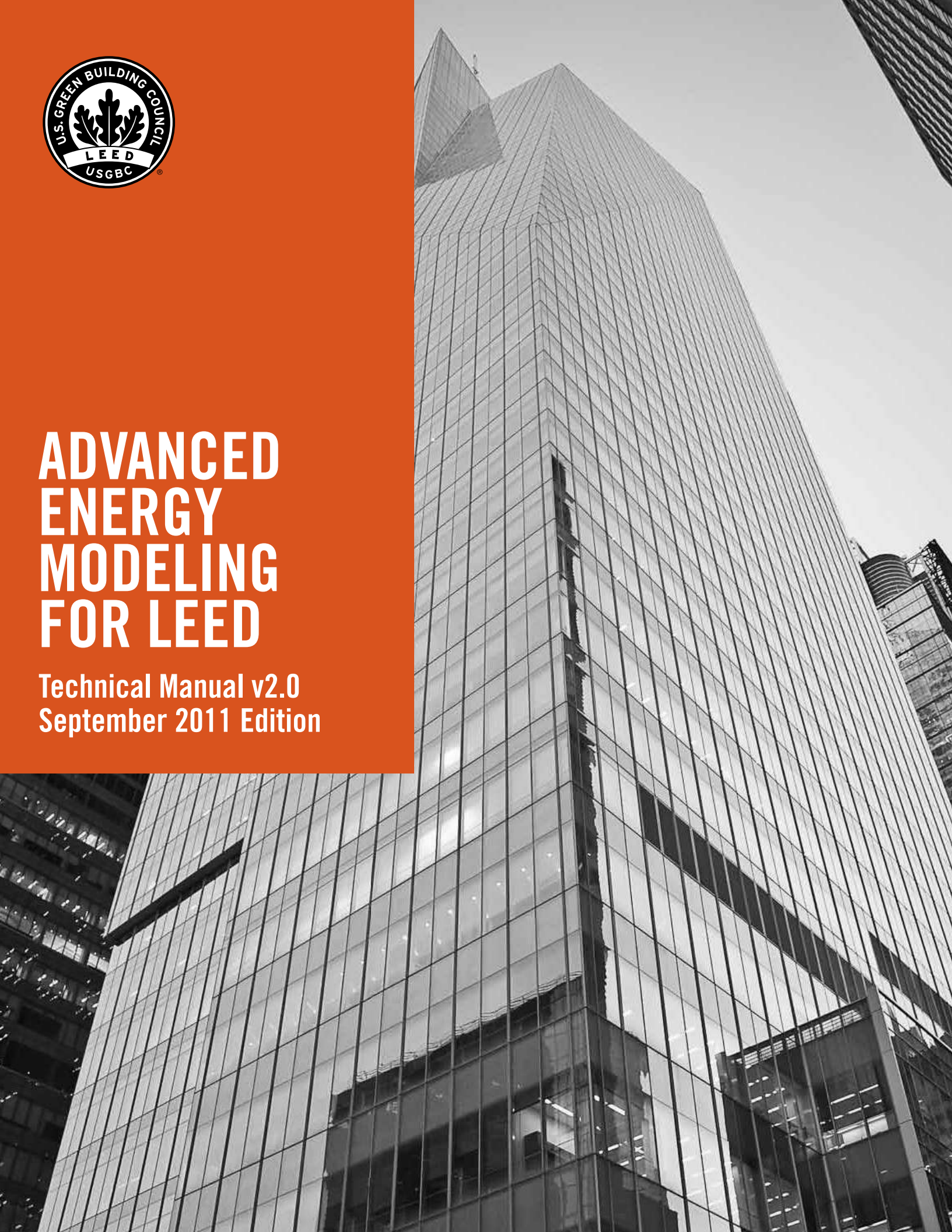

ADVANCED ENERGY MODELING FOR LEED

Technical Manual v2.0
September 2011 Edition

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Applicable to LEED for New Construction & Major Renovations v2009, LEED Core & Shell v2009, LEED for Schools 2009, and LEED for Commercial Interiors v2009.

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PREFACE

Energy performance is a critical element of integrated design for green buildings. The LEED Rating System acknowledges its importance with the minimum efficiency requirements associated with Energy and Atmosphere Prerequisite 2, Minimum Energy Performance, and the significant emphasis on points assigned to Energy and Atmosphere Credit 1, Optimize Energy Performance.

Demonstrating compliance for EA Prerequisite 2 and EA Credit 1 has been challenging for project teams because of the complexity of the referenced standards, energy codes, and energy modeling. Historically, USGBC has observed a significant variation in the approach, documentation, and level of information from applicants for this credit, making it one of the credits most often marked for clarification in LEED reviews.

This manual is intended to guide project teams and LEED reviewers on EA Prerequisite 2 and EA Credit 1 requirements and documentation. It offers further information on EA Prerequisite 2 and EA Credit 1, streamlines the LEED documentation process, and provides a greater degree of consistency for both applicants and reviewers. It elaborates on the information provided in the LEED rating systems, reference guides, LEED Interpretations, and other guidance published by USGBC. Its content is based on existing requirements as stipulated in the rating system and interpretations, but it is not considered a precedent-setting document. The rating system supersedes the content of this manual in case of any conflicts.

The intended users of this manual are both LEED reviewers and applicants with intermediate or advanced understanding of energy modeling, referenced standards, and energy codes.

The manual consists of five chapters and four appendixes. Readers may find certain sections in the manual particularly useful based on their degree of familiarity with the referenced standards, such as ASHRAE 90.1–2007, and their energy modeling skills. Critical tools and guidance for advanced users include the following:

- a comparative summary of energy modeling requirements for baseline and proposed design models for ASHRAE Standard 90.1–2007, Appendix G, and California Title 24-2005 (Chapter 2, Table 2.1);
- critical steps recommended for verification of energy savings for EA Prerequisite 2 and EA Credit 1 (Chapter 3, Figure 3.1);
- input quality control checklist, with common ASHRAE 90.1–2007 errors (Chapter 3, Table 3.1); and
- input-output consistency checklist (Chapter 3, Table 3.3).

CHAPTER 1.
INTRODUCTION

This chapter describes the scope and structure of the manual and summarizes the major changes between LEED v2.x rating systems and LEED 2009 as they relate to Energy and Atmosphere (EA) Prerequisite 2.

1.1. Scope

This manual provides guidance on how to prepare and review documentation for EA Prerequisite 2, Minimum Energy Performance, for the LEED for New Construction (NC) v2009, LEED for Core & Shell (CS) v2009, and LEED for Schools v2009 rating systems. It also covers the following prerequisites and credits that directly relate to EA Prerequisite 2 in these rating systems: EA Credit 1, Optimize Energy Performance; EA Credit 2, On-Site Renewable Energy; and EA Credit 6, Green Power.

The manual focuses on technical guidance for the performance compliance path (whole building energy simulation) and is based on the primary energy standards and codes used in the United States: ASHRAE Standard 90.1–2007 and California Title 24–2005. The user of this manual is expected to have an intermediate or advanced level of energy modeling skills and knowledge about the referenced codes and standards.

1.2. Structure

The manual is organized as follows:

- **Chapter 2,** Energy Performance Compliance Path Requirements, focuses on the requirements of the credit and provides guidance on how to use the referenced standards and applicable LEED Interpretations. It also introduces common energy simulation software programs used for documenting LEED compliance and describes their output reports.
- **Chapter 3,** Energy Performance Compliance Path Documentation and Review, provides detailed guidance on documenting and reviewing credits. Common errors made in LEED EA Credit 1 applications and quality control guidance relevant to both reviewers and applicants are also discussed.
- C**hapter 4,** Atypical Energy Systems and Scenarios, provides guidance on the variances presented by atypical scenarios, such as existing building expansions, multiple buildings on campus, exceptional calculations, district energy systems (DES), and combined heat and power (CHP) plants.
- **Chapter 5,** Related Credits, addresses the review and documentation of two credits directly related to EA Credit 1: EA Credit 2, On-Site Renewable Energy; and EA Credit 6, Green Power.

1.3. LEED EA Prerequisite 2 Compliance Paths

To achieve LEED EA Prerequisite 2, project teams can choose to demonstrate compliance through one of three options: performance (Option 1) or prescriptive (Options 2 or 3). This manual focuses on the performance compliance path (Option 1), which requires a whole building energy simulation.

Table 1.1. LEED EA Prerequisite 2 and EA Credit 1 Compliance Paths

Rating System	Prescriptive compliance path	Performance compliance path
LEED-NC v2009, LEED-CS v2009	1. Option 2: Comply with prescriptive measures of Advanced Energy Design Guide for Small Office Buildings 2004, Advanced Energy Design Guide for Small Retail Buildings 2006, or Advanced Energy Design Guide for Small Warehouses and Self Storage Buildings 2008; or 2. Option 3: Comply with prescriptive measures in Advanced Buildings Core Performance Guide.	Option 1: Conduct whole building energy simulation, using either 1. Building Performance Rating Method in ASHRAE 90.1–2007, Appendix G and addenda; or 2. California Title 24–2005, Part 6.
LEED for Schools v2009	1. Option 2: Comply with prescriptive measures in Advanced Energy Design Guide for K–12 Schools; or 2. Option 3: Comply with prescriptive measures in Advanced Buildings Core Performance Guide.	

CHAPTER 2.
ENERGY PERFORMANCE COMPLIANCE PATH REQUIREMENTS

Project teams can achieve Energy and Atmosphere (EA) Prerequisite 2, Minimum Energy Performance, and EA Credit 1, Optimize Energy Performance, through the energy performance compliance path in the LEED rating system. This compliance path requires projects to perform a whole building energy simulation to demonstrate energy savings over a baseline established by a referenced standard. This chapter focuses on the credit requirements and provides guidance on the following:

- the use of the referenced standards and applicable codes as approved by USGBC, with information on applicable addenda;
- energy modeling requirements for the baseline and proposed design cases for the different rating systems addressed by this manual;
- approved simulation software and reports reviewed for this credit; and
- significant and relevant LEED Interpretations published by USGBC.

2.1. Referenced Standards

ASHRAE 90.1–2007 is the technical standard referenced as a basis for the energy performance credits in LEED for New Construction (NC) v2009, LEED for Core & Shell (CS) v2009, and LEED for Schools v2009. Projects following the whole building energy simulation compliance path can demonstrate improvement in energy performance using the building performance rating method detailed in Appendix G of this standard. Projects in California that elect to conduct a whole building energy simulation for EA Credit 1 may use Title 24–2005 to determine the energy savings.

2.1.1. ASHRAE 90.1–2007

ASHRAE Standard 90.1–2007 is an industry standard that provides minimum requirements for the energy-efficient design of commercial buildings and criteria for determining compliance with these requirements. The performance rating method in Appendix G is "provided for those wishing to use the methodology to quantify performance that substantially exceeds the requirements of Standard 90.1" (ASHRAE 2007). This manual is written for users with intermediate or advanced understanding of ASHRAE 90.1–2007, Appendix G, and will therefore not address every detail.

Note: *Projects using Appendix G also need to comply with all the minimum requirements noted in the ASHRAE 90.1–2007 standard. All LEED projects must comply with the mandatory provisions in ASHRAE Standard 90.1–2007: Sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4.*

The protocol for building each of these models is detailed in ASHRAE 90.1–2007, Appendix G, Table G3.1. Appendix G also defines the requirements for the modeling software used to simulate energy use, the climate zones and weather data, the necessary energy simulation runs, and the energy savings calculation protocol. Most projects attempting EA Credit 1 adopt the performance compliance path and use Appendix G.

Frequently, EA Credit 1 applications use ASHRAE 90.1–2007 addenda. Project teams are permitted to use the addenda in the most recent supplement of the referenced ASHRAE standard, as well as any approved addenda published between supplements. Project teams must notify LEED reviewers of the use of ASHRAE addenda when submitting documentation. Also, if a project team elects to apply requirements in an addendum, the entire addendum must be applied; this addendum must also be applied to all other relevant credits in the LEED submittal.

Appendix A of this manual lists the standard's Appendix G addenda that affect achievement of EA Credit 1.

2.1.2. California Title 24–2005

Title 24, Part 6, of the California Code of Regulations, titled Energy Efficiency Standards for Residential and Nonresidential Buildings, responds to a legislative mandate to reduce California's energy consumption. The standards are updated periodically to allow consideration and possible incorporation of new energy efficiency technologies and methods. The standard referenced in LEED-NC v2009, LEED-CS v2009, and LEED for Schools v2009 is Title 24–2005. Project teams may elect to use Title 24–2008 instead; however, the percentage improvement thresholds for achieving minimum compliance with EA Prerequisite 2 and for achieving additional points under EA Credit 1 are identical for projects documented using Title 24–2005 and for projects documented using Title 24–2008.

The standard applies to all buildings that are heated and/or mechanically cooled and are defined under the Uniform Building Code as A, B, E, H, N, R, or S occupancies, except registered historical buildings, institutional buildings (including hospitals), and prisons. Local governmental agencies can modify the state energy standard to be more stringent when documentation is provided to the California Energy Commission.

The 2005 Building Energy Efficiency Standard (2005 BEES) is documented in the Non-residential Compliance Manual. The Non-residential Alternative Calculation Method (ACM) Approval Manual for the 2005 BEES is a related document specifying the computer software to be used for compliance purposes.

Title 24 users can find the code requirements for the baseline model in the 2005 Building Energy Efficiency Standards and the Non-residential Alternative Calculation Method (ACM) Approval Manual. However, the qualified simulation program used for this purpose can automatically generate the baseline and calculate the performance of a project in compliance mode. This manual will therefore not address the detailed modeling requirements of Title 24 but instead summarize its major differences with ASHRAE 90.1–2007, Appendix G.

Equivalency to ASHRAE 90.1–2007

Title 24–2005 is deemed to be directly equivalent to ASHRAE 90.1–2007 by USGBC for projects in California for the purpose of certification of EA Prerequisite 2 and EA Credits 1, 2, and 6. Projects in California may still elect to use ASHRAE 90.1–2007 instead of Title 24–2005. However, once the Title 24 or ASHRAE path is chosen, it must be used consistently for the prerequisite and credits listed above. Projects do not need to provide justification or support of Title 24–2005 equivalence when applying for LEED-NC v2009, LEED-CS v2009, or LEED for Schools v2009 certification.

2.2. Energy Modeling Requirements

The methodology described in ASHRAE 90.1–2007, Appendix G, and California Title 24–2005 involves the generation of two energy models: one representing a baseline minimum-standard building and the other representing the proposed building with all its designed energy enhancements.

Table 2.1 summarizes the three referenced standards' modeling requirements for typical projects. Since project specific information may vary, project teams should refer to the referenced standard for all applicable details and modeling requirements. LEED-CS, LEED for Schools, LEED for Commercial Interiors (CI), LEED for Retail (NC and CI), and LEED for Healthcare are identical to LEED-NC except as noted in this table. For LEED-CI projects, the simulation should use either the energy cost budget method or the Appendix G performance rating method. If served by a common building HVAC system, a LEED-CI project should include both the project space and the building segment that uses the common HVAC system.

Table 2.1. Comparison of Modeling Requirements for ASHRAE 90.1–2007 and California Title 24–2005

ASHRAE 90.1–2007		California Title 24–2005	
Baseline Case	**Proposed Case**	**Baseline Case**	**Proposed Case**
Schedule of Operation			
Same as proposed design. **Exception:** Schedule may differ from proposed design if proposed design is implementing some nonstandard efficiency measures.	Use actual operating hours for schedule of operation in proposed design. **Exception:** Schedules can be modified if schedule changes are necessary to model nonstandard efficiency measures, such as lighting controls, natural ventilation, demand control ventilation, or service water heating load reductions (Table G3.1.4). Describe any schedule of operation differences between baseline and proposed cases. Follow modeling guidance in Chapters 3 and 4 of this manual. **LEED-CI** Follow Table 11.3.1. 4 or Table G3.1.4 of ASHRAE 90.1–2007 when field verification cannot be obtained.	Same as proposed design. Automatically modeled in compliance mode.	Use default Title 24 schedules for heating, cooling, fans, lighting, receptacle loads, etc.
Orientation			
Four baseline design simulations are required for generating baseline building performance. Models are identical except that building orientation for each model is modified as described in Table G3.5.1(a), and window solar heat gain coefficients are revised to reflect minimum ASHRAE building envelope requirements for revised building orientation.	Model proposed design (with minor exceptions).	Same as proposed design. Automatically modeled in compliance mode. Simulations of four orientations are not required.	Model building orientation as designed.

Table 2.1. Comparison of Modeling Requirements for ASHRAE 90.1–2007 and California Title 24–2005 (continued)

ASHRAE 90.1–2007		California Title 24–2005	
Baseline Case	**Proposed Case**	**Baseline Case**	**Proposed Case**
Building Envelope			
Model building envelope using Table G3.1.5. **New buildings:** Model above-grade walls, roof, and floor assemblies using lightweight assembly types (i.e., steel-framed walls, roofs with insulation entirely above deck, and steel-joist floors). Match values with appropriate assembly maximum U-factors in Tables 5.5.1–5.5-8. **Existing buildings:** Model building envelope using existing (pre-retrofit) building envelope thermal parameters rather than referenced standard's prescriptive building envelope requirements for specified climate. Existing buildings with less than 50% renovations should not be rotated, since building orientation is considered an existing condition. **LEED-CI** For envelope components inside project space, use existing envelope conditions for existing components and use ASHRAE mandatory and prescriptive requirement for any upgraded envelope components. Rest of envelope should be modeled as is, identically to proposed case. *Alternative baseline case:* Use G3.1.5 (Appendix G method) or Table 11.3.1.5 (energy cost budget method) for entire baseline segment.	Model building components as shown in architectural drawings. Model any exceptions using Table G3.1.5. **Existing buildings:** Include any renovations in existing building envelope (such as replacing windows or increasing roof insulation). **LEED-CI** Use proposed design of project space, and use existing envelope conditions for rest of modeled building segment.	Automatically modeled in compliance mode 2. **Major difference from ASHRAE 90.1–2007** Assembly U-values are typically higher than default ASHRAE assembly U-values, especially for wall assemblies. Same framing type typically used in baseline and proposed cases. All west-facing glazing that is greater than 40% of wall area must be modeled as opaque surface, even if overall window-to-wall ratio is less than 40%. **Note:** Model existing buildings as for new construction or use ASHRAE 90.1–2007, since Title 24 has no specific category for major renovations.	Model building components as shown in architectural drawings or as built for existing building envelopes.

Table 2.1. Comparison of Modeling Requirements for ASHRAE 90.1–2007 and California Title 24–2005 (continued)

ASHRAE 90.1–2007		California Title 24–2005	
Baseline Case	**Proposed Case**	**Baseline Case**	**Proposed Case**
Building Envelope (continued)			
Match percentage of vertical fenestration in proposed design, or use 40% of gross wall area, whichever is smaller. Distribute windows on each face of building in same proportion as in proposed design (e.g., if proposed case has overall window-to-wall ratio of 60%, and baseline case has overall window-to-wall ratio of 40%, determine area of each baseline case window by using corresponding proposed case window multiplied by ratio of overall window-to-wall ratio for baseline versus proposed case:(40% / 60% = 2/3). Fenestration U-factor must match appropriate requirements in Tables 5.5-1 through 5.5-8.	Model fenestration location and its properties (U-value, solar heat gain coefficient, and transmittance) as shown on architectural drawings.		
Use fixed vertical glazing in baseline design, flush to exterior wall with no shading projections. Do not model manually controlled interior shading devices, such as blinds or curtains, in baseline design.	Shading projections to reduce solar gain may be modeled to demonstrate energy savings compared with baseline. Do not model manually controlled interior shading devices, such as blinds and curtains. Automatically controlled interior shading devices may be modeled, as per Appendix G.		
Model all roof surfaces with reflectivity of 0.30.	"Cool roofs" (light-colored roof finishes that have low heat absorption) may be modeled to show reduced heat gain. Model proposed roof with solar reflectance greater than 0.70 and emittance greater than 0.75 with reflectivity of 0.45 (accounting for degradation in actual reflectivity) versus default reflectivity value of 0.30.		

Table 2.1. Comparison of Modeling Requirements for ASHRAE 90.1–2007 and California Title 24–2005 (continued)

ASHRAE 90.1–2007		California Title 24–2005	
Baseline Case	**Proposed Case**	**Baseline Case**	**Proposed Case**
Lighting Systems			
Model lighting using building area (Section 9.5) or space-by-space (Section 9.6) method depending on proposed design categorization. If using building area method (9.5), each distinct building function should be modeled based on building area allowance for that building function (e.g., office or retail or parking garage). Baseline design model should also include exterior lighting power allowance (9.4.5). Lighting in multifamily living units should be modeled identically in baseline and proposed cases, based on proposed case lighting power allowance. **LEED-CS** Model lighting power in core and shell areas as determined by space type classification in Table 9.6.1. For tenant spaces, model separate electric meters for lighting in core building and tenant spaces. Use lighting power allowances for each space as indicated in Section 9.6.1. **LEED-CI** Use either Section 9.5 or 9.6 for project space; use same values in proposed model for rest of modeled building segment. *Alternative baseline case:* Use either Section 9.5 or 9.6 for entire modeled building segment. Include lighting system in model but omit cost from calculation for energy reduction.	Model proposed design with installed lighting power density. If using space-by-space method, model interior lighting power density as designed for each thermal block. Account for all installed lighting on site, including interior ambient and task lighting, parking garage lighting, and exterior lighting. **LEED-CS** Model proposed design with installed lighting power density and account for all installed lighting on site, including interior ambient and task lighting, parking garage lighting, and exterior lighting. For project areas where no lighting system has been specified, model lighting identically in both baseline and design cases as minimally code compliant according to building area method, using appropriate space type classification in Table 9.6.1. For tenant spaces, model separate electric meters for lighting in core building and tenant spaces. If tenant lighting is designed or installed, use as-designed values; otherwise classify space types for building spaces and use lighting power allowances for each space as indicated in Section 9.6.1. **LEED-CI** Use proposed design for project space, and use field-verified lighting for rest of modeled building segment. Include lighting system in model but omit cost from calculation for energy reduction.	Automatically modeled in compliance mode 2. **Major difference from ASHRAE 90.1–2007** Exterior lighting and unconditioned lighting must be added to analysis manually unless LEED compliance module from software developer allows user to add exterior lighting and unconditioned lighting. Multiply total power with equivalent full-load hours (EFLHs). Title 24 provides allowance for general site illuminance, per 2005 BEES Table 147-A. This is tradable within its own category. Credit may be taken for improved efficiency. Title 24 also provides allowance for specific applications in 2005 BEES Table 147-B. Credit may not be taken for improved efficiency. **LEED-CS** Same as ASHRAE 90.1–2007.	Model lighting system as designed. **Major difference from ASHRAE 90.1–2007** 0.20 W/sf portable lighting must be modeled in open office spaces whose portable lighting design is not completed. Different lighting power savings allowance: 10% to 20% for occupancy sensors. Exterior lighting and unconditioned lighting must be manually added to analysis; multiply total power times equivalent full-load hours. **LEED-CS** Same as ASHRAE 90.1–2007.
Do not take credit for automatic lighting controls, such as daylight controls, occupancy controls, or programmable controls.	Model any daylight-responsive lighting control systems in proposed design. Also model occupant sensor lighting controls (Table G3.1, No. 6) in spaces where they are not mandatory; note that such controls are mandatory in classrooms, conference rooms and employee lunch and break rooms (Section 9.4.1.2).		
Lighting exempted from interior lighting power allowance is classified as process energy and must be identical to proposed case.	Model lighting exempted from interior lighting power allowance; include this lighting under process energy (Table G.3.1.6).		

