities heating system used radiant panels and the ventilation system was a DOAS. The choice of heating system also allowed the fan energy to be reduced by 67.9%, which reduced the total energy use by 8.6%. In this case, the heating energy and the interior fan energy were sufficient to achieve a 31% reduction in total energy use, and a 34.8% reduction (not including plug loads).

(c) In this example Battalion Headquarters facility, applying the 2013 ASHRAE 90.1 version only reduced the energy savings by less than 2%. Energy reductions in warmer climates would likely to be impacted more between application of the 2007 and 2013 versions of 90.1

d. Another source for estimating "End-use" consumption could be the Commercial Buildings Energy Consumption Survey (CBECS), which is located at the following website: https://www.eia.gov/consumption/commercial/estimation-enduse-consumption.php. Note: CBECS data is often difficult to sort through. There are large inventories represented in the CBECS; however, keep in mind that the breakout is generally not organized by ASHRAE 90.1 facilities.

e. And the final source of energy "End-use" data may come from your customer's utility data, or from the number of energy models that have been run over the past few years of similar facility types, including (for the Army) the myriad of projects that were analyzed during Military Construction Transformation.

4. The Review Process. The following review process example uses ASHRAE 90.1-2013. This process is not exclusive to this version of ASHRAE 90.1 and can be applied to other versions.

a. Check to see if the report contains a brief description of the project, the key energy efficiency improvements, and most important, a list of the energy related features that are included in the design. The list of energy related features is required documentation per ASHRAE 90.1, but it is often missing. This list is very important, as it is the energy related components that will inform you as to where you should expect to see energy savings.

(1) For example, if your facility is in a heating dominated climate zone, and if your ventilation system is sized such that ASHRAE 90.1-2013 Table 6.5.6.1-1 Exhaust Air Energy Recovery Requirements for Ventilation Systems Operating Less than 8000 Hours per Year, or Table 6.5.6.1-2 Exhaust Air Energy Recovery Requirements for Ventilation Systems Operating Greater than 8000 Hours per Year, does not require the addition of an energy recovery device, then the voluntary addition will be able to reduce the heating ventilation load from 50% up to 70%. Along with decreased envelope U-values, i.e. betterments to the envelope, experienced modelers state that one can reasonably expect to reduce the total heating EUI by 50% from the baseline (reference example above).

(2) In the absence of an energy recovery device, where it is not otherwise required by

ASHRAE 90.1, large reductions in the heating load should not be expected. If there are substantial reductions shown in the heating EUI, without energy recovery, or a significantly improved envelope, then a closer look at the section of the model is warranted.

b. Go to the Summary Report, and check the baseline versus proposed values for the envelope. Make sure that the baseline values comply with Table 5.5-0 through 8 of ASHRAE 90.1-2013 for the appropriate climate zone.

c. Check the Summary Report to make sure that the baseline equipment efficiency values comply with the minimum efficiency requirements given in Table 6.8.1-1 through 16.

d. Check the Summary Report for the proposed equipment efficiencies, and validate (as necessary) any efficiencies that appear to be too good to be true.

e. Check the baseline EUI. Is it reasonable? If it is unreasonably high, you really don't need to go much further at this stage of review, you could return the energy reports with a single comment, stating that the baseline EUI is unreasonably high, and request that they make corrections and resubmit. However, in the interest of time, it is probably better to help them find their error, and point it out.

f. Finding Errors. Take the various energy by end use values (space heating, space cooling, pumps, heat of rejections, fans, receptacle equipment, interior lighting, exterior (parking lot) lights, exterior building lighting, and domestic hot water) and divide out by the square footage of the appropriate space, and see what the individual end use intensity is.

(1) Example. An office building will have a lighting power density of 0.82 watts/square foot using the building area method (reference Table 9.5.1 of ASHRAE 90.1-2013). The 2010 ASHRAE 90.1 User's Guide will indicate the annual lighting hours for a typical office to be 2,288 hours per year. If you have an office building, you can then expect your annual lighting energy use to be 6.4 kbtu/sq ft yr. If the reported baseline is much greater than this value, then there is a good chance that either the hours of operation have been boosted, or a higher lighting power density has been inadvertently entered. Check the proposed lighting power density and ensure that the hours of operation are matched up between the baseline and the proposed facilities. Though it would seem obvious that the hours of operation are critical, and they should be clearly reported, there are many energy reports produced where the hours of operation are not clearly stated.

(2) Note. There will be discrepancies between various documents regarding EUI's by end use. In the referenced document "Managing energy costs in office buildings", the average U.S. office electricity use is stated to be 17.3 kWh per square foot. It is also indicated that the lighting is 39% of the total electric. That would put the lighting EUI at 23.04 kbtu/sq ft yr, and that is 3.59 times what the ASHRAE 90.1 value would came to using 0.82 as a lighting power density

with 2,288 hours of operation. The referenced energy model has the baseline lighting EUI at 8.81 kbtu/sq ft yr, which 1.37 times what the ASHRAE 90.1 value is. The source data for the "Managing energy costs in office buildings" reference is indicated to be the U.S. Energy Information Administration, so one might suspect that the information is reasonably accurate. While this discrepancy may seem disconcerting, the explanation most likely lies in the hours of operation. The ASHRAE 90.1 user's manual indicating 2,288 hours of lighting equates to just 44 hours per week. While the lighting power density was undoubtedly higher in the average office building used to collect the U.S. EIA data, it is most likely that the majority of the discrepancy is due to the ASHRAE occupancy schedule versus a real schedule. In any event, the modeling review can be carried out with integrity by ensuring that the hours of lighting use are the same for both the baseline and the proposed facility.

So in this example, it can be seen that a disconcerting difference in the lighting EUI between two, or three sources can be remedied by ensuring that occupancy schedules are identical and the lighting power densities are appropriate.

g. Where should you expect to see energy reductions? Energy reductions by end-use can be expected to vary with the climate zone. Typical legitimate energy savings for cooler weather climates of ASHRAE Climate Zone 4C will primarily be generated as follows:

(1) Heating – 50% reduction resulting in up to 25% overall reduction.

(2) Fan energy 50-70% reduction resulting in up to 10% overall reduction.

(3) Interior lighting – 30% reduction resulting in overall 5% reduction.

h. Where should you not expect to see significant reductions in energy use?

(1) Exterior "Parking lot" Lighting. If there is a significant energy savings being shown for parking lot lighting, this will warrant a closer look. Earlier versions of ASHRAE 90.1 simply set an upper bound of lighting power density per square foot, and some modelers took that to be the baseline. Those values were not baseline values, and actual savings needed to be determined by having a baseline and a proposed exterior lighting design with equivalent lighting performance, with credit taken for improvements in exterior lighting efficacy or wattage.

(2) Building exterior lighting should have modest energy savings.

(3) Pump energy for HVAC systems should have modest energy savings.

(4) Domestic hot water should have modest savings, unless there is a heat pump application, in which case more substantial savings could be realized. When there are significant domestic hot water savings in the absence of a heat pump, it most likely means that the modeler is taking credit for reduced hot water use. Since Federal facilities are mandated to use low flow faucets, it

is inappropriate to assign high flow fixtures to the baseline, and then model the proposed facility with low flow fixtures.

5. Conclusion. Finally, in closing, as this ER is continually updated to reflect changes to Energy Modeling and Life-Cycle Cost Analysis requirements, more examples will hopefully be added to provide more help and guidance to those performing quality assurance reviews for energy models. Any lessons learned should be submitted to the point of contact so that this appendix can remain current and up to date with as much useful and valuable information as possible, including more examples of different climate zones.