Table 2.1. Comparison of Modeling Requirements for ASHRAE 90.1–2007 and California Title 24–2005 (continued)

ASHRAE 90.1–2007		California Title 24–2005	
Baseline Case	**Proposed Case**	**Baseline Case**	**Proposed Case**
HVAC System Selection			
Determine HVAC system type using actual building area, usage, number of floors, occupancy (residential or nonresidential), and heating fuel source, per Tables G3.1.1A and G3.1.1B. As per G3.1.1, use same baseline HVAC system type for entire building except for specific exceptions listed in G3.1.1: (a) nonpredominant conditions if they apply to more than 2,000 square feet of building area; (b) spaces with significant variances in process loads or occupancy schedules; (c) spaces with special pressurization or cross-contamination requirements that preclude use of variable air volume (VAV); or (d) laboratory spaces. System types 1–4 should be modeled with one system per thermal block. System types 5–8 should be modeled with one system per floor, except that floors with identical blocks can be grouped together. **LEED-CI** If project involves no modifications to central plant or if only auxiliary components of central plant, such as pumps, have been upgraded, replace changed central plant components with mandatory and prescriptive equivalent of ASHRAE 90.1–2007, and change items within project area to mandatory and prescriptive requirements of standard. Model rest of building segment using existing conditions same as proposed case. • Appendix G method: Determine HVAC system type following Tables G3.1.1A and G3.1.1B, based on LEED CI project area and other parameters noted above. • Energy cost budget method: Determine HVAC system type following Figure 11.3.2 and Table 11.3.2A based on HVAC system serving project space.	Use proposed design HVAC system type and quantities. If no cooling system has been specified, model design case cooling system identically to baseline cooling system. **Exception:** Heated-only storage spaces that follow exception for modeling baseline system types 10 or 11 from ASHRAE 90.1–2007 Addendum dn or types 9 or 10 from ASHRAE 90.1–2010 should be modeled as designed, as heated-only systems. If no heating system has been specified, assume electric heating. For project areas without heating or cooling systems (e.g., parking garages), no air-conditioning systems should be modeled in either proposed or baseline designs; any fans should be modeled identically in baseline and proposed cases as process loads unless exceptional calculation method is used. **LEED-CS** Model building system as described in design documents. If HVAC system is not yet designed, use same HVAC system as baseline case. **LEED-CI** Use proposed design of project space, and use field-verified HVAC system information for any existing central plant.	Automatically modeled in compliance mode. **Major difference from ASHRAE 90.1–2007** Baseline HVAC system is selected based on number of floors, occupancy type, proposed design HVAC system type (multi- or single zone), and heating fuel. No credit or penalty for efficient duct design and low fan static pressure, unless maximum requirements are exceeded. No credit or penalty for limiting pump head. Reporting unmet load hours is not required if EnergyPro compliance mode is used. Unmet load hour requirement is less than 10% unmet load hours (876 hours per year).	Proposed design HVAC system type and quantities should reflect actual design. **Major difference from ASHRAE 90.1–2007** Reporting unmet load hours is not required if EnergyPro compliance mode is used. Unmet load hour requirement is less than 10% unmet load hours (876 hours per year).

Table 2.1. Comparison of Modeling Requirements for ASHRAE 90.1–2007 and California Title 24–2005 (continued)

ASHRAE 90.1–2007		California Title 24–2005	
Baseline Case	**Proposed Case**	**Baseline Case**	**Proposed Case**
HVAC System Selection (continued)			
If extensive modifications to central plant are included in proposed case, use one of following methods: • Appendix G method: Determine HVAC system type following Tables G3.1.1A and G3.1.1B, based on CI project area and other parameters noted above. • Energy cost budget method. Determine HVAC system type following Figure 11.3.2 and Table 11.3.2A based on central HVAC system in proposed case. *Alternative baseline case:* • Appendix G method: Determine HVAC system type following Tables G3.1.1A and G3.1.1B, based on entire modeled segment area and other parameters noted above. • Energy cost budget method: Determine HVAC system type following Figure 11.3.2 and Table 11.3.2A based on HVAC system serving entire modeled segment area.			
HVAC equipment capacities for baseline system should be oversized 15% for cooling and 25% for heating (G3.1.2.2 and G3.1.2.2.1). **LEED-CI** • Appendix G method: Same as above. • Energy cost budget method: Size HVAC proportionally to capacities in proposed design based on sizing runs.	Proposed design HVAC system should reflect actual design capacities and system efficiencies.		
Unmet load hours (occupied periods where any zone is outside its temperature setpoints) may not be exceeded by more than 300 hours. Also, unmet load hours for proposed design may not exceed unmet load hours for baseline design by more than 50 (G3.1.2.2). **LEED-CI** • Appendix G method: Same as above. • Energy cost budget method: Unmet load hours should not differ by more than 50 hours between two cases.	Same as baseline case.		

Table 2.1. Comparison of Modeling Requirements for ASHRAE 90.1–2007 and California Title 24–2005 (continued)

ASHRAE 90.1–2007		California Title 24–2005	
Baseline Case	**Proposed Case**	**Baseline Case**	**Proposed Case**
HVAC System Selection (continued)			
Outdoor ventilation rates should be identical to proposed case.	Proposed design should reflect actual outdoor ventilation rates.		
Operate fan continuously when spaces are occupied and cycle it during unoccupied hours, except for spaces that have mandated minimum ventilation requirements, where fan must remain on during unoccupied hours for health and safety reasons (G3.1.2.4). Baseline system fan supply air volume should be based on a supply-air-to-room-air temperature difference of 20°F or required ventilation or makeup air, whichever is greater (G3.1.2.8). Use this supply air volume to calculate total fan power for baseline system design (G3.1.2.9). This value reflects sum of power modeled for supply, exhaust, return, and relief fans. **LEED-CI** • Appendix G method: Same as above. • Energy cost budget method: Fan operation is same as proposed case. Fan system bhp/cfm should be same as proposed case or up to limit in Section 6.5.3.1, whichever is smaller.	Proposed HVAC design should reflect actual fan operation, fan supply rate, and fan motor horsepower.		
Fan energy must be separated from cooling system. Overall efficiency rating, such as energy efficiency ratio, must be separated into component energy using coefficient of performance or other conversion (Equations G-A, G-B, and G-C, ASHRAE 90.1–2007 User's Manual, pp. G-24, G-26). Note that fan power is broken out from cooling energy at AHRI conditions and does not necessarily correspond to installed fan power at design conditions.	Same as baseline case.		
Model economizers and exhaust air energy recovery systems in baseline HVAC systems when required for given climate zone and system parameters (G3.1.2.6 and G3.1.2.10).	Include economizers if indicated in actual design parameters.		

Table 2.1. Comparison of Modeling Requirements for ASHRAE 90.1–2007 and California Title 24–2005 (continued)

ASHRAE 90.1–2007		California Title 24–2005	
Baseline Case	**Proposed Case**	**Baseline Case**	**Proposed Case**
HVAC System Selection (continued)			
Follow HVAC system-specific requirements (chillers, boilers, heat pumps) as indicated in G.3.1.3. **LEED-CI** • Appendix G method: Same as above. • Energy cost budget method: Follow HVAC system specific requirements indicated in notes for Table 11.3.2A.	System-specific requirements should reflect actual conditions. **LEED-CS** System-specific requirements should reflect actual conditions. If system-specific requirements are not specified, model HVAC system identically to baseline case.		
Process Energy*			
Process loads must be identical to proposed case. Occupancy and occupancy schedules may not be changed. However, variations of power requirements, schedules, or control sequences are allowed based on documentation that installed equipment in proposed design represents significant, verifiable departure from conventional practice, using exceptional calculation method. **LEED-CS** For tenant spaces, model separate meters for tenant plug loads and process loads. Use values indicated in Table G-B to model tenant plug loads or provide documentation for modeled loads. **LEED-CI** Model process energy identically to proposed building, but exclude cost from calculation. If EAc1.4 is pursued, the plug load may be modeled using a higher plug load value reflecting the occupancy type within the project space and existing plug load values for the balance of the segment. *Alternative baseline case:* Use a higher plug load value reflecting occupancy type for entire segment area.	ASHRAE 90.1–2007 User's Manual, Table G-B, provides acceptable receptacle power densities for typical occupancy types, which can be incorporated into building energy models when proposed building occupancy type matches occupancy shown in Table G-B but actual projected building loads are unknown. Model other process energy inputs (e.g., elevators, escalators, data center and telecom room computing equipment, refrigeration, process lighting, and non-HVAC motors) based on actual power requirements, assuming reasonable schedules of operation. Total process energy cost must be at least 25% of baseline building performance. If process energy cost is less than 25%, provide substantiating documentation. **LEED-CI** Use actual process loads in project space, and use field-verified loads for rest of building segment. Omit cost from calculation for energy reduction. **Exception:** End-uses excluded in Sections 13 and 14 of Table 11.3.1 (e.g., exhaust fans, parking garage ventilation fans, swimming pool heaters and pumps, elevators and escalators, refrigeration and cooking equipment) may be excluded.		Process loads must be identical to baseline case. Process energy use should be at least 25% of baseline building total. If less than 25%, provide substantiating documentation. **LEED–CS** Same as ASHRAE 90.1–2007.

Table 2.1. Comparison of Modeling Requirements for ASHRAE 90.1–2007 and California Title 24–2005 (continued)

ASHRAE 90.1–2007		California Title 24–2005	
Baseline Case	**Proposed Case**	**Baseline Case**	**Proposed Case**
Process Energy* (continued)			
LEED for Retail-NC Exceptional calculation method may be used to document measures that reduce process loads. Project teams can use spreadsheet calculators provided in LEED Online to calculate process energy savings for commercial kitchen equipment and refrigeration equipment. These calculators include many industry standard baseline conditions that have been defined in Tables 1–4 in LEED for Retail-NC v2009. For equipment not covered in Tables 1–4, describe and document clear baseline to compare proposed improvements in process load categories.			
Energy Rates			
Use same rates for both baseline and proposed cases. **LEED-CS** For tenant spaces, energy-using components are metered and apportioned and/or billed to tenant. Tenant pays for components.	Rates from local utility schedules are default option for computing energy costs. However, intent is to encourage simulations that help owners minimize energy costs. If local utility rate schedule (or energy rate schedule approved by local ASHRAE 90.1–2007 adopting authority) is unavailable, use energy rates listed in state average prices, published annually by Energy Information Administration (http://www.eia.doe.gov). Whichever source is used, model same rate schedule in both baseline and proposed cases; if average EIA rates are used, apply them for all fuel types in model.		Rates from local utility schedules are default option. If local utility rate schedule is unavailable, use state average energy prices published by EIA for commercial building customers; if average EIA rates are used, apply them for all fuel types in model. **LEED-CS** Same as ASHRAE 90.1–2007.
Service Hot Water System			
Use same energy sources as proposed building. Model system-related specific parameters as indicated in Table G3.11. **LEED-CI** May be modeled, but omit cost from calculation for energy reduction.	Reflect actual system installed or designed. Meet mandatory provisions in Section 7.4. **LEED-CI** May be modeled, but omit cost from calculation for energy reduction.		Reflect actual system installed or designed. **Major difference from ASHRAE 90.1–2007** For high-rise residential or lodging uses, domestic water heating consumption from UTIL-1 report must be multiplied by virtual utility rate to calculate energy cost.

** Process energy includes office and general miscellaneous equipment, computers, elevators and escalators, kitchen cooking and refrigeration, laundry washing and drying, lighting exempt from lighting power allowance (e.g., lighting integral to medical equipment), and other (e.g., waterfall pumps).*

EAc1 = Energy and Atmosphere Credit 1

2.3. Simulation Software

2.3.1. ASHRAE Standard 90.1–2007 Qualified Simulation Software

ASHRAE 90.1–2007, Section G2.2.1, requires that a qualified simulation program explicitly model all of the following:

- 8,760 hours per year;
- hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat setpoints, and HVAC system operation;
- thermal mass effects;
- 10 or more thermal zones;
- part-load performance curves for mechanical equipment;
- capacity and efficiency correction curves for mechanical heating and cooling equipment;
- air-side economizers with integrated control; and
- baseline building design characteristics specified in ASHRARE 90.1–2007, Appendix G, Section 3.

The simulation program must be able either to directly determine the proposed energy use and code baseline energy use or to produce hourly reports of energy use, by energy source, suitable for determining the proposed energy use and code baseline energy use using a separate calculation engine.

The simulation program must also be capable of performing design load calculations to determine required HVAC equipment capacities and airflow and water flow rates in accordance with generally accepted engineering standards and handbooks (e.g., *ASHRAE Handbook of Fundamentals*) for both the proposed building design and the code baseline building design.

The simulation program must include calculation methodologies for the building components being modeled. For components that cannot be modeled by the simulation program, the exceptional calculation method requirements in Section G2.5 may be used. In addition, a thermodynamically similar component model that can approximate the expected performance of the component may be substituted (see Table G3.1.13).

Commonly used modeling software packages for ASHRAE 90.1–2007, Appendix G, include DOE-2-based modeling programs (eQuest, EnergyPro, and VisualDOE), TRACE, HAP, IES, VisualDOE, and EnergyPlus. This manual offers brief descriptions of these programs in Appendix B.

Energy modeling software packages have differing approaches for building the ASHRAE 90.1–2007 Appendix G baseline building model. In some cases, the baseline is automatically defined within the software, based on the proposed case inputs; in other cases the user follows prompts to build the baseline model using certain predefined input parameters built into the software program; in still other cases, the user must build the entire baseline model. In all cases, the modeler is encouraged to verify the baseline inputs in the software package against the baseline requirements of ASHRAE 90.1–2007 to confirm conformance to the Appendix G requirements before submitting the results for a preliminary LEED review.

Note: USGBC does not certify or formally approve simulation software packages for compliance with ASHRAE requirements or for generating an appropriate baseline model. As part of the LEED submittal, it is the responsibility of the project team to document that the building inputs for any software package conform to the baseline and proposed case modeling requirements listed in ASHRAE 90.1–2007, Appendix G, in accordance with the EA Prerequisite 2 submittal requirements.

2.3.2. California Title 24 Qualified Simulation Software

The current energy compliance software programs approved by California for use with the Title 24-2005 standards are EnergyPro and eQuest Compliance Module (D2comply 3.6, the DOE-2.2 component contained within eQUEST 3.6 to perform Title 24 compliance analysis) and Perform 2005. These programs can automatically generate the energy budget for the standard design and calculate the energy use of the proposed case after the design inputs are complete. However, some postprocessing or additional software modules may be required to include the additional energy

consumption required for LEED documentation (e.g., unconditioned lighting, exterior lighting, process loads) and to revise the metric to cost rather than time-dependent valuation (TDV) energy.

2.4. Key Output Reports

Information from the energy simulation software output reports is used to complete the LEED submittal template and calculate energy savings for EA Credit 1. This section highlights the output report parameters critical to the quality control process for credit compliance. The summary output reports provide information necessary for verification of the modeling results reported on the LEED submittal template.

Note: *Typically, the summary output reports contain information on energy use by end use, energy cost, and unmet load hours for both the baseline and the design case energy models.*

2.4.1. DOE-2 Simulation Software Output Reports

All the DOE-2 based simulation software programs can generate Building Energy Performance Summary (BEPS) reports, Building Energy Performance–Utility (BEPU) reports, and Energy Cost Summary (ES-D) reports. They are the most important output files provided as supplemental documentation for EA Credit 1 applications.

The BEPS and BEPU reports (Figure 2.1) summarize building energy performance in terms of end use by fuel type, total use by fuel type, and the energy use intensity. Both reports also display the percentage of hours that any system zone is outside throttling range and the percentage of hours that any plant load is not satisfied. The difference between them is that the BEPS report summarizes energy use in units of MBtu (million Btu), whereas the BEPU report presents it in the units of Therms and kWh.

The ES-D report (Figure 2-2) summarizes the energy use and energy cost by utility type, provides the virtual energy rate for each utility type, and reports the project's total energy cost. Since EA Credit 1 points are based on energy cost savings, the ES-D reports for the baseline and proposed buildings are the reports used to calculate the savings percentage and points achieved.

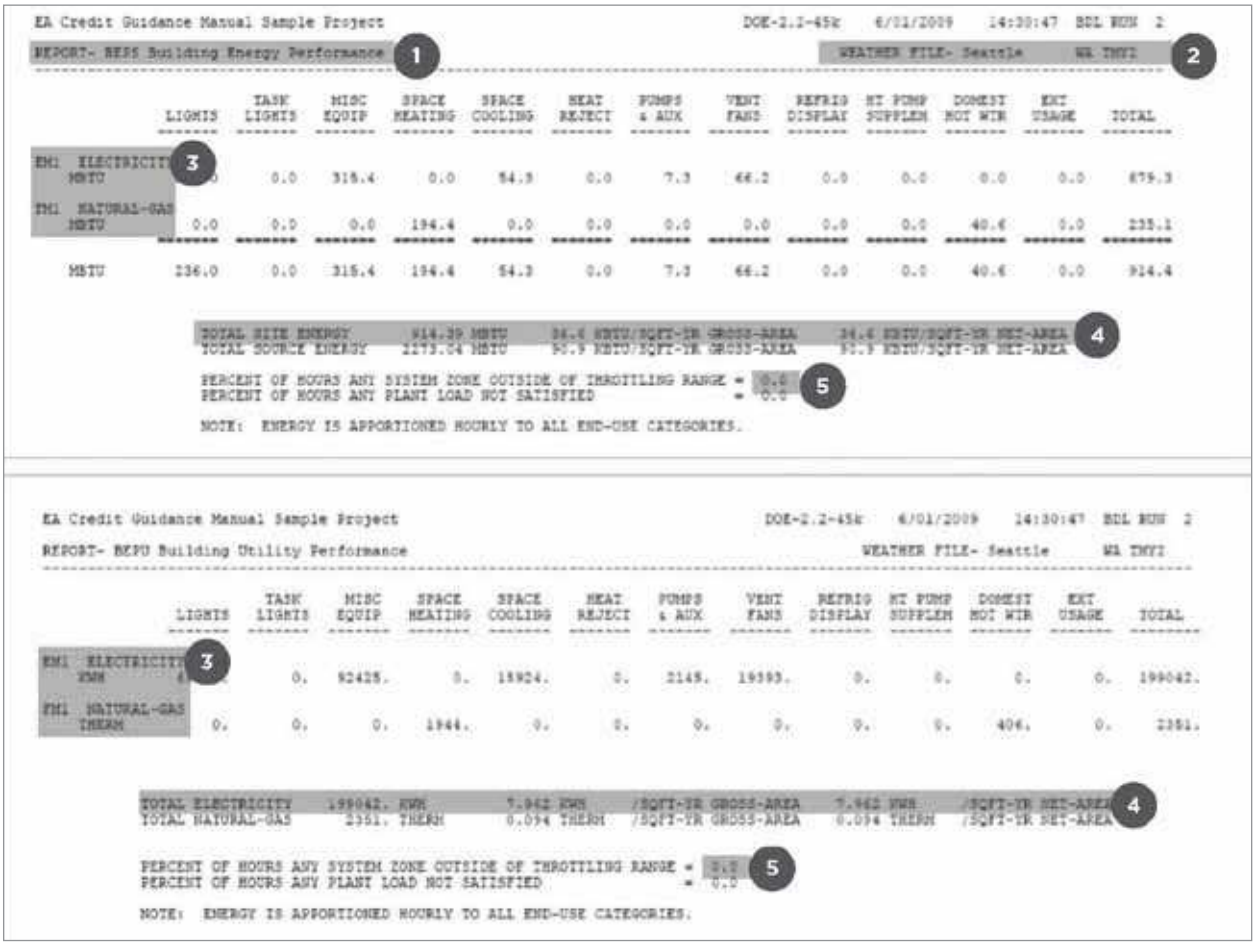
Highlights in Figure 2.1 correspond to the following:

1. BEPS and BEPU reports are building-level reports. The BEPS report includes only energy drawn or supplied across the building boundary—that is, energy provided by generators or photovoltaics is not included unless it "flows" through a utility meter (i.e., is supplied back to the utility grid). Strictly, the BEPS report does not report energy used within the building; rather, it reports energy "imported" into or "exported" from the building.
2. The weather file should be for the correct location. If the weather file for the project's exact location is not available, that for the closest available location is typically considered appropriate. If the selected weather file is not the closest available—for example, because of altitude or microclimate—an explanation for the selection is required.
3. The energy types shown are those specified with the ELEC-METER, FUEL-METER, STEAM-METER, and CHW-METER commands in PLANT.
4. Ensure that the site's energy use intensity (EUI) is reasonable for the building type and climate. Consult the Commercial Buildings Energy Consumption Survey (CBECS) database and the EnergyStar Target Finder database for comparables.
5. Check here for unmet load hours, defined as hours when one or more zones are out of the throttling range. The denominator used for this calculation is 8,760 unless the total run hours for the longest-operating air handler is reported (SS-R report). If this value is provided along with the SS-R DOE-2 output for that system, then that value may be used in place of 8,760. When 8,760 hours is used as the denominator, the percentage reported here should be less than 3.4% because the annual unmet load hours should not exceed 300. The number of unmet load hours for the proposed case should not exceed the number of unmet load hours for the baseline case by more than 50. That is, Proposed Case Unmet Load Hours <= Baseline Case Unmet Load Hours + 50.

Highlights from Figure 2.2 correspond to the following:

1. The ES-D report is also a building-level report.
2. Confirm that the virtual energy rates are reasonable.
3. Ensure that the energy cost per unit floor area is reasonable for the building type and climate (see item 4 under Figure 2.1).

Figure 2.1. Sample BEPS and BEPU Reports from eQuest[1]



EA Credit Guidance Manual Sample Project — DOE-2.2-45k 6/01/2009 14:30:47 BDL RUN 2

REPORT- BEPS Building Energy Performance — WEATHER FILE- Seattle WA TMY2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
FM1 ELECTRICITY MBTU	0	0.0	315.4	0.0	54.3	0.0	7.3	66.2	0.0	0.0	0.0	0.0	679.3
FM1 NATURAL-GAS MBTU	0.0	0.0	0.0	194.4	0.0	0.0	0.0	0.0	0.0	0.0	40.6	0.0	235.1
MBTU	236.0	0.0	315.4	194.4	54.3	0.0	7.3	66.2	0.0	0.0	40.6	0.0	914.4

TOTAL SITE ENERGY 914.39 MBTU 34.6 KBTU/SQFT-YR GROSS-AREA 34.6 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 2173.04 MBTU 82.3 KBTU/SQFT-YR GROSS-AREA 82.3 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 0.0
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.0

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

EA Credit Guidance Manual Sample Project — DOE-2.2-45k 6/01/2009 14:30:47 BDL RUN 2

REPORT- BEPU Building Utility Performance — WEATHER FILE- Seattle WA TMY2

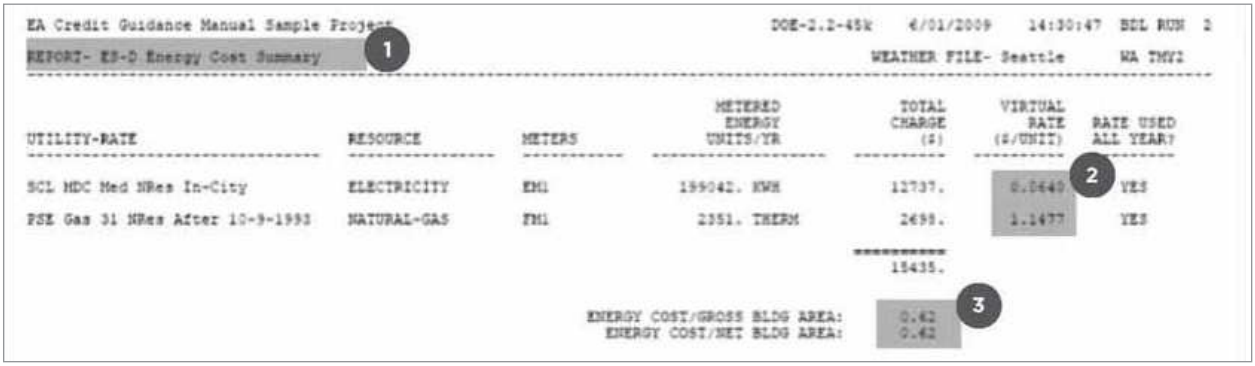
	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
FM1 ELECTRICITY KWH	0.	0.	92425.	0.	15924.	0.	2145.	19393.	0.	0.	0.	0.	199042.
FM1 NATURAL-GAS THERM	0.	0.	0.	1944.	0.	0.	0.	0.	0.	0.	406.	0.	2351.

TOTAL ELECTRICITY 199042. KWH 7.962 KWH /SQFT-YR GROSS-AREA 7.962 KWH /SQFT-YR NET-AREA
TOTAL NATURAL-GAS 2351. THERM 0.094 THERM /SQFT-YR GROSS-AREA 0.094 THERM /SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 0.0
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.0

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

Figure 2.2. Sample ES-D Reports from eQuest[2]



EA Credit Guidance Manual Sample Project — DOE-2.2-45k 6/01/2009 14:30:47 BDL RUN 2

REPORT- ES-D Energy Cost Summary — WEATHER FILE- Seattle WA TMY2

UTILITY-RATE	RESOURCE	METERS	METERED ENERGY UNITS/YR	TOTAL CHARGE ($)	VIRTUAL RATE ($/UNIT)	RATE USED ALL YEAR?
SCL MDC Med NRes In-City	ELECTRICITY	FM1	199042. KWH	12737.	0.0640	YES
PSE Gas 31 NRes After 10-9-1993	NATURAL-GAS	FM1	2351. THERM	2698.	1.1477	YES
				15435.		

ENERGY COST/GROSS BLDG AREA: 0.62
ENERGY COST/NET BLDG AREA: 0.62

1 Based on DOE-2.2 Reports and Modeling Quality Control Concepts, available at: http://doe2.com/download/eQUEST/DOE22Reports-and-QC_2001-06-07.zip

2 DOE-2.2 Reports and Modeling Quality Control Concepts, available at: http://doe2.com/download/eQUEST/DOE22Reports-and-QC_2001-06-07.zip

Additional DOE-2 reports that are often provided to verify building model input parameters include the following:

- Summary portion of LV-D report. Documents roof area and the window and above-grade wall areas per orientation, as well as the U-values for each input.
- SV-A report. Documents the fan supply volume and fan power at the system and zone level, as well as other system input parameters.
- PS-C report. Documents the plant equipment's energy consumption and the number of hours within each part load range.
- PS-E report: Documents the monthly and total annual energy consumption and demand per end-use.

2.4.2. Title 24 Output Reports

The current state-approved energy compliance software programs for use with California Title 24—2005, EnergyPro and eQuest Compliance Module, are both DOE-2-based software. These programs can generate DOE-2 reports and Title 24 report forms summarizing the modeling inputs and outputs.

The PERF-1, UTIL-1, and ECON-1 reports are the major forms required as backup documentation for EA Credit 1. DOE-2 outputs may be used to complete the EA Credit 1 submittal template and provide additional backup documentation.

- PERF-1 report. Provides summaries of Title 24 TDV energy consumption by end use, lighting power density, envelope inputs, and HVAC inputs for both baseline and proposed cases.
- UTIL-1 report. Summarizes electricity and fossil fuel consumption per end use. When residential domestic water heating is modeled, the value from the UTIL-1 report must be used rather than the ECON-1 report for fuel consumption, and the virtual natural gas rate must be used to add the residential water heating costs to the values reported in ECON-1.
- ECON-1 report. Summarizes economic outputs, including energy use and energy cost information for both cases.

Note: *The UTIL-1 and ECON-1 reports may be used only when the model is run in compliance mode. PERF-1, UTIL-1, and ECON-1 reports should not be used with eQuest, since the eQuest Savings by Design runs are completed using actual building schedules, versus Title 24 default schedules.*

2.4.3. HAP Output Reports

For LEED projects, the most important output report in Carrier's Hourly Analysis Program (HAP) v4.5 is the EA Credit 1 summary. This report mimics the format and content of the LEED credit form. If the project preference is set to "LEED 2009," the report will be formatted according to the LEED 2009 EA Prerequisite 2 credit form. The report contains the following information:

- energy use and peak demand by end-use component, and total energy use for the proposed building, all four baseline building orientations, and the baseline average;
- energy cost for the proposed building, all four baseline buildings, and the baseline average.
- unmet load hours for cooling and heating;
- energy-use intensity (energy per unit floor area);
- documentation of compliance with the 25% process energy cost requirement; and
- EA Credit 1 points earned.

In addition, the following HAP v4.5 reports provide useful information for documenting and troubleshooting LEED project results:

- Annual Cost Summary report. Lists the energy cost and energy cost per unit floor area by end use categories and as a total for the building.

- Energy Cost Budget by System Component report. Summarizes the energy use and energy use intensity (energy use per unit floor area) for end use categories and as a total for the building.
- Zone Temperature Report and Unmet Load Report (for air systems) and Unmet Load Report (for plants). Provide the raw data that are the basis for LEED unmet load hours reported on the EA Credit 1 summary report.
- Monthly Energy Use by Component report. Lists monthly energy use for end use categories on a building-wide basis (e.g., total indoor fan kWh by month). This information is helpful for understanding the relative energy consumption of major energy end uses.
- Monthly Air System Simulation Results and Monthly Plant Simulation Results reports. Provide monthly and annual energy use and load information for individual system and plant equipment components. This information is helpful for understanding the behavior of specific systems and plants in the building.

2.4.4. TRACE Output Reports

The most important summary output files for Trane Air Conditioning Economics (TRACE) are the Energy Cost Budget and the Energy Consumption Summary reports. The Energy Cost Budget report (Figure 2.3) compares the energy use and cost of the proposed case with those of the baseline building. Energy use is listed for the total building and by end use. The report also includes the numbers of unmet load hours for both cases. The Energy Consumption Summary report (Figure 2.4) summarizes the energy use in terms of fuel type.

Figure 2.3. Sample Energy Cost Budget Report from TRACE 700

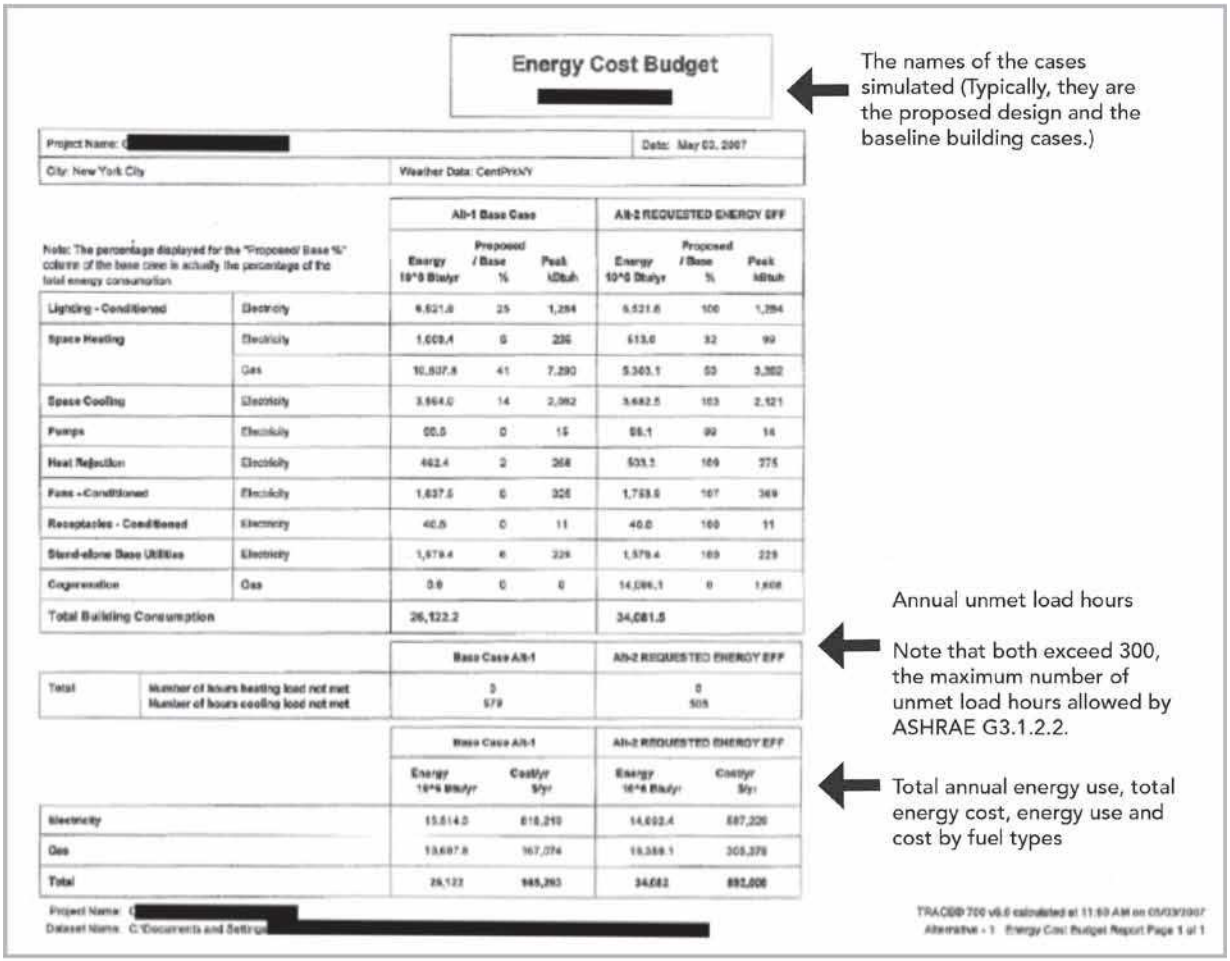
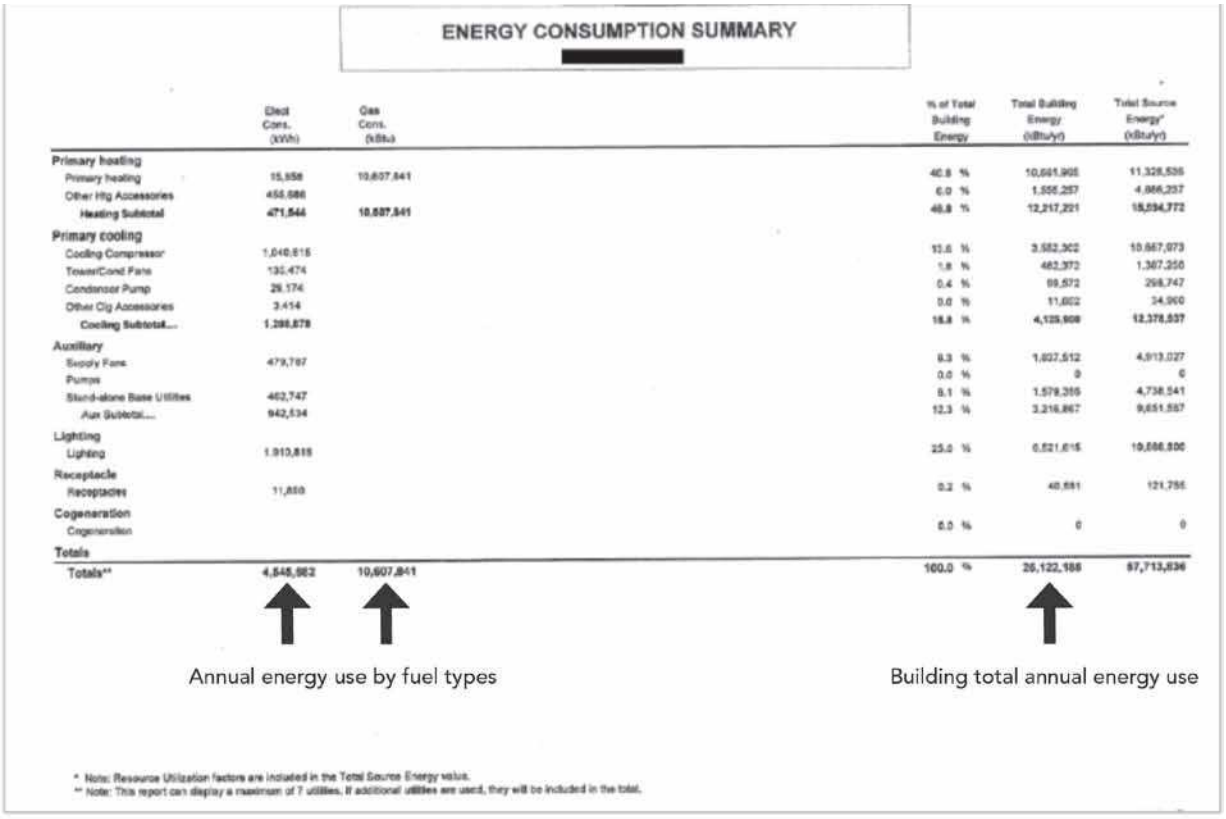


Figure 2.4. Sample Energy Consumption Summary Report from TRACE 700



ENERGY CONSUMPTION SUMMARY

[redacted]

	Elect Cons. (kWh)	Gas Cons. (kBtu)	% of Total Building Energy	Total Building Energy (kBtu/yr)	Total Source Energy* (kBtu/yr)
Primary heating					
Primary heating	15,858	10,607,841	40.8 %	10,661,905	11,328,535
Other Htg Accessories	455,986		6.0 %	1,555,257	4,866,237
Heating Subtotal	**471,844**	**10,607,841**	46.8 %	12,217,221	16,194,772
Primary cooling					
Cooling Compressor	1,040,815		13.6 %	3,552,302	10,667,073
Tower/Cond Fans	130,474		1.8 %	462,372	1,387,255
Condenser Pump	26,174		0.4 %	99,572	298,747
Other Clg Accessories	3,414		0.0 %	11,602	34,900
Cooling Subtotal....	**1,200,878**		15.8 %	4,125,908	12,378,037
Auxiliary					
Supply Fans	479,797		6.3 %	1,607,512	4,913,027
Pumps			0.0 %	0	0
Stand-alone Base Utilities	462,747		6.1 %	1,579,355	4,738,541
Aux Subtotal....	942,534		12.3 %	3,216,867	9,651,567
Lighting					
Lighting	1,913,815		25.0 %	6,531,615	19,596,800
Receptacle					
Receptacles	11,850		0.2 %	40,581	121,755
Cogeneration					
Cogeneration			0.0 %	0	0
Totals					
Totals**	4,545,982	10,607,841	100.0 %	26,122,188	57,713,836

Annual energy use by fuel types

Building total annual energy use

* Note: Resource Utilization factors are included in the Total Source Energy value.
** Note: This report can display a maximum of 7 utilities. If additional utilities are used, they will be included in the total.

2.4.5. IESVE Output Reports

The reports created by the Integrated Environmental Solutions (IES) VE-Navigator for ASHRAE 90.1 are designed to mirror the format required for EA Credit 1 submissions. They are available in an interactive html format, which facilitates quick interrogation and completion of the LEED credit form and supporting documentation.

A collection of reports produces output in accordance with EA Credit 1's Option 1: Performance Rating Method, including required "10-minute checklists":

1. General information
Project and model information, calculation data, weather file, climate data

2. Space summary
Conditioned area, unconditioned area, total area

3. Advisory messages
Number or hours heating/cooling loads not met, errors, warnings, overridden defaults

4. Comparison of proposed vs. baseline design energy model inputs
Construction, MEP, HVAC

5. Energy type summary
Utility types and rates

6. On-site renewable energy (if applicable)
Source, energy generated, capacity, energy cost

7. Exceptional calculation measure summary (if applicable)

8. Performance rating method compliance report

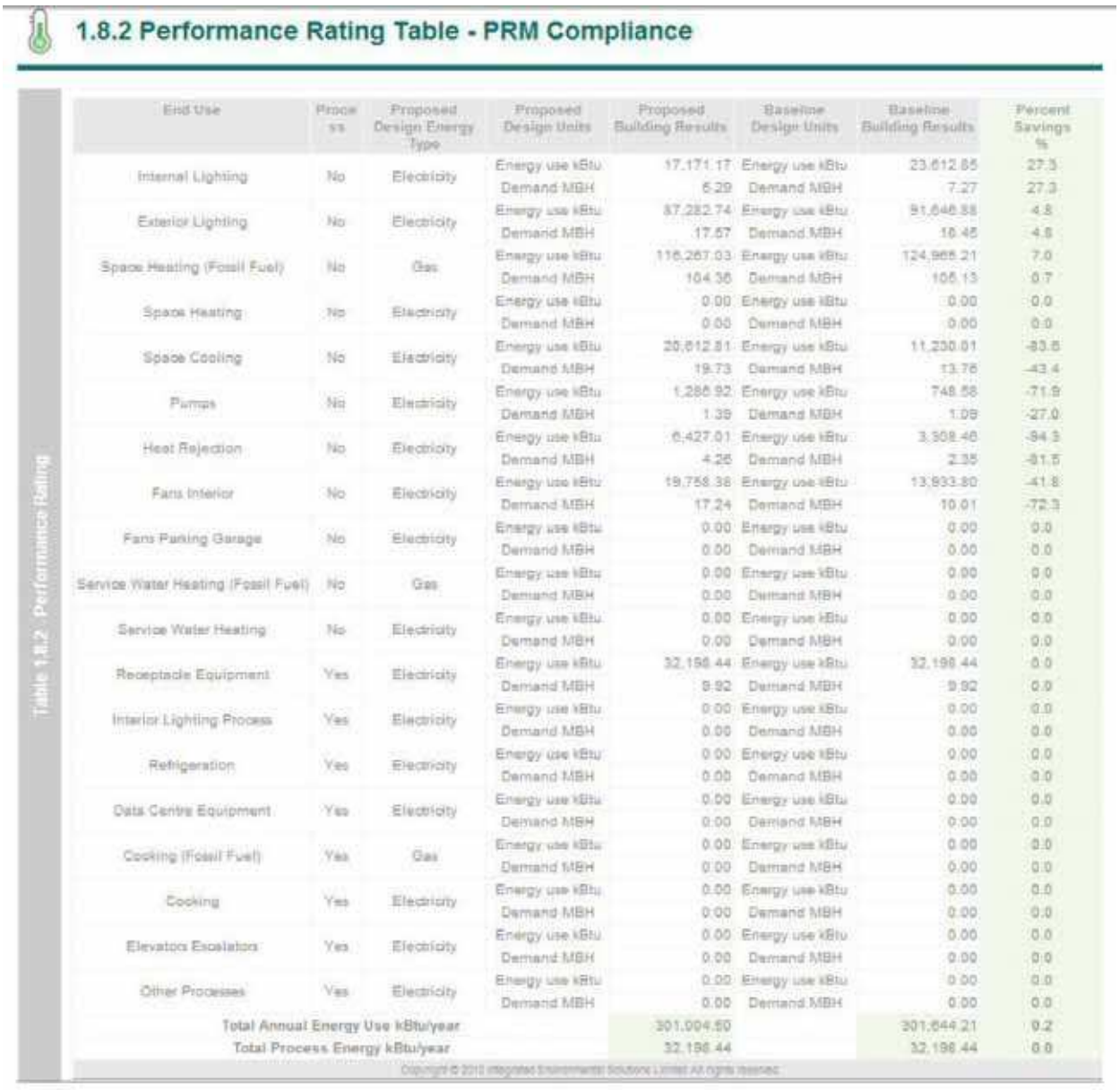
8.1 (a) Baseline performance: energy performance in terms of end use by fuel type (kBtu) and demand (MBH), plus annual totals

8.1 (b) Baseline energy costs: energy costs by utility type

8.2 (a) Performance rating table: energy performance of proposed and baseline cases in terms of end use by fuel type (kBtu) and demand (MBH), plus annual totals and % savings

8.2 (b) Energy cost and consumption by energy type: summary table containing information for LEED credit form

Figure 2.5. Sample Performance Rating Table: Compliance Report from IESVE



1.8.2 Performance Rating Table - PRM Compliance

Table 1.8.2 : Performance Rating

End Use	Process	Proposed Design Energy Type	Proposed Design Units	Proposed Building Results	Baseline Design Units	Baseline Building Results	Percent Savings %
Internal Lighting	No	Electricity	Energy use kBtu	17,171.17	Energy use kBtu	23,612.85	27.3
			Demand MBH	6.29	Demand MBH	7.27	27.3
Exterior Lighting	No	Electricity	Energy use kBtu	87,282.74	Energy use kBtu	91,646.88	4.8
			Demand MBH	17.67	Demand MBH	18.46	4.8
Space Heating (Fossil Fuel)	No	Gas	Energy use kBtu	116,267.03	Energy use kBtu	124,966.21	7.0
			Demand MBH	104.36	Demand MBH	105.13	0.7
Space Heating	No	Electricity	Energy use kBtu	0.00	Energy use kBtu	0.00	0.0
			Demand MBH	0.00	Demand MBH	0.00	0.0
Space Cooling	No	Electricity	Energy use kBtu	20,612.81	Energy use kBtu	11,230.01	-83.6
			Demand MBH	19.73	Demand MBH	13.76	-43.4
Pumps	No	Electricity	Energy use kBtu	1,286.92	Energy use kBtu	748.58	-71.9
			Demand MBH	1.39	Demand MBH	1.09	-27.0
Heat Rejection	No	Electricity	Energy use kBtu	6,427.01	Energy use kBtu	3,508.46	-94.3
			Demand MBH	4.25	Demand MBH	2.35	-81.5
Fans Interior	No	Electricity	Energy use kBtu	19,758.38	Energy use kBtu	13,933.80	-41.8
			Demand MBH	17.24	Demand MBH	10.01	-72.3
Fans Parking Garage	No	Electricity	Energy use kBtu	0.00	Energy use kBtu	0.00	0.0
			Demand MBH	0.00	Demand MBH	0.00	0.0
Service Water Heating (Fossil Fuel)	No	Gas	Energy use kBtu	0.00	Energy use kBtu	0.00	0.0
			Demand MBH	0.00	Demand MBH	0.00	0.0
Service Water Heating	No	Electricity	Energy use kBtu	0.00	Energy use kBtu	0.00	0.0
			Demand MBH	0.00	Demand MBH	0.00	0.0
Receptacle Equipment	Yes	Electricity	Energy use kBtu	32,198.44	Energy use kBtu	32,198.44	0.0
			Demand MBH	9.92	Demand MBH	9.92	0.0
Interior Lighting Process	Yes	Electricity	Energy use kBtu	0.00	Energy use kBtu	0.00	0.0
			Demand MBH	0.00	Demand MBH	0.00	0.0
Refrigeration	Yes	Electricity	Energy use kBtu	0.00	Energy use kBtu	0.00	0.0
			Demand MBH	0.00	Demand MBH	0.00	0.0
Data Centre Equipment	Yes	Electricity	Energy use kBtu	0.00	Energy use kBtu	0.00	0.0
			Demand MBH	0.00	Demand MBH	0.00	0.0
Cooking (Fossil Fuel)	Yes	Gas	Energy use kBtu	0.00	Energy use kBtu	0.00	0.0
			Demand MBH	0.00	Demand MBH	0.00	0.0
Cooking	Yes	Electricity	Energy use kBtu	0.00	Energy use kBtu	0.00	0.0
			Demand MBH	0.00	Demand MBH	0.00	0.0
Elevators Escalators	Yes	Electricity	Energy use kBtu	0.00	Energy use kBtu	0.00	0.0
			Demand MBH	0.00	Demand MBH	0.00	0.0
Other Processes	Yes	Electricity	Energy use kBtu	0.00	Energy use kBtu	0.00	0.0
			Demand MBH	0.00	Demand MBH	0.00	0.0
Total Annual Energy Use kBtu/year				301,004.60		301,644.21	0.2
Total Process Energy kBtu/year				32,198.44		32,198.44	0.0

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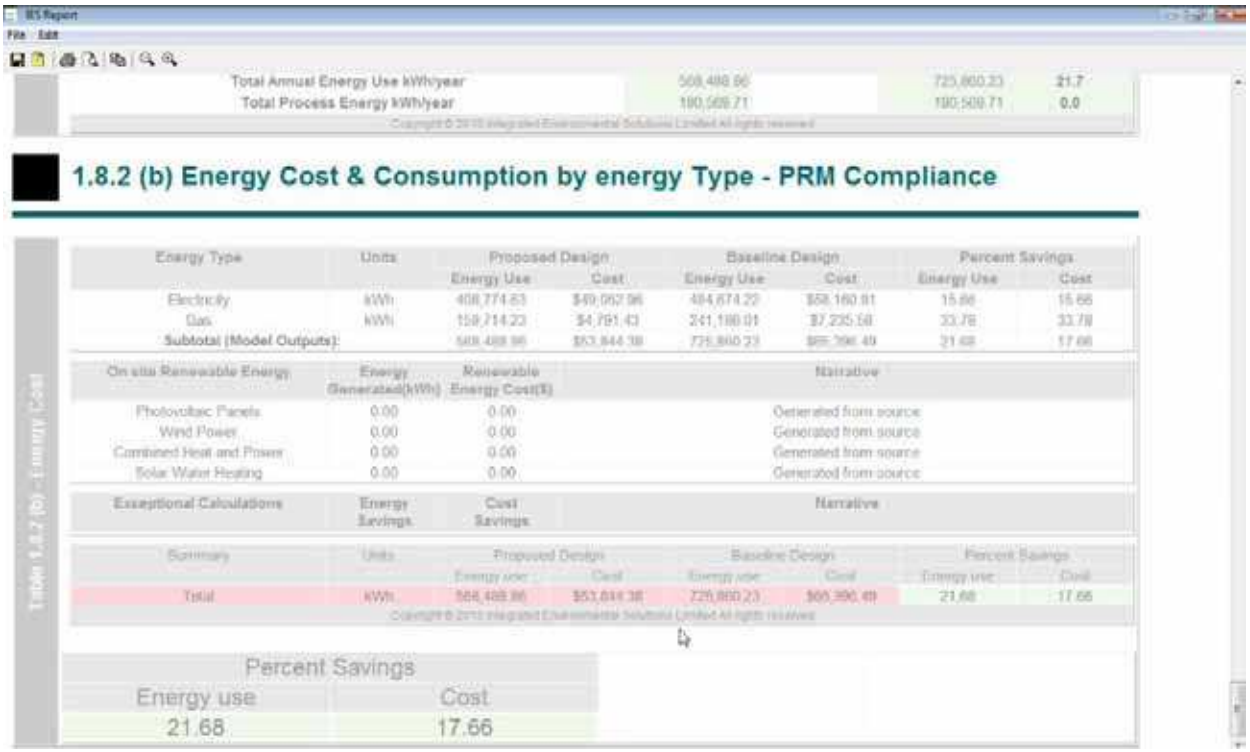
Figure 2.6. Sample Energy Cost and Consumption, by Energy Type: Compliance Report



2.4.6. EnerSim Output Reports

These reports consist of the following:

- an energy summary showing monthly energy use by fuel and by major equipment types such as lighting, heating and cooling;
- heating and cooling reports showing monthly and annual equipment details such as temperature, relative humidity, energy, peak demand, and percent loading for various run times;
- monthly and annual energy and demand by equipment or end-use;
- a project review showing building weather, exposures, area, r-values, glass area, occupants, HVAC equipment details, end-use data, water heating data and water usage; and
- an energy cost report showing monthly and annual kW, energy and electric costs, plus monthly and annual other fuel usage and associated costs.

2.5. LEED Interpretations

Table 2.2. Summary of Major EA Prerequisite 2 and Credit 1 Interpretations

Topic	Rating System and LEED Interpretation (CIR Date)	Summary	Description
Building			
Building dimensions	*NC v2009* LI-10029 *NC v2.2* LI-10021	Clarifies that baseline and proposed building must be same size	Project cannot take credit in energy model for features or employee schedules that reduce necessary square footage between baseline and proposed models. Per ASHRAE 90.1–2007, Table G3.1.a., baseline building must be modeled with same number of floors and conditioned area as proposed design.
Space types	NC v2009 LI-10030	Clarifies procedures when converting unconditioned to conditioned space	Project cannot use existing envelope thermal parameters for baseline model if space is being converted from unconditioned to conditioned space. In such cases, minimally compliant envelope must be modeled for baseline, per ASHRAE 90.1–2007, Tables 5.5-1 through 5.5-8.
HVAC System			
Baseline HVAC system	*NC v2.2* LI -2249 (8/26/2008)	Clarifies how to determine baseline HVAC system(s) for a building eligible for more than one system type.	For projects with multiple uses in same building, predominant condition as determined by total floor area should determine system type for entire building. Ruling references note following Table G3.1.1A in ASHRAE 90.1–2004 [2007]: "Where attributes make a building eligible for more than one baseline system type, use the predominant condition to determine the system type for the entire building."
Baseline HVAC system serving high process load spaces	*NC v2.2* LI-5043 (3/23/2007)	Clarifies use of exception G3.1.1 to document baseline and achieve greater energy savings from single-zone systems in high process load areas.	Project may demonstrate substantial energy savings for well-designed HVAC systems serving high process load spaces based on following exception to G3.1.1: "Any space that has high occupancy or process loads that differ by at least 10 BTU/h-sq. ft. shall be modeled with packaged single zone system per Exception to G3.1.1."
HVAC systems controlled by occupancy sensors	*NC v2.2* LI-1847 (8/13/2007)	Clarifies how to document energy savings from HVAC systems controlled by occupancy sensors.	ASHRAE 90.1–2004 [2007], Appendix G, Table 3.2, defines default power adjustment percentages for automatic lighting controls. Although this table is not intended to address other systems controlled by occupancy sensors, 10% power adjustment indicated in table may be used for buildings larger than 5,000 sf for all systems controlled by occupancy sensors. Alternatively, if published, credible data demonstrate energy savings for equipment controlled by occupancy sensors, then demonstrated values may be used, as long as study is referenced or (preferably) provided.
Natural ventilation	*NC v2.2* LI-1734 (3/22/2007)	Describes requirements for documenting energy savings from natural ventilation.	Submittals for natural ventilation savings will be evaluated on case-by-case basis and should include following information: • detailed project description; • clear identification of areas taking credit for natural ventilation; • detailed description or references that document modeling algorithms and/or methodology for natural ventilation portion of energy model; • all thermostat, fan, infiltration, and other appropriate schedules for naturally ventilated areas; • documentation to demonstrate that range of unmet load hours is similar for both baseline and proposed buildings, to ensure that savings are not claimed for hours outside control parameters; • documentation to demonstrate that operational schedule for natural ventilation system aligns with anticipated occupants' behavior; and • exceptional calculations to document manual control features.

Table 2.2. Summary of Major EA Prerequisite 2 and Credit 1 Interpretations (continued)

Topic	Rating System and LEED Interpretation (CIR Date)	Summary	Description
Lighting System			
Manual lighting controls	*NC v2.2* LI-1928 (10/23/2007)	Prohibits inclusion of manual lighting controls in energy savings calculations.	As indicated in Table G3.1.6 of ASHRAE 90.1–2004 [2007], only automated lighting controls are eligible for energy savings credit. Use of manual master switch, such as manual master switch control in each apartment to turn off lights and to control HVAC system in response to occupancy, does not qualify for credit under EA Credit 1. Manual controls are not eligible for energy savings.
Automatic lighting controls	*NC v2.2* LI-2360 (10/24/2008)	Clarifies use of exceptional calculation method to document higher savings from automatic lighting controls.	For automatic lighting controls, ASHRAE 90.1–2004 [2007], Appendix G, Table G3.2, Power Adjustment Percentages for Automatic Lighting Controls, defines default percentages of savings that can be claimed. Project teams may claim greater savings for use of automatic lighting controls than default savings percentage, based on statement in ASHRAE 90.1–2004 [2007], Table G3.1.4, Baseline Building Performance, indicating that nonstandard efficiency measures, such as lighting controls, can be modeled by modifying schedules, provided revised schedules have approval of rating authority (here, USGBC). Schedule change and energy savings must be modeled and submitted as exceptional calculation method with documentation that supports proposed lighting schedule.
Lighting in multilevel residential buildings	*NC v2.2* LI-5253 (3/23/2007)	Describes specific requirements for modeling lighting in multilevel residential buildings.	All common areas and support areas, including circulation, lounges, and lobbies, should be included in lighting power density calculations and modeled in both baseline and proposed cases. All hard-wired lighting in living units that is shown on building plans must be considered process energy and modeled identically in baseline and proposed building simulations as shown in plans. Credit may be taken for efficient hard-wired lighting in living units using exceptional calculation method.
Process Energy			
Process loads	*NC v2.2* LI-5253 (3/23/2007)	Describes methodology for documenting process energy savings from efficient hard-wired lighting in residential living units.	Maximum allowable baseline for residential lighting is restricted to 2 watts/sf. Baseline residential lighting assumptions need to be supported by specific study results. Studies must address both lighting power density and daily duty cycle. Some studies suggest that duty cycle of hard-wired residential fixtures is about 2 hours per day or less. Lighting credit can be taken only in rooms where permanently installed hard-wired lighting fixtures meet illumination requirements for space. Ruling also indicates energy offset penalty of approximately 40% for reductions to residential lighting load. That is, 4 of every 10 watts saved by reduced lighting loads must be made up for by increased heating energy. Offset must be accounted for by energy model.
	NC v2.2 LI-5313 (5/27/2008)	Clarifies some specific process load situations.	Energy use by personal cooling and heating systems is not considered process energy. LI-5313 clarifies that energy used in greenhouse for comfort of occupants should be reported as regulated end uses. Space-conditioning equipment and lighting used primarily to support plant growth functions should be reported as process energy in EA Credit 1 (EA Prerequisite 2 form).
	NC v2.2 LI-2397 (1/07/2009) LI-5043 (3/23/2007)	Confirms that process loads must be included in simulations.	Process loads for entire facility must be included in both baseline and proposed cases. This reinforces ASHRAE 90.1–2004 [2007], Appendix G1.2, requirements that both baseline and proposed building performance include all end-use load components.

Table 2.2. Summary of Major EA Prerequisite 2 and Credit 1 Interpretations (continued)

Topic	Rating System and LEED Interpretation (CIR Date)	Summary	Description
Process Energy (continued)			
Process energy use reduction	*NC v2.2* LI-2339 (10/24/2008) LI-5317 (10/3/2008) LI-1844 (8/13/2007) LI-1693 (2/26/2007)	Defines exceptional calculation method to document process energy use reduction.	Process load reduction must be documented by an exceptional calculation methodology, as described in ASHRAE 90.1–2004 [2007], Appendix G2.5. For example, all four rulings require use of exceptional calculation method to determine process energy savings for domestic condensing dryer, boilers serving industrial processes, manufacturing process, and pool process energy loads. Project teams must provide justification for assumptions used in both baseline and proposed cases. LI-2339 specifies two requirements for exceptional calculation method for process load reduction when comparison baseline installation is available: (1) all loads are included in energy models (do not separate process and regulated loads in two models) so that models accurately reflect any interactions between process loads and space conditioning loads; and (2) calculations include reasonable assumptions for baseline and proposed cases, supported by following: • side-by-side comparison of industry standard equipment and new proposed equipment, with energy efficiency metric for each piece of equipment (e.g., kWh/ pound of material processed); • list of modifications that make new equipment more efficient; • detailed utility bills from comparison facility for reference; and • operation schedules for facility and equipment.
	NC v2.2 LI-1847 (8/13/2007)	Describes requirements for documenting process energy savings from appliances.	To document process energy savings from energy-efficient appliances, obtain actual measured energy use data from both baseline and proposed equipment. Project teams can conduct studies themselves or cite studies of identical equipment.
	NC v2.2 LI-2147 (2/10/2009)	Defines specific requirements for documenting waste energy recovery from process loads.	Ruling addresses facility that uses large process heating and cooling plants to test HVAC equipment, then captures heating and cooling energy from tested equipment for reuse by process heating and cooling plants. Requirements for modeling use of waste energy recovery for systems are summarized as follows: • Tested equipment should be modeled using identical types, quantities, efficiencies, controls, and pump power in baseline and proposed cases. • In baseline model (prior to applying any exceptional calculation measures), process heating and cooling plants for simulating test conditions should be modeled with identical quantities and capacities of equipment, pump power, controls, and schedules of operation as in proposed case. However, equipment efficiencies for baseline case process equipment should reflect those listed in Tables 6.8.1A-J. • Other baseline assumptions used for process heating and cooling plants should reflect standard practice for newly constructed facilities with similar functions. These assumptions should be modeled identically in baseline and proposed cases, and then modified in proposed exceptional calculation method model. Exceptional calculation narrative must provide sufficient information to verify that efficiency measures modeled are not standard practice for this type of facility. Exceptional calculation method model for proposed case should reflect any parasitic energy associated with waste energy recovery, but this parasitic energy should not be reflected in baseline model.

Table 2.2. Summary of Major EA Prerequisite 2 and Credit 1 Interpretations (continued)

Topic	Rating System and LEED Interpretation (CIR Date)	Summary	Description
Process Energy (continued)			
Data center	*NC v2.2* LI-2441 (1/14/2009)	Describes requirements for documenting process energy savings from use of server visualization technique.	Data centers may use server virtualization technique to reduce energy consumption. Server virtualization techniques replace multiple servers with one large, high-performance server that runs multiple "virtual" servers. To account for savings from technology, ruling requires use of exceptional calculation method. Supporting documentation should address all assumptions made in calculations and include detailed data, any actual measurements taken to support savings, and all other pertinent information.
	NC v2009 LI-10051	Clarifies that server power must be included in energy model.	For data centers that also contain office space, exception G3.1.1(b) from ASHRAE 90.1–2007 is applicable, but server power must be included in model. Process load energy reduction can be captured using exceptional calculation method.
Refrigerated warehouse	*NC v2.2* LI-5178 (1/12/2009)	Clarifies that refrigerated warehouses should be modeled as energy neutral.	ASHRAE 90.1–2004 [2007] does not apply to refrigerated warehouses and therefore does not prescribe any minimum efficiency requirements for these spaces. Because all energy end uses must be included in EA Credit 1 calculations, refrigerated warehouse portion of project must be modeled as energy neutral.
Tenant Requirements			
Energy efficiency measures in tenant guidelines	*CS v2.0* LI-5158 (10/24/2008)	Clarifies when efficiency improvements in tenant guidelines can and cannot be included in proposed model.	Whether energy efficiency measures in tenant guidelines should be modeled in proposed design depends on what items are under owner's control. Efficiency improvements recommended in tenant guidelines cannot be included in proposed model; efficiency improvements mandated by tenant requirements can be included. In addition, efficiency requirements must be strictly enforced and be part of tenant lease.

CHAPTER 3.
ENERGY PERFORMANCE COMPLIANCE PATH DOCUMENTATION AND REVIEW

This section helps LEED project teams document the energy modeling compliance path, focusing on documentation requirements for EA Credit 1. It offers detailed technical and procedural guidance on the quality control process for verifying energy savings, and it describes common errors made in EA Credit 1 applications.

The flow diagram in Figure 3.1 indicates the critical steps recommended to verify the energy savings proposed in the application. These are explained in more detail in the sections and tables that follow.

3.1. Energy Performance Compliance Path: Submittal Documentation

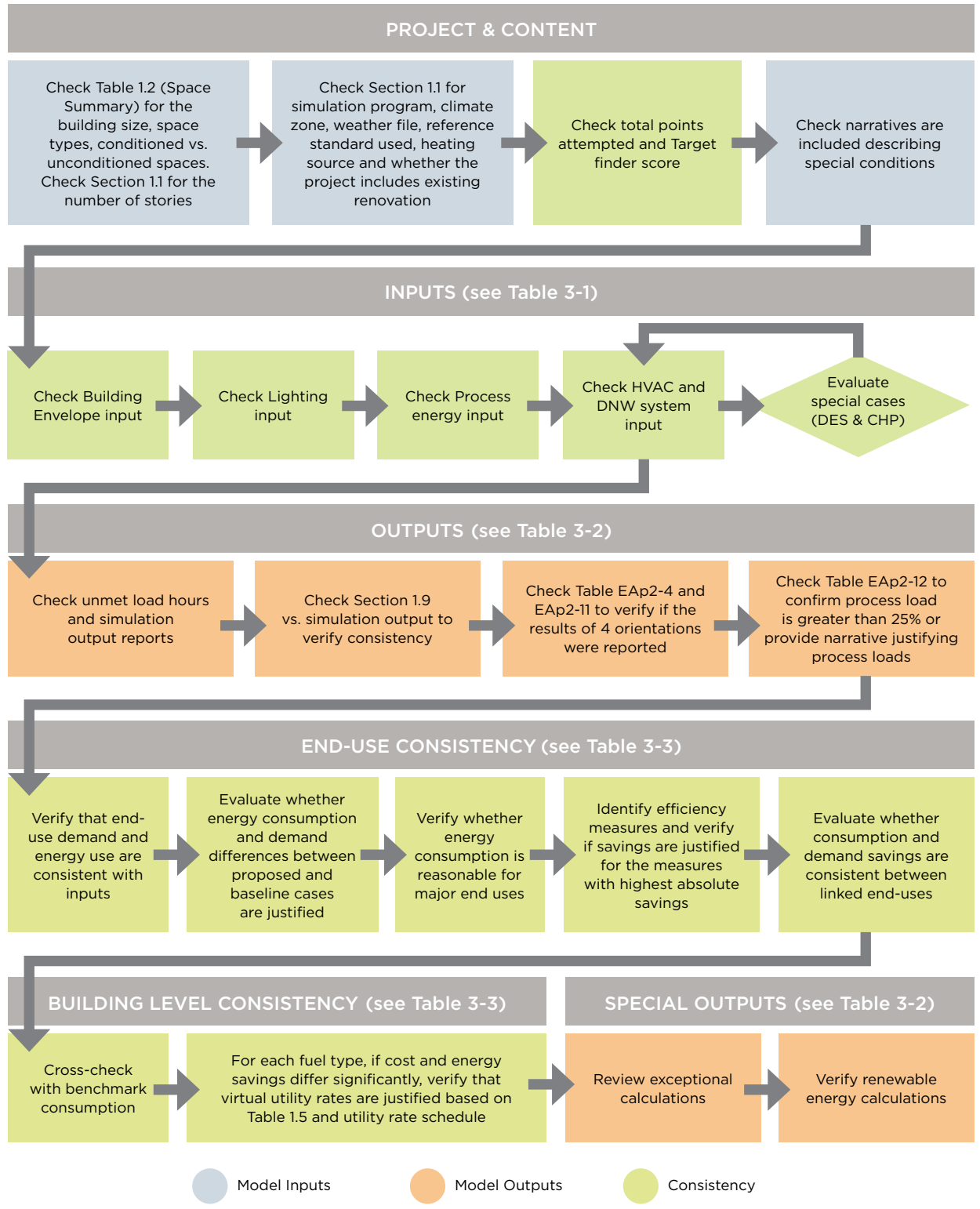
3.1.1. LEED Credit Form

The LEED credit form is the primary document required for EA Prerequisite 2 and EA Credit 1. The form must be completed with the required information and a sufficient level of detail. This expectation for LEED EA Credit 1 applications is further described below, in Appendix C, where an annotated sample credit form includes descriptions of the required content. The sample form assumes that applicants are using ASHRAE 90.1–2007 but is an example of the level of information required for projects using other referenced standards or energy codes.

3.1.2. Supporting Documentation

In addition to the credit form, applicants must provide building-level simulation output reports and utility rate schedules, as shown in Appendix B. The required building-level reports for representative types of simulation software were introduced in Chapter 2. For example, BEPS, BEPU, and ES-D reports are required for projects using DOE-2–based software. The reviewer may request additional simulation input and/or output reports during the preliminary review for clarification when results are questionable. However, providing entire output files for both models with the LEED application is not recommended.

Figure 3.1. Critical Steps to Verify Proposed Energy Savings



3.2. Energy Performance Compliance Path: Documentation Checklist

Most of the problems in EA Credit 1 applications that follow the simulation compliance path come from the incorrect use of referenced standards, inconsistencies between the energy model inputs and outputs, and lack of validation of energy savings demonstrated. This section includes three checklists to help both applicant and reviewer determine whether the energy modeling accurately demonstrates the project's potential energy savings.

3.2.1. Input Quality Control Checklist

The first step in verifying the accuracy of the energy savings is to confirm that the modeling inputs comply with the requirements of the referenced standard. Table 3.1 presents a checklist for reviewing the energy modeling inputs and identifies the common errors found in LEED applications. Projects following ASHRAE 90.1–2007 can use the table as a guide to perform quality assurance for completeness and accuracy. The inputs are found in the LEED Online credit form and energy modeling summary reports.

The most common errors are for projects using ASHRAE 90.1–2007, Appendix G. For projects using California Title 24, the baseline input is automatically generated by the simulation software and is therefore not separately included in this section.

3.2.2. Output Quality Control Checklist

The next step is to determine whether the outputs comply with the referenced standard's requirements and LEED requirements, such as unmet load hours, process energy use, and exceptional calculations. Table 3.2 presents a checklist to help teams and reviewers confirm that the requirements have been met and the output values reported in the LEED credit form are consistent with the simulation output reports. The checklist applies to projects using ASHRAE 90.1–2007 and California Title 24–2005, Part 6.

3.2.3. Output-Input Consistency Checklist

The last step for verifying the accuracy of the energy savings is to check for consistency between outputs and inputs.

Table 3.3 is a checklist for reviewing the consistency of energy modeling outputs and inputs and provides calculation methods and rules of thumb to predict rough order-of-magnitude results. It can assist with quality assurance on projects using ASHRAE 90.1–2007 and California Title 24.

Table 3.1. Input Quality Control Checklist

Topic	Check	Common errors	Resources
General Information			
Simulation program	Verify that approved energy simulation software has been used.	• Using unqualified simulation software, e.g. using Energy-10 for buildings with more than 2 thermal zones or larger than 10,000 sf.	ASHRAE 90.1–2007, Section G2.2
Weather file and climate zone	Verify that weather file and climate zone are correct.	• n/a	n/a
Referenced standard	Verify that approved referenced standard has been used.	• Using referenced standard other than ASHRAE 90.1–2007 for project not located in California.	n/a

Table 3.1. Input Quality Control Checklist (continued)

Topic	Check	Common errors	Resources
Target Finder score	Confirm that Target Finder score is provided. If not, check Section 1.2 of EA Prerequisite 2 form to verify project's primary occupancy.	• Not providing Target Finder score even though project has Target Finder standard occupancy type. • Target Finder "Design" score has been confused with Target Finder "Target Rating." • Target Finder score is very low but percentage of energy savings reported is high.	Target Finder Web site
Space summary			
Building floor area	Verify that building floor area in Section 1.2 of EA Prerequisite 2 form is consistent with other credits. Verify conditioned area with IEQ Prerequisite 1. Consider +10% variance to account for built-up area.	• Building floor area is inconsistent with other credits.	n/a
Building envelope			
Existing building	Verify baseline energy modeling approach for existing building renovation.	• Baseline building shell of existing construction is not modeled as it exists prior to any revisions.	ASHRAE 90.1–2007, Table G3.1.5(f)
Opaque assemblies	Verify that opaque envelope input reflects correct assembly construction and U-values, C-values and F-values.	• Incorrect envelope constructions are modeled in baseline building (e.g., exterior walls not modeled with lightweight, steel-framed assemblies).	ASHRAE 90.1–2007, Table G3.1.5(b)
		• The baseline slab-on-grade floor construction has been modeled with U-value rather than F-factor of 0.73.	ASHRAE 90.1-2007, Table G3.1.5(b) and Table 5.5
Fenestration	Verify that fenestration area modeled for baseline meets referenced standard requirements.	• Baseline vertical fenestration exceeds 40% of gross above-grade wall.	ASHRAE 90.1–2007, Table G3.1.5(c)
	Verify that baseline and proposed design U-values reflect assembly U-values.	• Proposed design uses center-of-glass U-values rather than whole window assembly U-values (including frame). • Baseline building adds frame conductance to prescriptive Baseline assembly U-values.	ASHRAE 90.1–2007, Table G3.1.5(c)
	Verify that solar heat gain coefficient (SHGC) is correct for baseline.	• n/a	
Shading devices	Verify that proposed design includes correct type of shading devices.	• Proposed case models manually controlled shading devices, such as blinds.	ASHRAE 90.1–2007, Table G3.1.5, Exception (d)
	Verify that baseline building includes no shading devices.	• Baseline building includes shading devices.	
Cool roofs	Verify that proposed cool roof is modeled with appropriate reflectance from Table G3.1, Section 5, Exception (c).	• Proposed roof modeled with rated reflectance greater than 0.45.	ASHRAE 90.1–2007, Table G3.1.5, Exception (c)

Table 3.1. Input Quality Control Checklist (continued)

Topic	Check	Common errors	Resources
Lighting			
Interior lighting power density (LPD)	Verify that consistent calculation methodology is used for baseline design.	• A combination of building area method and space-by-space method is used to model interior lighting.	ASHRAE 90.1– 2007, Table G3.1.6
	Verify that baseline building LPD meets ASHRAE requirements.	• Baseline building LPD does not follow Table 9.5.1 or Table 9.6.1. • Additional LPD allowance modeled in baseline case is not equal to additional connected lighting power for accent and retail display lighting. • Additional LPD allowance is modeled in baseline case when building area method is used. • Baseline lighting systems for existing building renovation projects are modeled with existing conditions rather than ASHRAE 90.1 allowances. • Space function inconsistent with space type is selected for determination of baseline lighting power allowance.	ASHRAE 90.1–2007, Sections 9.5, and 9.6
Lighting controls	Verify that lighting control inputs are consistent with ASHRAE requirements.	• Proposed design lighting power adjustment for use of occupancy sensors is greater than default value in ASHRAE Table G3.2, and no exceptional calculation is provided to justify increase. • Proposed design adjusts lighting power for use of occupancy sensors in spaces where occupancy sensors are required by Section 9.4.1.2(a). • Baseline building includes controls in addition to mandatory control requirements that are incorporated by lighting schedules. • Proposed design claims lighting control credit for use of manual controls. • Proposed design takes credit for lighting controls in addition to those required for code compliance using schedule change without exceptional calculations or narrative explaining use of different schedules.	ASHRAE 90.1–2007, Table G3.2, Table G3.1.6, and Section 9.4.1.2

Table 3.1. Input Quality Control Checklist (continued)

Topic	Check	Common errors	Resources
Lighting (continued)			
	(LEED-CS projects only):	• Credit for daylighting control, occupancy sensor control, and/or reduced lighting power is taken in tenant spaces where lighting has not been designed, but tenant guidelines do not require implementation of these measures.	
Lighting schedules	Verify that lighting schedule has been correctly modeled for residential buildings.	• Lighting in residential dwelling units is on more than 2–3 hours per day and/or lighting in corridors and subterranean parking is on less than 24 hours per day in proposed case and/or baseline case.	NCv2.2 CIR dated 3/23/2007 (LEED Interpretation 5253)
Exterior lighting	Verify that baseline exterior lighting power has been correctly calculated and that proposed exterior lighting power is consistent across credits.	• Baseline lighting power is not calculated per ASHRAE Table 9.4.5. • Proposed lighting power is inconsistent with that reported in documentation for SS Credit 8. • Nontradable surfaces are not modeled with lesser of nontradable allowance and installed lighting power for each nontradable surface, as required by LEED Interpretation 5261. • Lighting power allowance is claimed in baseline model for surfaces that are not provided with lighting in actual design, or lighting fixtures are double-counted for different exterior surfaces.	ASHRAE 90.1–2007, Table 9.4.5
	(Title 24 projects only):	• Exterior lighting energy use is not correctly calculated based on lighting kW in OLTG forms and annual equivalent full-load hours of operation.	
Process loads			
Process lighting	Verify that qualified process lighting is reported.	• Regulated lighting use is incorrectly reported as process lighting.	ASHRAE 90.1–2007, Exceptions to Section 9.2.2.3
Other process loads	Verify that all process loads are reported identically for baseline and proposed buildings and that all end-use load components within and associated with project are modeled.	• Receptacle and other miscellaneous loads are different in baseline and proposed cases. • Process loads, such as cooking equipment and elevator, are omitted from baseline and proposed case models.	ASHRAE 90.1–2007, Table G3.1.12

Table 3.1. Input Quality Control Checklist (continued)

Topic	Check	Common errors	Resources
HVAC system			
Primary system type	Verify that HVAC system type selected for baseline is correct.	• Baseline building is modeled with wrong HVAC system (e.g., Title 24 project baseline system is not consistent with system mapping from N2-10). • Baseline HVAC systems use both fossil fuel and electricity when exception (a) to G3.1.1 is not applicable. • Baseline HVAC system is mapped using "Electric and Other" heating source classification when fossil fuel is used in conjunction with electricity to heat spaces in proposed case (the heating type should be hybrid). • Baseline HVAC system type includes makeup air units as separate air handler when baseline system should be modeled with outside air supplied directly to air handlers. (Exceptions are allowed for residential buildings in hot, humid climates where dedicated outside air system is necessary to maintain humidity requirements in baseline case model. The total fan power for baseline case for fan coils plus dedicated outside air system should still be same as if project were modeled with outside air supplied directly to air handlers.) • Heating source of proposed case with fossil fuel preheat is not treated as hybrid if heating source of rest of building is electricity. • Baseline HVAC system for retrofitted building is modeled as existing condition rather than HVAC system required by Tables G3.1.1A, and G3.1.1B.	ASHRAE 90.1–2007, Tables G3.1.1A, G3.1.1B

Table 3.1. Input Quality Control Checklist (continued)

Topic	Check	Common errors	Resources
HVAC system (continued)			
	Verify that both heating and cooling systems have been modeled for proposed design. For heated-only storage spaces, verify that baseline system type has been modeled using system types 10 or 11 from ASHRAE 90.1-2007 Addendum dn, or types 9 or 10 from ASHRAE 90.1–2010, where all relevant requirements of system type have been applied (this optional compliance path allows proposed case system to be modeled as designed rather than with both heating and cooling).	• No heating or cooling system is modeled in proposed case for conditioned spaces.	ASHRAE 90.1–2007, Table G3.1.10, and Table G3.1.1(b)
Additional system type	Verify that baseline additional system type meets requirements in exceptions to G3.1.1.	• Baseline incorrectly includes additional type(s) of systems.	ASHRAE 90.1–2007, Exceptions to G3.1.1
Thermal blocks	Verify that thermal blocks are appropriately modeled.	• Proposed case spaces served by single-zone system are modeled with multiple thermal blocks. • Proposed case HVAC zones are not defined consistently with HVAC design drawings.	ASHRAE 90.1-2007, Table G3.1.7 and 8
Equipment capacity	Verify that proposed case equipment capacities are modeled as designed and baseline case equipment capacities are modeled per G3.1.2.2.	• Proposed case equipment capacities are not modeled as designed, or are increased to meet requirement for unmet load hours in G3.1.2.2 without quality check for causes of high unmet load hours. • The baseline equipment capacities are not based on sizing runs and are oversized by 25% for heating and 15% for cooling. • Baseline capacities are oversized at both system and plant levels. • Auto-sizing is performed for baseline case in energy model, but cooling degree day and heating degree day schedules are not defined correctly, leading to significant additional oversizing. Energy simulation reports show no equipment operating hours above 80% part-load range for cooling or above 70% part-load range for heating.	ASHRAE 90.1-2007, G3.1.2.2

Table 3.1. Input Quality Control Checklist (continued)

Topic	Check	Common errors	Resources
HVAC system (continued)			
Fan volume	Verify that baseline fan volume has been sized correctly.	• Proposed and baseline buildings show equal fan supply volumes instead of following ASHRAE airflow rate sizing guidelines. • Baseline case is sized using supply-air-to-room-air temperature difference from proposed case, and not using supply-air-to-room-air temperature difference of 20ºF as required. • Fan volume in proposed design is autosized, not using design conditions.	ASHRAE 90.1–2007, G3.1.2.8
Fan power	Verify that baseline fan power has been calculated correctly.	• Baseline fan power does not conform to G3.1.2.9. • Insufficient information is provided regarding fan pressure adjustments to confirm whether fan power has been calculated correctly. • Proposed and baseline buildings show equal fan power instead of following ASHRAE fan power calculations. • Additional fan power allowance is claimed in baseline for return, exhaust, or relief fans. • Baseline fan power is calculated incorrectly in simulation software with automated baseline.	ASHRAE 90.1–2007, G3.1.2.9.
Exhaust air energy recovery	Verify that exhaust energy recovery has been modeled in baseline building where required, and that it is modeled appropriately in proposed case when included in proposed design.	• Baseline building omits exhaust air energy recovery when required. • Heat recovery system omits bypass of airside economizer. • Baseline case energy recovery efficiency is not modeled in accordance with G3.1.2.10. • Proposed case energy recovery efficiency is not modeled as designed. • Proposed case energy recovery bypass is not modeled as designed. • Baseline and proposed case ventilation rates are not modeled with zero flow during unoccupied periods, or modeled identically between two cases where health or safety regulations mandate an alternative minimum flow during unoccupied periods.	ASHRAE 90.1–2007, G3.1.2.10

Table 3.1. Input Quality Control Checklist (continued)

Topic	Check	Common errors	Resources
HVAC system (continued)			
Economizer control	Verify that economizers are properly included or excluded in baseline building.	• Economizer type and/or control is incorrectly modeled in baseline building. • Economizer high limit shutoff is not in accordance with Table G3.1.2.6B.	ASHRAE 90.1–2007, G3.1.2.6, G3.1.2.7
Ventilation	Verify that ventilation is appropriately modeled in baseline and proposed cases.	• Outdoor air is not modeled with identical flow in baseline and proposed case models (exception: demand control ventilation). • Outdoor air is modeled with same design ventilation percentage instead of same ventilation rates in baseline and proposed cases. • Outdoor air systems in both cases are not modeled with zero outside airflow when fans are cycled on to meet unoccupied setback temperatures, except where health or safety regulations mandate an alternative minimum flow during unoccupied periods. • When infiltration rates are modeled differently between baseline and proposed case, differences are not justified using exceptional calculation method and/or there is no provision for commissioning building to confirm infiltration rates are consistent with design intent and energy model inputs.	ASHRAE 90.1–2007, G3.1.2.4
Demand control ventilation	Verify that demand control ventilation has been excluded or included in baseline building and modeled appropriately.	• Baseline case is not modeled using minimum outdoor air rates required by ASHRAE 62.1–2007 wherever credit is taken for demand control ventilation in proposed case. • Demand control ventilation is not included in baseline building when its use is required for high-occupancy areas by ASHRAE 90.1–2007, Section 6.4.3.9 Ventilation Controls for High-Occupancy Areas.	ASHRAE 90.1–2007, G3.1.2.5

Table 3.1. Input Quality Control Checklist (continued)

Topic	Check	Common errors	Resources
HVAC system (continued)			
	(LEED-CS projects only):	• Credit for demand controlled ventilation has been taken in tenant spaces where CO_2 sensors are not specified, but tenant guidelines do not require tenants to install CO_2 sensors that interface with building air handlers.	
	Verify that demand control ventilation is correctly modeled in proposed design case.	• Insufficient information is provided regarding demand control ventilation in proposed design case. • Proposed case minimum outdoor airflow rates at design conditions are not modeled as designed.	n/a
Unitary equipment cooling and heating efficiency	Verify that equipment efficiencies of proposed design and baseline building meet referenced standard's requirements.	• Proposed building HVAC equipment does not meet mandatory minimum efficiencies listed in Tables 6.8.1A–6.8.1G. • Baseline building HVAC equipment is modeled as other than minimum efficiencies listed in Tables 6.8.1A–6.8.1G. • Baseline system capacities are omitted in EAp2 Section 1.4 table to verify efficiencies listed. • Cooling efficiencies do not break out cooling efficiency separately from fan power, or EER is modeled for cooling efficiency component only. • Cooling efficiencies incorrectly break out cooling efficiency separately from fan power using design fan power rather than fan power at AHRI rating conditions. • Proposed case part-load performance curves do not appropriately reflect operating parameters of installed ground-source heat pumps or water-source heat pumps.	ASHRAE 90.1–2007, Table G3.1.10, G3.1.2.1

Table 3.1. Input Quality Control Checklist (continued)

Topic	Check	Common errors	Resources
HVAC system (continued)			
System-specific information	Verify that system-specific HVAC system requirements are met for baseline.	• Baseline heat pumps allow electric backup heat to operate above 40ºF. • Baseline heat pumps are turned off when outdoor air temperature is 40oF or lower, rather than operating with supplemental electric resistance heat below 40ºF, and operating as low as 17ºF (low temperature rating condition using heat pump ARI 340/360 test procedure). • Baseline fan systems (5–8) omit supply temperature reset. • Fan-powered VAV boxes are modeled for systems 5 and 7. • Multiple zones are modeled under single-zone system type, and reheat is modeled (systems 1, 2, 3, and 4). • Baseline case uses 30% minimum flow ratio rather than required 0.4 cfm/sf.	ASHRAE 90.1–2007, G3.1.3.1, G3.1.3.12, G3.1.3.13, G3.1.3.14
Chiller parameters	Verify number, type, and capacity of chillers in baseline.	• Baseline has incorrect number and/or type of chillers. • Baseline chiller capacities are equal to proposed design chiller capacities instead of following ASHRAE system sizing guidelines.	ASHRAE 90.1–2007, G3.1.3.7
Chilled water loop and pump parameters	Verify that chilled water loop configuration and pump inputs for baseline meet referenced standard's requirements for configuration, temperature settings, and supply temperature reset.	• Baseline chilled water loops are modeled with incorrect pumping energy and/or incorrect configuration (e.g., modeled as primary-only loops). • Baseline chilled water loops are modeled with incorrect temperature settings. • Baseline chilled water loops omit supply temperature reset. • Number of primary chilled water pumps modeled is inconsistent with number of chillers.	ASHRAE 90.1–2007, G3.1.3.8, G3.1.3.9, G3.1.3.10

Table 3.1. Input Quality Control Checklist (continued)

Topic	Check	Common errors	Resources
HVAC system (continued)			
Condenser water loop, heat rejection, and pump parameters	Verify that condenser water loop configuration and pump inputs for baseline meet referenced standard's requirements for configuration, temperature settings, fan power, and supply temperature reset.	• Baseline condenser water loops are modeled with incorrect pumping energy. • Baseline condenser water loops are modeled with incorrect temperature settings. • Baseline condenser water loops omit wet bulb reset controls. • Number of condenser water pumps modeled is inconsistent with number of chillers. • Baseline cooling tower fans are not modeled as 2-speed. • Baseline cooling tower fans are not modeled as axial fans with 38.2 gpm/hp.	ASHRAE 90.1–2007, G3.1.3.11
Boiler parameters	Verify that number, type, and capacity of boilers for baseline meet referenced standard's requirements.	• Baseline building includes incorrect number of boilers. • Baseline boiler capacities are equal to proposed design boiler capacities instead of following ASHRAE system sizing guidelines.	ASHRAE 90.1–2007, G3.1.3.2
Hot water loop and pump parameters	Verify that baseline hot water loop configuration and pump inputs meet referenced standard's requirements.	• Baseline hot water loops are modeled with incorrect pumping energy and/or incorrect loop configuration (e.g., modeled as primary-secondary loops). • Baseline hot water loops are modeled with incorrect temperature settings. • Baseline hot water loops omit supply temperature reset.	ASHRAE 90.1–2007, G3.1.3.3, G3.1.3.4, G3.1.3.5
District thermal energy	Verify that projects using district or campus thermal energy have been correctly modeled.	• For project using DES Guidance v2, average efficiency of proposed case virtual central plant is not modeled following requirements. • Project takes credit for efficiency of district energy systems serving project, but does not follow DES Guidance v2 in its entirety. • Project not using DES Guidance v2 models on-site boilers for systems using purchased hot water or steam in baseline case, contrary to ASHRAE requirements. • Project not using DES Guidance v2 does not model cooling energy using purchased energy rates in proposed case and appropriate Appendix G baseline cooling system in baseline case.	USGBC DES Guidance v2 and ASHRAE 90.1–2007, G3.1.1.1

Table 3.1. Input Quality Control Checklist (continued)			
Topic	**Check**	**Common errors**	**Resources**
HVAC system (continued)			
Cooling tower parameters	Verify that baseline cooling tower is modeled per referenced standard's requirements.	• Baseline case includes incorrect type of cooling tower and/or fan control. • Baseline case models condenser water temperatures incorrectly.	ASHRAE 90.1–2007, G3.1.3.11
Service hot water system			
Service hot water system	Verify that service hot water system, if specified, is modeled correctly.	• Service hot water system is not included in either baseline or proposed case. • Separate hot water heater system in baseline case is not modeled when proposed case combines space heating with service hot water heating.	ASHRAE 90.1–2007, Table G3.1.11, Section 6.5.6.2
		• Storage heating volumes modeled for service water heating are inconsistent. • Baseline does not conform to values for minimum efficiency required in ASHRAE 90.1–2007, Table 7.8, for corresponding system type.	ASHRAE 90.1-2007, Table 7.8
	Verify that condenser heat recovery for service hot water heating is modeled in baseline building where required.	• Large, 24-hour-per-day facility that meets criteria for use of condenser heat recovery systems, described in Section 6.5.6.2, omits condenser heat recovery in baseline case. • Baseline case includes incorrect condenser heat recovery inputs.	
	If credit is taken for low-flow fixtures, verify calculations.	• Backup water heating calculations are inconsistent with annual fixture flows shown in WE Credit 3, and/or insufficient information is provided to show that water heating temperature differential and standby losses were appropriately accounted for in calculations.	ASHRAE 901.-2007, Exceptions to Table G3.1.11(i)
Energy type summary			
Energy rates	Check that actual rates of purchased energy or state average energy prices are reported.	Both actual rates and state average energy prices are used.	ASHRAE 90.1–2007, G2.4

EAp2 = Energy and Atmosphere Prerequisite 2

Table 3.2. Input Quality Control Checklist

Topic	Check	Common errors	Resources
Unmet load hours	Verify that unmet load hours of both baseline and proposed buildings meet requirements. (Projects using Title 24 and EnergyPro need not report unmet load hours in EA Prerequisite 2 form.)	• Proposed and/or baseline cases have more than maximum 300 hours of unmet load. • Unmet load hours of proposed case exceed unmet load hours of baseline case by more than 50 hours. • Worst-case zone instead of entire building is used to comply with these requirements. Typical causes for high unmet load hours: • Zones are inappropriately modeled, resulting in lack of separation between perimeter and core spaces, or between perimeter spaces facing different directions. • Internal heat conduction properties are modeled incorrectly for adjacent spaces with varying temperature setpoints or temperature setpoint schedules. • High internal loads are mistakenly applied. • Spaces with high loads are not modeled with correct system capacity and/or airflow. • Supply air temperature resets are modeled incorrectly. • Morning warm-up period is inadequate. • Outside air schedules are not set to zero when fans cycle on at night. • Multiple thermal blocks are modeled under single-zone system. • Airflow at zone level is inadequate. • Capacities and flow rates from central plant equipment are inadequate. • Central plant loops are off during calls for heating and/or cooling. • Electric resistance heating is not modeled for heat pump units when outdoor temperature drops below 40ºF.	ASHRAE 90.1–2007, G3.1.2.2

Table 3.2. Input Quality Control Checklist (continued)

Topic	Check	Common errors	Resources
Renewable energy	Verify that renewable energy reported in Section 1.8 of EA Prerequisite 2 form is consistent with EA Credit 2.	• Renewable energy reported is inconsistent with EA Credit 2. • Renewable energy does not include backup calculations or narrative describing calculation methodology.	n/a
	Verify that amount of renewable energy generated is reasonable, cross-checking information provided by EA Credit 2.	• Renewable energy generated is inconsistent with power input. • Calculations to justify renewable energy generation are omitted.	National Renewable Energy Laboratory (NREL), PV Watts Calculator
Exceptional calculation method	Verify validity of exceptional calculation methodology (general).	• Defensible baseline is not established. • Narrative describing baseline and proposed case assumptions for energy efficiency measure is not provided. • Calculations and theoretical or empirical information supporting accuracy of methodology are omitted. • Methodology for exceptional calculations for measures, such as refrigeration, heat recovery, and process load savings, is incorrect.	ASHRAE 90.1–2007, G2.5
	Verify validity of exceptional calculation methodology for manufacturing facilities.	• The baseline case description does not verify that manufacturing equipment is standard practice for similar newly constructed facility.	
	Verify validity of exceptional calculation methodology for demand controlled ventilation and garage ventilation.	• The baseline case description does not provide evidence that garage demand control ventilation is not standard practice for similar newly constructed facilities where project is located. • Information regarding ventilation rates, fan power, operating schedules of proposed, and baseline case garage fans is not provided. • Baseline fan volume exceeds minimum ventilation rates of 0.75 cfm/sf for parking garage as required by ASHRAE 62.1–2007.	ASHRAE 62.1-2007, Table 6-4
Simulation output	Verify consistency between energy consumption and cost simulation outputs and values reported in EA Prerequisite 2 form.	• Energy use and/or cost values reported in Tables EAp2-4 and EAp2-5 of EA Prerequisite 2 form are inconsistent with simulation output. • Consumption and cost values for electricity or natural gas vary by more than 10%, and narrative providing demand and utility tariff is not provided.	n/a

Table 3.2. Input Quality Control Checklist (continued)

Topic	Check	Common errors	Resources
	Verify that process energy costs are not less than 25% of baseline total energy cost.	• Process energy cost represents less than 25% of baseline total energy cost, and supporting documentation substantiating low process energy inputs is missing. • Process energy is arbitrarily set to 25% of total baseline building cost.	LEED v2009 EA Credit 1 requirements
	If building load output reports are provided, verify envelope loads to confirm reasonable heat gains and losses from walls, windows, skylights, slabs, floors, and roofs. If one element seems to have unreasonably high heat gains or losses, check total exterior surface area and construction assembly to confirm accuracy.	• Envelope elements are not correctly modeled.	n/a
	If California Title 24–2005 is referenced, check UTIL-1 report to verify that EnergyPro was run in compliance mode.	• EnergyPro is not run in compliance mode, and narrative with sufficient supporting documentation to verify that baseline case system type and parameters match Title 24 requirements is omitted.	

EAp2 = Energy and Atmosphere Prerequisite 2

Table 3.3. Output-Input Consistency Quality Control Checklist

Topic	Check	Comments
End-use level energy demand, consumption, and savings		
Interior and exterior lighting power	Calculate lighting demand for both cases with average lighting power densities reported in EAp2 Section 1.4 table. Verify consistency with lighting power demand and consistency of exterior lighting demand reported in Table EAp2-5.	• Calculate lighting demand based on building floor area provided in Table 1.2 and lighting power density input in EAp2 Section 1.4 table. Lighting Demand = Average Lighting Power Density x Building Floor Area
	Determine whether any differences can be justified based on lighting control credits.	• Lighting schedule differences and daylighting, occupancy sensor, and other controls can account for differences in lighting power.
Interior and exterior lighting consumption	Verify that equivalent full-load hours (EFLHs) of both cases are based on lighting energy use and demand reported in Table EAp2-5.	• Calculate interior lighting EFLHs of proposed design: • EFLHs = Lighting Energy Use/ Lighting Power
	Determine whether any differences in EFLHs can be justified based on lighting control credits.	• Proposed case EFLHs can be reduced by lighting controls, such as daylighting controls, and reduced lighting schedules.
	If project references California Title 24–2005, verify that exterior lighting and unconditioned space lighting have been added to results reported in Tables EAp2-4 and EAp2-5.	• Include exterior and unconditioned lighting energy use for both baseline and proposed cases.
	Check Form OLTG-2-C for exterior lighting input and Form LTG-5-C for unconditioned space lighting input. Verify that energy use is calculated correctly.	• Multiply installed wattages by average annual operating hours, then divide by 1,000 to obtain annual energy consumption. • Multiply average annual energy consumption by average electricity cost to obtain annual energy cost.

Table 3.3. Output-Input Consistency Quality Control Checklist (continued)

Topic	Check	Comments
End-use level energy demand, consumption, and savings (continued)		
Cooling equipment efficiency	Confirm whether average efficiency of cooling equipment correlates (within reasonable margin) with Integrated Part Load Value IPLV reported in EAp2 Section 1.4 table.	• Use output of total ton-hours (or million Btu) of cooling and total kWh of cooling energy use to calculate cooling equipment average efficiency. • Average Efficiency (kW/ton) = Input kWh/ Output Ton-Hours
	Identify any parameters that may cause variance.	• Chillers operating mostly at full load show different IPLV from those operating mostly at part load (for DOE-2 models, see PS-C report, Equipment Load and Energy Use, for number of hours within each part-load range).
Fan and pump power	Verify that fan and pump demand reported in Tables EAp2-4 and EAp2-5 is consistent with fan and pump power reported in EAp2 Section 1.4 table.	• Demand reported in Table EAp2-4 and EAp2-5 should not be greater than total power reported in EAp2 Section 1.4 table. • Input kW = Output Hp x 0.746/Efficiency
	Verify that differences in fan and pump energy consumption versus demand between baseline and proposed cases can be justified.	• Variable-speed fans instead of constant-speed fans may justify variance in fan energy consumption versus demand. Variable-speed fans can lead to large consumption savings even when peak demand is similar.
System demand	Verify that system demand reported in Tables EAp2-4 and EAp2-5 is consistent with demand calculated with system capacities and efficiencies reported in EAp2 Section 1.4 table of Template, particularly for cooling system.	• If cooling is provided only by chillers, project's cooling demand can be calculated with following equation: • Cooling Demand (ton-hours) = Chiller Capacity (tons)/ • Chiller Efficiency (kW/ton)
Energy consumption by end use	Verify that energy consumption by end use is reasonable for project's climate zone based on inputs provided	• Large baseline end-use consumption may result from inappropriate autosizing for cooling and heating capacities, fan supply volume, and pump flow. Autosizing ratio cannot be double-counted (applied at both system and plant levels).
Energy end-use savings	Identify efficiency measures from input summary table and verify that heating, cooling, fan, and pump savings are justified based on combined efficiency measures. Confirm that top two end uses with highest energy savings (absolute savings) are reasonable based on energy efficiency measures implemented.	**Envelope energy efficiency measures** Determine whether building is internally or externally load dominated. Verify consistency of variation in heating and cooling loads between baseline and proposed cases versus envelope efficiency measures, such as increased insulation, high-performance fenestration or shading, thermal mass, cool roof, and optimized building orientation. **Exhaust air heat recovery** If exhaust energy recovery is noted as efficiency measure, check that proposed case accounts for additional fan power associated with energy recovery. ERV savings are often exaggerated when fan power increases are not included in model. **Ground-source heat pumps** If no supplemental fossil fuel boiler, expect to see significant heating energy savings in cold climates associated with electric resistance heating. Expect to see increased pump power in most cases. Verify that modeled efficiency curves and loop temperatures are consistent with actual design. **Variable refrigerant volume systems** Expect limited savings in climates where there is little simultaneous heating and cooling in thermal zones, unless heat recovery is implemented for water heating or other uses. Highest savings (about 30%) occur in climates where heating and cooling of thermal zones is often simultaneous (e.g., heating in north-facing zones while cooling in south-facing zones).

Table 3.3. Output-Input Consistency Quality Control Checklist (continued)

Topic	Check	Comments
End-use level energy demand, consumption, and savings (continued)		
		Variable-speed drives If constant-volume fan control is modeled in baseline and VAV in proposed, expect to see 30%–60% savings from full-load values. Higher values should be questioned. For chilled water, condenser water, and hot water pumps, significant savings can be achieved from variable primary configuration versus constant primary or variable secondary configuration. **Variable-speed chillers** Depending on control methods, these chillers can save 50%–60% of cooling energy. Level of savings requires control strategy that usually operates chillers at 35%–50% load and is typically associated with chilled water and condenser water reset controls. **Reduced domestic hot water flow** Calculations reflecting reduced flow should not affect standby loss calculations; energy savings equal to flow reduction are unlikely. Calculations reflecting savings should account for percentage of hot water versus cold water flow to fixtures. **Condensing boilers** • Delta-T and entering water temperatures are critical parameters. Large heating savings should not be approved unless control strategies generally limit entering water temperature to 130ºF or below. The baseline curve should also be carefully scrutinized to verify that average fuel utilization efficiency (AFUE) is consistent with average efficiency reported for baseline case. **Increased CHW delta-T:** • Expected results for elevated chilled water differential temperatures include lower pumping energy due to reduced flow, improved performance of variable speed chillers at low lift conditions, and increased fan power unless measures are taken to lower fan static pressure.
Consistency between end uses	Identify reasons for cooling capacities that vary substantially from 400 sf/ton, and for supply air flows that vary substantially from 1 cfm/sf.	n/a
	Verify cooling versus heat rejection energy savings.	• Cooling and heat rejection should reflect similar savings. *Exception:* If control strategies for heat rejection vary between baseline and proposed case, differences may be justified (e.g., difference may occur if wet bulb temperature is reset to 60ºF versus 70ºF or design temperature is 75ºF versus 85ºF, or water-side economizer is used).
	Calculate approximate expected proposed design fan energy savings of VAV systems and verify consistency with percentage savings reported in Table EAp2-5.	• After normalizing fan power, VAV system fan energy savings should align with cooling (and to lesser extent heating) energy savings. Approximate Expected Proposed Design Fan Energy Savings = 1 – [100% – Percentage of Proposed Design Fan Demand Savings] x [100% – Percentage of Proposed Design Cooling Energy Savings] *Exception:* Cooling equipment efficiency measures that improve cooling performance at part load would not be reflected in fan savings.
	Verify cooling energy savings or heating energy increase versus lighting or process power density reduction.	• Cooling savings should occur with lighting or process power density reductions. *Exception:* Projects with economizer controls will not reflect maximum savings associated with loads reductions. • Heating energy increase should occur with lighting or process power density reductions.

Table 3.3. Output-Input Consistency Quality Control Checklist (continued)

Topic	Check	Comments
Building-level energy consumption and cost		
Benchmark comparison	Verify that total energy consumption, EUI, and energy cost per unit floor area relative to benchmark data are reasonable for both baseline and proposed cases for building type and climate. Verify that statistically significant differences are justified based on building-specific parameters.	• Commercial Buildings Energy Consumption Survey (CBECS consumption and expenditures tables, available at http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html). • Check Commercial End-Use Survey (CEUS data, available at http://www.energy.ca.gov/ceus/).
Virtual energy rates	Determine whether differences in virtual energy rates are justified based on utility rate information provided.	• Calculate virtual energy rates for each type of fuel by dividing total cost by total use. • Higher virtual rates are seen when peak demand charges are high and demand by end use are high. • Lower virtual rates are seen when peak demand rates are high and energy efficiency measures, such as thermal energy storage or daylight harvesting controls, curb peak demand.
	Verify that natural gas rate for residential projects modeled with EnergyPro reflects cost of domestic hot water heating, and that virtual rate is calculated based on tariff, not virtual rate comprising mostly monthly meter fees.	• Gas rate is calculated based on virtual rate comprising mostly monthly meter fees.

EAp2 = Energy and Atmosphere Prerequisite 2

CBECS = Commercial Buildings Energy Consumption Survey

CEus = Commercial End-Use Survey

EFLH = equivalent full-load hours

EUI = energy use intensity

VAV = variable air volume

CHAPTER 4.
ATYPICAL ENERGY SYSTEMS AND SCENARIOS

This chapter provides guidance to reviewers and applicants on the variances presented by site, project, or systems scenarios. These include the following:

- HVAC systems that are difficult to model and require exceptional calculations;
- energy cost savings calculations for existing building additions;
- energy cost savings calculations for multiple buildings on the same site;
- district energy system (DES) modeling requirements; and
- combined heat and power (CHP) system modeling requirements.

4.1. Exceptional Calculations

Section G2.5 of ASHRAE 90.1–2007 stipulates that when no simulation program can adequately model a design, material, or device, the rating authority (here, USGBC) may approve an exceptional calculation method to demonstrate above-standard performance. Applications for approval of an exceptional method must include documentation of the calculations performed and theoretical and/or empirical information supporting the accuracy of the method. The LEED reviewer evaluates whether the exceptional calculations can substantiate the energy savings and whether the energy and costs saved are entered appropriately in the LEED credit form.

Table 4.1 lists examples of energy efficiency measures for which exceptional calculations are required and cites applicable LEED Interpretations with further guidance on the methodology.

Table 4.1. LEED Interpretations Regarding Exceptional Calculations

Scenario	LEED Interpretation
Energy savings from HVAC systems controlled by occupancy sensors	LEED Interpretation 1847
Energy savings from natural ventilation	LEED Interpretation 1734
Energy savings from automatic lighting controls	LEED Interpretation 2360
Process energy use reduction	LEED Interpretations 2339, 5317, 1844, 1693
Process energy savings from efficient hard-wired lighting in residential units	LEED Interpretation 5253
Process energy savings in data centers	LEED Interpretation 2441

In addition, this manual offers the following resources for further guidance on performing and documenting exceptional calculations:

- Appendix D includes examples of well-documented exceptional calculations used by project teams.
- Appendix C presents guidance on the exceptional calculations section of the LEED credit form.
- Table 2.2, Summary of Major EA Prerequisite 2 and EA Credit 1 Interpretations, includes detailed requirements on exceptional calculations.
- Table 3.2, Output QC Checklist, summarizes common errors. This list is a good resource for both applicants and reviewers on the use of exceptional calculations.

4.2. Calculations for Additions to Existing Buildings

If a project consists of both an existing building renovation and new construction, the following equation is used to determine the appropriate point thresholds for EA Prerequisite 2 and EA Credit 1:

$$\text{Target Percentage} = \frac{\text{Existing Floor Area}}{\text{Total Floor Area}} \times \text{Target Percentage of Savings for Existing Buildings} + \frac{\text{New Floor Area}}{\text{Total Floor Area}} \times \text{Target Percentage of Savings for New Buildings}$$

For example, if a project comprises 75,000 square feet of existing buildings and 40,000 square feet of new construction, the point threshold table must be modified as shown in Table 4.2.

Table 4.2. EA Credit 1 Point thresholds for New Construction plus Renovations to Existing Buildings

New Buildings	Existing Building Renovations	Project Target	Points
12%	8%	9.4%	1
14%	10%	11.4%	2
16%	12%	13.4%	3
18%	14%	15.4%	4
20%	16%	17.4%	5
22%	18%	19.4%	6
24%	20%	21.4%	7
26%	22%	23.4%	8
28%	24%	25.4%	9
30%	26%	27.4%	10
32%	28%	29.4%	11
34%	30%	31.4%	12
36%	32%	33.4%	13
38%	34%	35.4%	14
40%	36%	37.4%	15
42%	38%	39.4%	16
44%	40%	41.4%	17
46%	42%	43.4%	18
48%	44%	45.4%	19

4.3. Calculations for Multiple Buildings

LEED 2009 requires individual energy models for each building in a group of buildings within a master site; it does not allow project teams to calculate the performance of a group of buildings in one energy model.

LEED Application Guide for Multiple Buildings and On-Campus Building Projects (AGMBC 2010) requires LEED 2009 project teams to certify their buildings or spaces individually; that is, individual energy models are required for each building. AGMBC 2011 will contain guidance to help project teams certify multiple buildings as one group to receive a single certification; however, teams must still submit individual energy models for each building.

4.4. District Energy Systems

A district energy system (DES) uses a central energy conversion plant and a transmission and distribution system that provides thermal energy to a group of buildings (heating via hot water or steam, and/or cooling via chilled water). Plants providing only electricity are not considered DES.

"Treatment of District or Campus Thermal Energy in LEED v2 and LEED 2009: Design & Construction," published on August 13, 2010, is USGBC's second (v2.0) major release of guidance for district or campus thermal energy. It is the formal guidance for LEED 2009 projects and an update for the original Version 1.0 guidance (May 2008) for LEED for New Construction v2.2, LEED for Schools, LEED for Commercial Interiors v2.0, and LEED for Core and Shell v2.0. The guidance clarifies whether and how project teams should account for district energy systems in the prerequisites and credits. LEED 2009 projects are not formally required to use this guidance, but it is highly recommended. If the guidance is applied, it must be applied in its entirety, for all relevant Energy and Atmosphere credits. The guidance applies to all DES, whether new or preexisting, and whether owned by the project owner or another entity. If the project team opts to follow the guidance, all downstream equipment must be included in the scope of EA Prerequisite 2 and EA Credit 1. Such equipment includes heat exchangers, steam pressure reduction stations, pumps, valves, pipes, building electrical services, and controls.

Like conventional EA Credit 1 approaches, DES projects can take either a prescriptive or a performance-based approach to calculations. For the performance-based path, the modeling protocols that were called Step 1 and Step 2 in the Version 1.0 guidance have been recast as Option 1 and Option 2 in the new guidance. Each project team chooses one of the two performance options to show compliance with both EA Prerequisite 2 and EA Credit 1; it is not required to do both. The Version 2.0 guidance also provides clarification regarding the utility rates to be used for Option 2 and the determination of average efficiency. Additional options have also been provided for using an average seasonal, monthly, or hourly efficiency rather than an annual average efficiency.

A project team that follows the performance compliance path using ASHRAE 90.1-2007 can choose one of the two performance options to complete the analysis for EA Prerequisite 2 and EA Credit 1.

Option 1: Stand-alone building scenario

- This option documents the performance of the building alone, with upstream equipment modeled as cost neutral. The energy source is modeled as purchased energy in both the baseline and the proposed cases for all downstream equipments serviced by district or campus energy systems. This option has a point cap (the maximum number of points that can be earned). Projects seeking more points must use Option 2.

Option 2: Aggregate building and DES scenario

- This option documents the combined performance of the building and central plant by including the performance of upstream equipment. This option has a point floor (the minimum number of points that must be earned). Projects seeking fewer points must use Option 1 unless the building housing the thermal energy plant is itself the LEED project building.

A Project that uses Title 24–2005 can follow Version 2.0, Option 2 if it is taking credit for the efficiency of the district energy system serving the project.[3] Version 2.0 has additional guidance for projects using California Title-24. Specifically, the baseline case is modeled consistently with Title 24-2005 protocol. However, a virtual DES-equivalent plant for the proposed case is constructed and compared to the Title 24 baseline case. Title 24 projects following this option have the same point floors as projects using ASHRAE 90.1. Projects seeking fewer points must use Option 1.

4.5. Combined Heat and Power Systems

Combined heat and power (CHP) systems capture and use the heat that would otherwise be lost in traditional fossil fuel generation of electrical power. The total efficiency of these integrated systems is much greater than that from central station power plants and separate thermal systems. CHP systems can also reduce peak demand and CO_2 emissions.

3 Title-24 2005 does not allow credit for the efficiency of district energy systems. Therefore, if the project is taking credit for the efficiency of the district energy systems serving the project, then the DES v2 document http://www.usgbc.org/ShowFile.aspx?DocumentID=7671 must be followed in its entirety. The project team must clearly state whether credit is being modeled for the district energy system efficiency. If credit is being taken, follow the Option 2 requirements defined in the DES v2 document referenced here. Otherwise, the project team must confirm and clearly communicate that the proposed case plant inputs represent the default Title-24 inputs, and that no central plant has been modeled for the proposed case in the Title-24 software.

USGBC has published two guidance documents for treatment of CHP under the energy performance compliance path for LEED 2009 projects. The use of these guidance documents is optional for LEED 2009 projects.

- "Treatment of District or Campus Thermal Energy in LEED V2 and LEED 2009: Design & Construction" (August 13, 2010) incorporates the updated guidance for district or campus CHP systems under Option 2. Projects with district CHP can follow the modeling guidance in this document.
- "Methodology for Modeling Combined Heat and Power for EAp2/EAc1 credit in LEED 2009" (July 18, 2011) supplements the guidance in Appendix G for modeling on-site CHP plants. It is intended for project teams documenting energy savings with on-site CHP systems.

CHAPTER 5.
RELATED CREDITS

This chapter explains the synergies and overlaps of EA Prerequisite 2 with EA Credits 2 and 6 in the LEED rating systems. It also includes documentation guidance for these two credits.

5.1. EA Credit 2, On-Site Renewable Energy

5.1.1. Overview

EA Credit 2 requires that projects use eligible on-site renewable energy systems to offset building energy cost by at least 1% to achieve the minimum threshold. When the performance compliance method (Option 1) is used for EA Prerequisite 2, the total energy consumption and cost reported in EA Prerequisite 2 is linked to the data listed in EA Credit 2. The renewable energy generated on site can also offset total building energy use from traditional energy sources and help projects achieve higher performance ratings for EA Credit 1. Table 5.1 lists eligibility requirements for on-site renewable energy.

Table 5.1. Eligible and Ineligible Renewable Energy Systems

Eligible	Ineligible
1. Electrical production systems based on • photovoltaic (pv) • wind • hydroelectric • tidal or wave • biofuels, including untreated wood waste, agricultural crops or waste, animal waste and other organic waste, and landfill gas 2. Solar thermal systems 3. Geothermal systems that use deep-earth water or steam sources to produce electric power or thermal energy	1. Architectural passive design strategies, such as shading and daylighting 2. Earth-coupled HVAC systems that do not obtain significant quantities of deep-earth heat, such as ground-source heat pumps 3. Biofuels, including combustion of municipal solid waste, forestry biomass waste other than mill residual, wood coated with pains, plastics, or formica, and wood treated for preservation with some materials

(LEED Interpretation 1842 defined the conditions that must be met for projects to qualify for renewable energy credits under EA Credit 2:

1. The renewable energy system is installed within the boundaries of the project or on the project site.
2. The renewable energy system is connected immediately adjacent to the utility meter.
3. If on-site renewable energy sources are owned and operated by an entity other than the building owner, a minimum 10-year contract for on-site generation is established with the owner of the energy system, and the energy system owner does not count the renewable energy certificates (RECs) associated with the renewable energy system to meet a mandated renewable portfolio standard goal, or the owner of the energy system provides the RECs to the project owner. The RECs associated with the renewable energy system are not sold.

Green power generated off site may be eligible under EA Credit 2 if the off-site renewable energy system provides energy dedicated for the project building, as allowed by LEED Interpretation 10032.

Project teams that sell the renewable energy certificates associated with on-site energy production can achieve EA Credit 2 by purchasing a total amount of RECs equal to 100% of the renewable energy system's annual rated energy output for at least 10 years, as allowed by the LEED 2009 Building Design and Construction Reference Guide addenda.

For project teams documenting EA Prerequisite 2 using DES Guidance Version 2.0, Option 2 (the aggregate building DES scenario), qualified renewable energy sources used in a district energy system may earn points in EA Credit 2 for a connected building. That is, the energy sources count as on-site renewable energy for the connected building. For a project team using Option 1 for EA Prerequisite 2, renewable DES sources do not earn points under EA Credit 2 for a connected building. Detailed calculation and documentation requirements can be found in the DES Guidance Version 2.0 (http://www.usgbc.org/ShowFile.aspx?DocumentID=7671).

5.1.2. Calculation Methods

The percentage of renewable energy cost that is used to determine the points earned by a project is calculated with the following two equations:

$$\text{Renewable Energy Cost} = \text{On-Site Energy Generated} \times \text{Utility Rate (\$/unit)}$$

$$\text{Percentage Renewable Energy} = \frac{\text{Renewable Energy Cost}}{\text{Total Energy Cost}} \times 100$$

How total energy use is calculated depends on whether energy simulation is performed for EA Credit 1. Table 5.2 lists the ways to determine this figure.

Table 5.2. Calculation Methods for Renewable Energy Cost

	Simulation performed for EA Credit 1	Simulation not performed for EA Credit 1
Energy generated	Estimate, using same simulation tool employed for EA Credit 1 or separate calculation.	Use separate calculation.
Utility rate	Use actual utility schedule or virtual utility rate.	Use "Commercial Sector Average Energy Cost by State" (EIA 2003).
Total energy cost	Use total design energy cost of proposed design before credit for renewable energy is taken.	Default Total Energy Cost = Energy Intensity x Building Area x Utility Rate Energy intensities are median electricity and fuel consumption intensities, in kWh/sf and kBtu/sf, from CBECS database.

CBECS = Commercial Buildings Energy Consumption Survey

EIA = Energy Information Administration

5.1.3. Common Errors

The following common errors have been identified in EA Credit 2 applications:

- The total energy cost claimed does not match the figures from the EA Prerequisite 2 credit form or CBECS data.
- Electricity consumption is used instead of energy cost.
- The renewable energy source does not meet the credit requirements.
- The information provided to determine the renewable energy consumption and cost is insufficient.
- The renewable energy consumption and cost for weather-dependent systems are not based on hourly weather data.
- For renewable energy systems whose energy generation is limited to the loads of the building (such as solar energy with limited storage tank capacity), the renewable energy consumption and cost do not account for the building load profile data.

5.2. EA Credit 6, Green Power

5.2.1. Overview

EA Credit 6 requires that the project obtain at least 35% of its electricity from renewable sources by engaging in a minimum two-year renewable energy contract. A core and shell building's electricity is defined as the electricity usage of the core and shell square footage, but not less than 15% of the building's total gross square footage.

Electricity products certified by Green-e are typically greener and cleaner than the average retail electricity products sold in a region. EA Credit 6 can be achieved by purchasing Green-e power directly through utilities or, in regions without green power providers, by purchasing renewable energy certificates. The eligible power products are not necessarily Green-e certified but must meet the requirements for Green-e equivalency. If the purchased power is not Green-e certified, the project team should demonstrate that two major criteria for Green-e certification are met: (1) the energy source meets the requirements for renewable resources detailed in the current version of the Green-e standard, and (2) the renewable energy supplier has undergone an independent, third-party verification that the standard has been met. Documentation should include the state-mandated power disclosure label from the renewable energy supplier and a green power scorecard or rating from third-party verification or auditing. Project teams must confirm that the third-party entity's regulatory or verification program is valid, summarize the program, and highlight any auditing or other independent checks the program performs.

The purchase of Green-e certified carbon credits instead of RECs does not achieve this credit. The intent of the credit is to encourage the development and use of grid-source, renewable technologies on a net-zero-pollution basis. Carbon offsets do not necessarily meet this intent.

5.2.2. Calculation Methodology

The percentage of green power that is used to determine the points earned for this credit is calculated as follows:

$$\text{Percentage Green Power} = \frac{\text{Purchased Green Power}}{\text{Total Electricity}} \times 100$$

When the performance compliance method (Option 1) is used for EA Prerequisite 2, the total energy consumption and cost reported in EA Prerequisite 2 are linked to the data for EA Credit 6.

Table 5.3. Calculations Methods for Green PowerCalculation Method for Total Energy Use

	Simulation performed for EA Credit 1	Simulation not performed for EA Credit 1
Total electricity use	Use total electricity use of proposed design reported in EA Prerequisite 2 submittal form. **LEED-CS** Electricity Use = Total Building Electricity X Percentage of Core and Shell sf[4]	Calculate default total electricity consumption by multiplying median electricity intensity (in kWh/square foot) obtained from CBECS database with total building floor area. **LEED-CI** Use 8 kWh/sf/year to calculate required renewable energy purchase for 50% of tenants' electricity consumption

5.2.3. Common Errors

The following common errors have been identified in EA Credit 6 applications:

- The name of the green power provider is not provided.
- The amount of green power purchased or the value of green tags purchased is omitted.
- The CBECS value used to calculate default electricity use is incorrect.
- The green power purchase is based on electricity cost instead of electricity consumption.
- The contract duration is not stated.
- The purchase is for 35% of the total annual energy consumption for only one year instead of two.

4 The core and shell square footage is the gross square footage (GSF) minus the usable square footage (USF). Percentage of core and shell square footage = (GSF-USF)/GSF x100

APPENDIX A.
ASHRAE 90.1–2007 ADDENDA

The ASHRAE 90.1–2007, Appendix G, addenda that affect achievement of EA Credit 1 are listed and described in Table A.1. As previously noted, a project team that elects to apply requirements in an addendum must apply the entire addendum to all other relevant credits in the LEED submittal. In addition, USGBC allows the use of ASHRAE 90.1–2010, Appendix G, which includes all ASHRAE 90.1–2007 addenda and other modifications, in place of ASHRAE 90.1–2007, Appendix G, if the energy simulation follows the language of 2010 Appendix G in its entirety.

Table A.1. ASHRAE 90.1–2007, Appendix G, Addenda

Appendix G section	Topic	Description	Addendum text
Table G3.1.1A	Baseline HVAC system types exception	Addendum w adds exception to the footnotes.	Where attributes make a building eligible for more than one baseline system type, use the predominant condition to determine the system type for the entire building *except as noted in Exception a to Section G3.1.1.*
Section G3.1.2.10	Exhaust air energy recovery	Addendum w applies exception for exhaust air energy recovery for multifamily buildings.	**G3.1.2.10 Exception i:** i. Systems serving dwelling units in multifamily buildings.

Table A.1. ASHRAE 90.1–2007, Appendix G, Addenda (continued)

Appendix G section	Topic	Description	Addendum text
Section G3.1.1	Heating-only systems in storage buildings or spaces	Addendum dn allows heating-only systems to be modeled in baseline and proposed case models for storage spaces.	**Exceptions to G3.1.1** e. Thermal zones designed with heating only systems in the proposed design, serving rooms, stairwells, vestibules, electrical/mechanical rooms, and restrooms not exhausting or transferring air from mechanically cooled thermal zones in the proposed design shall use system type 10 or 11 in the *baseline building design*. f. If the baseline HVAC system type is 10 or 11, all spaces that are mechanically cooled in the *proposed building design* shall be assigned to a separate baseline system determined by using the area and heating source of the mechanically cooled spaces. **Table G3.1, Proposed Building Performance #10.** d. Where no cooling system exists or no cooling system has been specified, the cooling system shall be identical to the system modeled in the *baseline building design*. **Exception to d**: Spaces using baseline HVAC system types 10 and 11 **Table G3.1.1A Baseline HVAC System Types** Building Type: Heated Only Storage Fossil Fuel, Fossil/Electric Hybrid, and Purchased Heat: System 11 – Heating and Ventilation Electric and Other: System 10 – Heating and Ventilation **Table G3.1.1B Baseline System Descriptions** System 11. Heating and Ventilation, System Type: Warm air furnace, gas fired, Fan Control: Constant Volume, Cooling Type: None, Heating Type: Fossil fuel furnace System 10. Heating and Ventilation, System Type: Warm air furnace, electric, Fan Control: Constant Volume, Cooling Type: None, Heating Type: Electric resistance **G3.1.2.8.2 Baseline System Types 10 and 11.** System design supply airflow rates for the *baseline building design* shall be based on the temperature difference between a supply air temperature setpoint of 105 degrees F and the design space heating temperature setpoint, the minimum outdoor air flow rate, or the air flow rate required to comply with applicable codes or accreditation standards, whichever is greater. If the *Proposed Building Design* includes a fan(s) sized and controlled to provide non-mechanical cooling, the baseline building design shall include a separate fan to provide non-mechanical cooling, sized and controlled the same as the *proposed building design*. **G3.1.2.9 System Fan Power.** For systems 10 and 11 (supply fan), $P_{fan} = CFM_s \times 0.3$ For systems 10 and 11 (non-mechanical cooling fan if required by Section G3.1.2.9.2) $P_{fan} = CFM_{nmc} \times 0.054$ Where P_{fan} = electric power to fan motor (watts) CFM_s = the baseline system maximum design supply fan airflow rate in cfm CFM_{nmc} = the baseline non-mechanical cooling fan airflow in cfm

APPENDIX B.
COMMONLY USED ENERGY SIMULATION SOFTWARE

DOE-2–Based Software (eQUEST, VisualDOE)

DOE-2 is a publicly available simulation software engine that was developed by James J. Hirsch & Associates in collaboration with the Lawrence Berkeley National Laboratory. DOE-2–based programs simulate the hourly energy use and energy cost of a building based on hourly weather information and a description of the building, its HVAC equipment, and the utility rate structure. The program structure of DOE-2 is illustrated in Figure B.1. Several front-end programs have been developed that give DOE-2 a user-friendly input interface and generate formatted output reports.

DOE-2 based modeling software for the EA Credit 1 performance compliance path using ASHRAE Appendix G includes DOE2.1e (VisualDOE) and eQuest. The latter is a free building energy analysis simulation program widely used for LEED projects. eQuest can model buildings with multiple zones and interface with AUTOCAD to set up the floor and zone geometry and layout. The program can provide detailed modeling output files. More information on eQuest can be obtained at http://www.doe2.com/equest/.

HAP

Carrier's Hourly Analysis Program (HAP) is a multipurpose tool. It provides features for peak load estimating, system design, whole building energy simulation, EA Credit 1 analysis, and schematic design screening studies. HAP provides options for modeling a wide variety of HVAC systems and equipment and their controls. The program offers extensive tabular and graphical output reports. HAP is able to import gbXML for interoperability with BIM and CAD applications. The program can switch between different graphical user interfaces for efficient work in the schematic design and detailed design phases of a project. Further information about HAP, its availability, and training opportunities is available at http://www.carrier.commercial.com.

TRACE 700

Trane Air Conditioning Economics, or TRACE, is another design and analysis tool commonly used by mechanical and HVAC firms. It helps HVAC professionals optimize the design of a building's HVAC systems based on energy use and life-cycle cost. It can import and export gbXML data for CAD interoperability. The program also provides tabular and graphical outputs. More information on TRACE is available at http://www.trane.com/commercial/software.

EnergyPro

The EnergyPro software, produced by EnergySoft, uses the DOE-2.1E simulation engine, licensed from the Department of Energy, to simulate building energy consumption. EnergyPro performs an hourly (8,760) simulation of the building by passing the necessary BDL commands to DOE-2, which then performs the energy calculations. EnergyPro has been approved by the California Energy Commission for use with Title 24, and the software is configured to automatically generate the baseline building ("standard building" in Title 24 terminology). As part of the certification process, the baseline building generation ability was confirmed during a series of several hundred tests. The user cannot modify the baseline building from within the software. EnergyPro is also configured to run the ASHRAE 90.1 baseline per the Appendix G specifications, using the same type of automatic baseline generation procedures. More information on EnergyPro can be found at www.energysoft.com.

EnerSim

EnerSim is a Windows-based computer modeling tool developed by the Southern Company to simulate hourly electric and gas demands for new and existing buildings and the equipment associated with them. Simulation results are based on hourly weather data, building envelope details, types of equipment, and occupancy. Buildings can be modeled with multiple zones and spaces. EnerSim incorporates a rate calculator program that estimates energy costs based on various rate structures.

EnergyPlus

EnergyPlus is a simulation program based on Building Loads Analysis and System Thermodynamics (BLAST) and DOE-2. The program includes additional simulation capabilities, such as time steps of less than an hour, modular systems and plant integrated with heat balance-based zone simulation, multizone airflow, thermal comfort, water use, natural ventilation, and photovoltaic systems. Currently, a few third-party tools have been developed for creating, editing, and displaying EnergyPlus input files. EnergyPlus is on the list of qualified software for calculating compliance with the IRS 179D Tax Deduction for commercial buildings. Additional information on EnergyPlus and the interfaces available is available at http://www.energyplus.gov. AECOsim Energy Simulator (AES) incorporates the EnergyPlus simulation engine and automatically generates the baseline buildings and compliance reports for Standard 90.1–2007. In addition, AES automatically creates documentation for EA Credit 1. AES can import gbXML and other BIM information directly. More information on AECOsim Energy Simulator is available at http://www.bentley.com/en-US/Promo/AECOsim/aecosim+energy+simulator.htm.

IES Virtual Environment

The Virtual Environment (VE) software developed by Integrated Environmental Solutions (IES) is an integrated set of building performance analysis tools. The VE-Pro suite offers in-depth, advanced thermal design and energy simulation capabilities. The integrated components permit simultaneous consideration of thermal mass, HVAC plant, interior and exterior solar gains and shading, natural ventilation and dimming strategies, and other systems. It performs a comprehensive dynamic thermal simulation using hourly weather data and can operate at time steps as small as one minute. Calculations are based on first-principles models of heat transfer process.

A wide range of standard, high-performance and other nonconventional HVAC systems are supported, with detailed modeling of both airside and waterside equipment and controls. VE-Pro also supports load calculation via the ASHRAE heat balance method. Users can build from scratch or use a fully customizable library of predefined prototype HVAC systems to facilitate autosizing and modeling.

The company has developed a workflow VE-Navigator that takes users step-by-step though the ASHRAE 90.1 Appendix G performance rating method for LEED energy modeling. It automates creation of the baseline models, predefines and autosizes baseline systems, calculates ASHRAE 62.1 ventilation rates, calculates baseline fan power allowances, accounts for static pressure credits, and integrates quality control. It produces reports that mirror the EA Credit 1 submission format. A similar tool automates other LEED credit assessments for daylighting, thermal comfort, water efficiency, and renewable energy. See www.iesve.com.

Note: *USGBC makes no representation regarding the specific individual capabilities of the software programs listed above or their capabilities for developing the Appendix G baseline. Project teams are encouraged to follow the processes outlined in this manual to confirm that the ASHRAE 90.1 Appendix G baseline components have been correctly modeled for the project before making the preliminary LEED submission.*

APPENDIX C.
ANNOTATED LEED CREDIT FORM

Figure C.1. Target Finder and Prerequisite Compliance

ALL PROJECTS

TARGET FINDER

The following fields are required, but the values have no bearing on EA Prerequisite 2 compliance. Use the Target Energy Performance Results calculator on the ENERGY STAR website to generate the values. If using prescriptive compliance paths (Options 2 or 3), leave the Design energy consumption and cost values blank in the Target Finder website, and set the Design values equal to the Target values in this form.

	Design		Target	
Energy performance rating (1-100):				
CO_2-eq emissions:		metric tons/year		metric tons/year
CO_2-eq emissions reduction:		%		%

Use the Target Energy Performance Results calculator on the Energy Star website

Upload EAp2-1. Provide the Target Finder Energy Performance Results for the project building (a screen capture or other documentation containing the same information). (Optional) Upload

☐ The building is not able to get a Target Finder score because the tool does not support the primary building type of the project building and/or the project is not located in the United States

PREREQUISITE COMPLIANCE

Total gross square footage: sf

The content highlighted in yellow above is linked to Plf2, Plf3, SSc2, EAp1, EAc1, EAc2, EAc6, MRc1.1 & MRc1.2.

Principal project building activity:

The content highlighted in yellow above is linked to Plf3 & EAc1.

Select a compliance path:

- ◉ **Option 1. Whole Building Energy Simulation.** The project team will document improvement in the proposed building performance rating as compared to the baseline building performance rating per ASHRAE/IESNA Standard 90.1-2007 or California Title 24-2005 Part 6.
- ○ **Option 2. Prescriptive Compliance Path: ASHRAE Advanced Energy Design Guide.** The project team will document compliance with the ASHRAE Advanced Energy Design Guide.
- ○ **Option 3. Prescriptive Compliance Path: Advanced Buildings Core Performance Guide.** The project team will document compliance with the Advanced Buildings™ Core Performance™ Guide.

The content highlighted in yellow above is linked to EAc1, EAc2 & EAc6.

Figure C.2. General Information

SECTION 1.1A - GENERAL INFORMATION

☒ **Compliant energy simulation software:** The energy simulation software used for this project has all capabilities described in EITHER section "G2 Simulation General Requirements" in Appendix G of ASHRAE 90.1-2007 OR the analogous section of the alternative qualifying energy code used.

☒ **Compliant energy modeling methodology:** Energy simulation runs for both the baseline and proposed building use the assumptions and modeling methodology described in EITHER ASHRAE 90.1-2007 Appendix G OR the analogous section of the alternative qualifying energy code used.

Simulation program:

Principal heating source:

Energy code used:

List the ASHRAE addenda used in the modeling assumptions, if any. (Optional)

Zip/Postal Code:

The content highlighted in yellow above is linked to SSc1 & SSc2.

Weather file:

Climate zone:

List the climatic data from ASHRAE Standard 90.1-2007 Table D-1. Specify if another source is referenced for HDD & CDD data.

Heating Degree Days:

Cooling Degree Days:

HDD and CDD data source, if other than ASHRAE: (Optional)

New construction gross square footage:

Existing, renovated gross square footage:

Existing, unrenovated gross square footage:

Total gross square footage:

New construction percent: 0 %

Existing renovation percent: 0 %

Existing unrenovated percent: 0 %

The content highlighted in yellow above is linked to PII2, PII3, SSc2, EAp1, EAc1, EAc2, EAc6, MRc1.1 & MRc1.2.

Gross square footage used in the energy model, if different than gross square footage above: (Optional)

Figure C.3. Optional Interactive Compliance Forms

Provide the following Interactive Compliance Forms:

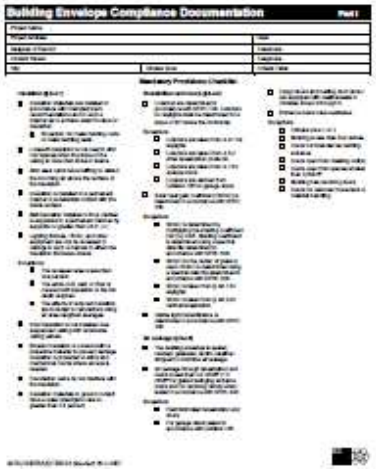
Link to downloadable forms on ASHRAE website

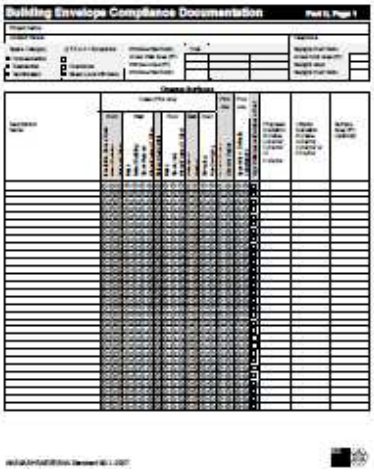
Upload EAp2-2. Building Envelope Compliance Documentation (Optional) Upload

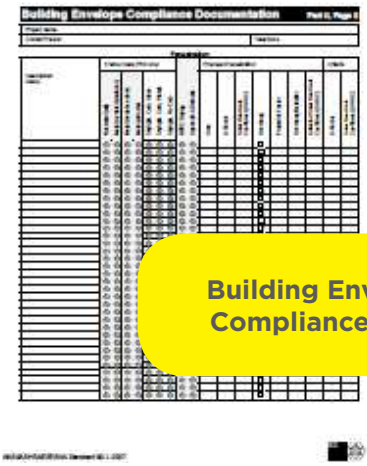
Upload EAp2-3. HVAC Compliance Documentation (Optional) Upload

Upload EAp2-4. Lighting Compliance Documentation (Optional) Upload

Upload EAp2-5. Service Water Heating Compliance (Optional) Upload







Building Envelope Compliance Form

Figure C.4. Project Space Usage Types Summary

SECTION 1.2 - SPACE SUMMARY

Table EAp2-1. Space Usage Type

Space Name / Description	Space Usage Type	Space Area (sf)	Regularly Occupied Area (sf)	Unconditioned Area (sf)	Typical Hours in Operation (per week)
Total		0	0	0	
Percentage of total (%)			0	0	

+ -

Figure C.5. Unmet Hours and Warnings

SECTION 1.3 - ADVISORY MESSAGES

Complete the table below based on information from the energy simulation output files.

Table EAp2-2. Advisory Messages

	Baseline Design (0° Rotation)	Proposed Design
Number of hours heating loads not met[1]		
Number of hours cooling loads not met[1]		
Total		
Difference [2] (Proposed minus baseline)	0	
Number of warning messages		
Number of error messages		
Number of defaults overridden		
Unmet load hours compliance	N	

1 Baseline design and proposed design unmet load hours each may not exceed 300
2 Unmet load hours for the proposed design may not exceed the baseline design by more than 50 hours.

Unmet load hours must be in compliance to achieve prerequisite/credit

The project does not meet the minimum compliance requirements for this credit for unmet load hours. Describe the reasoning for unmet load hours noncompliance, any special circumstances, or modeling difficulties.

Upload EAp2-6. Provide documentation to support the narrative above. (Optional)

Upload

Figure C.6. Proposed versus Baseline Comparison

SECTION 1.4 - COMPARISON OF PROPOSED DESIGN VERSUS BASELINE DESIGN ENERGY MODEL INPUTS

Download, complete, and upload "EAp2 Section 1.4 table.xls" (found under "Credit Resources") to document the baseline and proposed design energy model inputs for the project. Documentation should be sufficient to justify the energy and cost savings numbers reported in the Performance Rating tables below.

Upload EAp2-7. Provide the completed EAp2 Section 1.4 tables available under "Credit Resources."

Upload

Section 1.4 - Comparison of Baseline Design Versus Proposed Design

1.4.1A -ASHRAE 90.1 Section 5: Building Envelope (Construction Assemblies)

Model Input Parameter / Energy Efficiency Measure	Baseline Case			Proposed Case		
	Description	Insulation R-value	Assembly U-factor/ C-factor/ F-factor	Description	Insulation R-value	Assembly U-factor/ C-factor/ F-factor
Roofs						
Roof SRI						
Walls - Above Grade						
Walls - Below Grade						
Semiheated Exterior Envelope						
Floors						
Slab-On-Grade Floors						
Opaque doors						
Other						

Table 1.4.1A from Section 1.4 Tables

Figure C.7. Energy Types and Rates

SECTION 1.5 - ENERGY TYPE SUMMARY

List the energy types used by the project (i.e. electricity, natural gas, purchased chilled water or steam, etc.), and provide the the virtual energy rate from the baseline and proposed design energy model results or from manual calculations. *If revising the values in Table EAp2-3, reselect energy type in all affected rows in Table EAp2-4 and Table EAp2-5 to ensure that the revised values are propagated and that Table EAp2-4 and Table EAp2-5 calculations are refreshed.*

Table EAp2-3. Energy Type Summary

Energy Type	Utility Company Name	Utility Rate and Description of Rate Structure [1]	Baseline Virtual Rate[2] ($ per unit energy)	Proposed Virtual Rate[2] ($ per unit energy)	Units of Energy	Units of Demand
Electricity						
Natural Gas						

+ -

Notes:

1 Per ASHRAE 90.1-2007 G2.4, project teams are allowed to use the state average energy prices published by DOE's EIA for commercial building customers, available on EIA's website (www.eia.doe.gov). If project uses backup energy for on-site renewable energy, please specify the rate of backup source energy.

2 Rate is defined as the total annual charge divided by the metered energy from the plant for each resource.

Variances of more than 10% between Baseline and Proposed rates must be justified

Figure C.8. Baseline Performance

SECTION 1.6 - PERFORMANCE RATING METHOD COMPLIANCE REPORT

In the table below, list each energy end use for the project (including all end uses reflected in the baseline and proposed designs). Then check whether the end-use is a process load, select the energy type, and list the energy consumption and peak demand for each end-use for all four baseline design orientations.

Table EAp2-4. Baseline Performance - Performance Rating Method Compliance

End Use	Process	Baseline Design Energy Type	Units of Annual Energy & Peak Demand		Baseline (0° rotation)	Baseline (90° rotation)	Baseline (180° rotation)	Baseline (270° rotation)	Baseline Building Results
Interior Lighting			Energy Use						
			Demand						
Exterior Lighting			Energy Use						
			Demand						
Space Heating			Energy Use						
			Demand						
Space Cooling			Energy Use						
			Demand						
			Energy Use						
Elevators and Escalators	X		Energy Use						
			Demand						
			Energy Use						
			Demand						
BaselineTotal Energy Use (MMBtu/yr)									
Baseline Annual Process Energy (MMBtu/yr)					0				
Process Energy Modeling Compliance [1]					N				

1 Determined using Section 1.9 cost calculations after Section 1.9A is complete. Annual process energy costs must be at least 25% of the total energy costs for the proposed design. Process energy costs should be modeled to accurately reflect the proposed building.

Input results from all four rotations

Process energy must be at least 25% of total energy cost

Figure C.9. Design Case Performance

Table EAp2-5. Performance Rating - Performance Rating Method Compliance

End Use	Process	Baseline Building Units		Baseline Building Results	Proposed Design Energy Type	Units of Annual Energy & Peak Demand		Proposed Building Results	% Sav
Interior Lighting		Energy Use				Energy Use			
		Demand				Demand			
Exterior Lighting		Energy Use				Energy Use			
		Demand				Demand			
Space Heating		Energy Use				Energy Use			
		Demand				Demand			
Space Cooling		Energy Use				Energy Use			
		Demand				Demand			
						Energy Use			
		Demand							
Elevators and Escalators	X	Energy Use							
		Demand				Demand			
		Energy Use				Energy Use			
		Demand				Demand			
Total Energy Use (MMBtu/yr)								0	
Process Energy (MMBtu/yr				0				0	

Process energy must be the same for both cases, or projects must use the Exceptional Calculation Method

Figure C.10. Energy Use and Cost Summaries

Table EAp2-6. Section 1.6 Energy Use Summary

		Baseline		
Energy Type	Units	Process Subtotal	Total Energy Use	Proposed Energy Use
Electricity		0	0	0
Natural Gas		0	0	0
		0	0	0
Totals	MMBtu	0	0	0

Table EAp2-7. Section 1.6 Energy Cost Summary (Automatic)

		Baseline		
Energy Type	Units	Process Subtotal	Total Energy Cost	Proposed Energy Cost
Electricity	$	0	0	0
Natural Gas	$	0	0	0
	$	0	0	0
Total	$	0	0	0

Select one of the following:

- ○ **Section 1.6 Automatic Cost Calculation:** Total building energy costs will be based on the "virtual" energy rate defined in Section 1.5.
- ◉ **Section 1.6 Manual Cost Input:** The project team will analyze the total building energy costs based on local utility rate structures. Costs will be input separately from the energy model.

Note: Energy cost savings are summarized in Section 1.9A Total Building Performance Summary.

Project teams have the choice between using the virtual energy rates from Section 1.5, or manually calculating based on utility rate structures

Table EAp2-8. Section 1.6 Energy Cost Summary (Manual Cost Input) - Baseline Case

	Baseline				
Energy Type	Cost ($) (0° rotation)	Cost ($) (90° rotation)	Cost ($) (180°rotation)	Cost ($) (270° rotation)	Building Performance
Electricity					0
Natural gas					0
					0
Totals	0	0	0	0	0

Table EAp2-9. Section 1.6 Energy Cost Summary (Manual Cost Input)

		Baseline Case		Proposed Case
Energy Type	Units	Process	Section 1.6 Energy Cost	Section 1.6 Energy Cost
Electricity	$		0	
Natural Gas	$		0	
	$		0	
Totals	$	0	0	0

Figure C.11. Exceptional Calculation Method

SECTION 1.7 - EXCEPTIONAL CALCULATION MEASURE SUMMARY (if applicable)

Select one of the following:

- (●) The energy analysis includes exceptional calculation method(s) (ASHRAE 90.1-2007, G2.5).
- ( ) The energy analysis does not include exceptional calculation methods.

Exceptional Calculation Methods must be documented for any claims of savings from process load reductions

For each exceptional calculation method employed, document the predicted energy savings by energy type. If an end-use has an energy loss rather than an energy savings, enter it as a negative number.

Table EAp2-10. Exceptional Calculations

End Use	Exceptional Calculation Method Description	Energy Type(s)	Unit	Annual Energy Savings
Electricity				0
Natural Gas				0
				0
Total			MMBtu	0

Upload EAp2-11. Provide a narrative explaining the exceptional calculation method(s) performed, and theoretical or empirical information supporting the accuracy of the method(s). Reference any applicable Credit Interpretation Rulings.

Upload

Figure C.12. On-Site Renewable Energy

SECTION 1.8 - ON-SITE RENEWABLE ENERGY (if applicable)

Select one of the following

- (●) The project uses on-site renewable energy produced on-site.
- ( ) The project does not use on-site renewable energy.

Table L-1. Renewable Energy Source Summary

Renewable Source	Renewable Energy Source Allocation	Renewable System Owner	Backup Energy Type[1]	Rated Capacity	Annual Energy Generated	Units	Annual Energy Cost ($) (Optional[2])
Energy savings - Electricity					0		0
Energy savings - Natural gas					0		0
Energy savings -					0		0
Total energy savings					0	MMBtu	0

Notes:
1 Per ASHRAE 90.1 G2.4 Exception, baseline performance shall be based on the energy source used as backup energy or on the use of electricity if no backup energy source is specified.
2 Annual energy cost is required to document credit compliance with EA Credit 2, if attempted.

The content highlighted in yellow above is linked to EAc2.

Figure C.13. Total Performance Summary

SECTION 1.9A - TOTAL BUILDING PERFORMANCE SUMMARY

Table EAp2-15. Total Building Energy Use Performance

		Baseline		Proposed			
Energy Type	Units	Process Subtotal	Section 1.6 Total Energy Use	Section 1.6 Energy Use	Section 1.7 Energy Savings	Section 1.8 Renewable Energy Savings	Total Energy Use
Electricity		0	0	0	0	0	0
Natural Gas		0	0	0	0	0	0
		0	0	0	0	0	0
Totals	MMBtu	0	0	0	0	0	0
						Energy use savings (%)	0

The values below are automatically calculated using the virtual energy rate from Section 1.5 unless the project team has opted to manually input costs in Section 1.6, 1.7, and/or 1.8. To modify these values and/or to see automatically calculated results for reference see Sections 1.6, 1.7 or 1.8.

Table EAp2-16. Total Building Energy Cost Performance

		Baseline		Proposed			
Energy Type	Units	Process Subtotal	Section 1.6 Total Energy Cost	Section 1.6 Energy Cost	Section 1.7 Energy Savings	Section 1.8 Renewable Energy Savings	Total Energy Cost
Electricity	$		0		0	0	0
Natural Gas	$		0		0	0	0
	$		0		0	0	0
Totals	$	0	0	0	0	0	0
Baseline process energy costs as percent of total energy costs (%)		0				Energy cost savings (%)	0
						EA Credit 1 points documented	0

The content highlighted in yellow above is linked to EAc1.

Energy use savings will not necessarily match energy cost savings

APPENDIX D.
EXCEPTIONAL CALCULATION METHODOLOGY

This appendix describes exceptional calculation methodologies that have been submitted by project teams and accepted by USGBC. The actual values may have been tweaked, and the project names and any project-specific information are omitted for confidentiality reasons.

D.1. Natural Ventilation

Savings for natural ventilation should be claimed using an exceptional calculation methodology. Per Appendix G, if no cooling system exists, a default cooling system must be assumed and modeled. It must be identical to the system in the baseline building. The proposed system should be modeled as a hybrid, in which cooling is provided by natural ventilation when conditions are acceptable and by the default mechanical cooling system when natural ventilation is inadequate to provide thermal comfort. It is acceptable to use a combination of tools, evaluate indoor and outdoor temperatures, increase infiltration (to approximate natural ventilation), shut down the fans, and turn off the cooling during periods when open windows and natural ventilation have been determined to meet the cooling load.

Energy Efficiency Measure

The project is close to the ocean and consists of two small buildings, with a total of 8,500 sf, that achieve substantial energy savings by incorporating a natural ventilation strategy. No mechanical heating or cooling is intended for either building, with the exception of a small electrical and server room. The buildings meet the requirements of ASHRAE 62.1–2007, Section 6.8, and CIBSE Applications Manual 10: 2005. Openings include operable windows, through-the-roof ventilators, and vents between interior spaces. Control mechanisms for the natural ventilation openings are manual. A long, tall hallway situated perpendicular to the prevailing winds will collect heated air and exhaust it to the outside. The roof over much of the space is sloped, allowing air to enter on the low side and exit on the high side. Both buildings are designed to facilitate cross-ventilation, with windows low on the walls for drawing air in, and windows and vents high on opposite walls or on the roof to draw air out. The mean monthly outdoor temperature for the project is greater than 50°F and less than 92.3°F all months of the year, as required under ASHRAE 55–2007, Section 5.3, for naturally ventilated buildings.

Modeling Methodology

EnergyPlus was used to model the building, since the EnergyPlus software can evaluate energy and comfort parameters tied to natural ventilation. The method consists of four models, described in Table D.1.

The baseline case (B) was modeled using all input parameters required by ASHRAE 90.1–2007, Appendix G, Table

G3.1.1B System 4: Packaged single-zone heat pump; one heat pump modeled per building space.

The proposed case without natural ventilation (P1) was developed to reflect the design parameters for the envelope and lighting.

Operable windows were included in the model, along with natural ventilation parameters, but the natural ventilation schedule was set to off for every hour of the year; thus the model represents having fixed windows with no natural ventilation. Mechanical systems were modeled identically to the default heating, cooling, and fan systems in the

baseline case, except that fans were modeled as cycling on and off to meet heating and cooling loads during all hours in the proposed case but modeled as operating continuously during occupied hours in the baseline case (per the exception shown in ASHRAE 90.1–2007, Table G3.1.4). Cooling and heating setpoint temperatures modeled in the proposed case were identical to those modeled in the baseline case. For both models, the heating and cooling setpoints during occupied periods matched the 80% acceptability limits from ASHRAE 55–2007 for buildings in this location having natural ventilation (meaning the setpoints for both models were changed each month to reflect ASHRAE–55 acceptability limits for that month). Figure D.1 shows these temperature setpoints graphically.

Fan efficiency was identical for the baseline and proposed cases and complied with the motor efficiency specified in Section 10. Infiltration is modeled identically in both cases as required.

Using the exceptional calculation methodology, the proposed design case (P1) was modified to include natural ventilation for all hours when the cooling and heating loads could be met (P3). The following process was used to model this in accordance with the methodology approved by LEED Interpretation 1734:

- Comfort analysis model for natural ventilation (P2). Operable windows and vents were modeled as designed. The ventilation schedule set the natural ventilation availability to on year-round during occupied periods. The temperature-limiting feature in EnergyPlus was used to reflect the outdoor natural ventilation openings as closed when the outside air temperature was lower than 69.5°F and open when the outside air temperature exceeded 69.5°F. The hourly results from this model for each zone were used to identify the hours when natural ventilation alone could meet the temperature setpoints.
- Proposed mixed natural ventilation and mechanically conditioned model (P3). Using the hourly results of the comfort analysis model (P2), the hourly schedule for natural ventilation versus mechanical system availability for each space was revised to reflect the following algorithm:
    - **a.** If natural ventilation alone meets space temperature setpoints, and the number of occupants in the space is greater than zero, natural ventilation availability is on, and mechanical system availability is off.
    - **b.** If the number of occupants in the space is zero, natural ventilation availability is off and mechanical system availability is on. For both the baseline and the two proposed designs, the mechanical HVAC system is modeled as cycling on to meet loads during unoccupied operation, and setback temperatures are applied.
    - **c.** If natural ventilation alone does not reduce the unmet load hours below the levels allowed by ASHRAE 90.1–2007 for the proposed case, natural ventilation availability is off and mechanical system availability is on (P3).

Note: *The ASHRAE unmet load hour requirements were met at step b, so step c was not required.*

The number of hours of unmet load for all spaces in the proposed case did not exceed number of hours of unmet load for the baseline case by 50 hours, and the proposed case hours of unmet load for all spaces was less than 300. The final natural ventilation and mechanical system availability schedules are shown in Table D.2 (varying as shown between spaces):

Unmet Load Hours

At the time this project was modeled, EnergyPlus reported only the system-by-system unmet load hours, not a summary of the number of hours when the temperature setpoint for any zone in any system was not met. The hourly outputs from EnergyPlus for unmet load hours in each zone were imported into a spreadsheet and used to calculate the number of unmet load hours for any zone in any system was not met. The results from this analysis are shown in Table D.4.

Section G3.1.2.2 states, "Unmet load hours for the proposed design shall not exceed the number of unmet load hours for the baseline building design by more than 50." The proposed design has fewer unmet load hours than the baseline design, and therefore the proposed design meets the requirement.

D.2. Process Loads

Energy Efficiency Measure

The exhaust system for the proposed building's parking garage is controlled by carbon monoxide sensors located throughout the garage and modulated by a variable frequency drive. The fans run only to maintain the level of carbon monoxide in the space below 50 ppm and thus are turned down when fewer cars are running.

Baseline Energy

The baseline schedule runs 100% during occupied hours.

Proposed Case Energy

The schedule for the proposed case garage exhaust fans during occupied hours is modified to reflect the fewer number of vehicles. The proposed schedule turns down during early, midday, and late hours of operation to a minimum of 20% operating power.

Savings

Savings were determined in an exceptional calculation method using eQUEST. The savings from this measure amounted to $7,719 and 158,728 kWh.

D.3. Domestic Hot Water Heat Recovery

Energy Efficiency Measure

Purchased steam is used to heat domestic hot water for the 13 floors of the proposed hotel as well as to heat the hot water used in the fan coil units. To get as much energy out of the purchased steam as possible, a condensate cooler will be installed downstream of the hotel's heating hot water and domestic hot water (DHW) heat exchangers. Incoming domestic water will run through the cooler and be preheated before entering the heat exchangers. This measure will allow for the energy of the liquid condensate to be captured rather than dumped and lost.

Calculation Methodology

Savings are calculated as the heat recovered from the drain water and do not involve establishing baseline energy consumption. The method used to calculate the savings of this measure involved taking an hourly report of the hotel DHW gpm use, along with hourly reports of the amount of steam used for both DHW heating and hot water heating, and then calculating, based on the specified heat exchanger, the amount of heat transferred from the steam condensate to the incoming water. The UA value was derived from the design specs of the heat exchanger. Then, using the hourly steam and DHW gpm, the following three equations could be solved for the amount of heat transferred between the fluids:

1. $q = UA\Delta T_{lm}$

   $$\text{Where } \Delta T_{lm} = \ln \frac{\Delta T_1 - \Delta T_2}{(\Delta T_1 - \Delta T_2)} \quad \text{and } \Delta T_1 = T_{hot,in} - T_{cold,in}, \Delta T_2 = T_{hot,out} - T_{cold,out}$$

2. $q = 500 \; x \; GPM \; x \; (T_{hot,in} - T_{hot,out})$

3. $q = 500 \; x \; GPM \; x \; (T_{cold,out} - T_{cold,in})$

Savings

Using the exceptional calculations, the savings were expressed as BTUs reclaimed from the liquid condensate. This BTU value was then divided by 1,000 BTU/lb of steam to estimate the amount of steam saved. On this project, steam is charged by a fuel rate of $19.38 per Mlb of steam. The total savings of this measure is 556 Mlbs of steam, which amounts to an annual dollar savings of $10,776.

D.4. Interior Lighting Controls

Energy Efficiency Measure

Hotel guestroom lighting is often left on when the guests leave their rooms. A study on hotel guest room lighting energy, "Lighting Energy Savings Opportunities in Hotel Guestrooms" (Lawrence Berkeley National Laboratory,

October 1999), found that high-use fixtures (the bathroom fixtures and bed lamp) did not see a significant drop during standard unoccupied periods.

The potential energy savings of an occupancy sensor system to turn lights off when a guest leaves range from 30% to 50%. A study titled "Performance Analysis of Hotel Lighting Control System" (California Energy Commission, August 2003) found that a lighting control system saved 46.5% and suggested that 50% savings could be estimated for all hotel buildings. The proposed building would have the WattStopper Card Key system to determine occupancy. The project team then applied a 45% reduction in the lighting power of the hotel rooms. In LEED Interpretation 10102, this approach was deemed acceptable. The WattStopper is a reliable occupancy sensing system, since the key card acts as both the plug load activation switch and the door key. The only way the lights could remain on with no one in the room is if a guest gets locked out—a situation that would be resolved promptly. Supporting documentation for the measure included product cut sheets and the two peer-reviewed reports cited above. The savings amounted to $5,563 and 228,300 kWh of electricity, but there is an associated penalty of 285.6 Mlbs of steam due to a higher heating demand. Results were calculated using eQUEST. Please note that although spreadsheet calculations are acceptable, lighting savings should be calculated using simulation tools, since lighting affects the heating energy.

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