



# ADVANCED ENERGY MODELING FOR LEED

Technical Manual v1.0  
September 2011 Edition



# **ADVANCED ENERGY MODELING FOR LEED**

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September 2011 Edition**

Primarily applicable to LEED for  
New Construction & Major Renovations v2.2,  
LEED Core & Shell v2.0 and LEED for Schools  
and can be adapted to LEED Building Design  
and Construction 2009.

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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 significant emphasis on points assigned to Energy and Atmosphere (EA) Credit 1, Optimize Energy Performance. In addition, all pre-2009 LEED projects registered after June 26, 2007, are required to achieve a minimum of 2 energy points to achieve any level of LEED certification.

Demonstrating compliance for this credit has been challenging for project teams because of the complexity of the referenced standards, energy codes, and energy modeling involved to demonstrate compliance. Historically, USGBC has observed a huge 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.

To guide project teams and LEED reviewers on EA Credit 1 requirements and documentation, USGBC has developed this manual. The objective is to provide further information on EA Credit 1, streamline the LEED documentation process, and provide a greater degree of consistency for both LEED applications and reviewer comments. This manual should be considered a guiding document on EA Credit 1 requirements: It elaborates the information in the LEED rating systems, reference guides, Credit Interpretations and Rulings (CIRs), and other guidance published by USGBC. Its content is based on existing requirements as stipulated in the rating system and CIRs, but it is not considered a precedent-setting document. The rating system supersedes the content of this manual in case of any conflicts.

The document consists of five chapters and four appendixes. 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.

Readers may find certain sections in the manual particularly useful based on their degree of familiarity with the referenced standards, such as ASHRAE 90.1–2004, and their energy modeling skills. Critical tools and guidance for advanced users include the following:

- Comparative summary of energy modeling requirements for baseline and proposed design models for ASHRAE Standard 90.1–2004, Appendix G; Oregon Energy Code; and California Title 24 (Chapter 2, Table 2.1);
- Critical steps recommended for verification of energy savings for EA Credit 1 (Chapter 3, Figure 3.1);
- Input quality control checklist, with common ASHRAE 90.1–2004 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) Credit 1.

### 1.1. Scope

This manual provides guidance on how to prepare and review documentation for EA Credit 1, Optimize Energy Performance, for the LEED New Construction (NC) v2.2, LEED Core & Shell (CS) v2.0, and LEED for Schools rating systems. It also covers the following prerequisites and credits that directly relate to EA Credit 1 in these rating systems: EA Prerequisite 2, Minimum 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 90.1–2004, California Title 24–2005, and Oregon Energy Code 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 appropriately use the reference standards and applicable Credit Interpretations and Rulings (CIRs). It also introduces approved energy simulation software programs and 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.
- **Chapter 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 Credit 1 Compliance Paths

To achieve LEED EA Credit 1, project teams can choose to demonstrate compliance through one of two compliance paths: Prescriptive or Performance performance (Table 1.1). This manual focuses on the performance compliance path, which requires a whole-building energy simulation.

**Table 1.1.** LEED EA Credit 1 Compliance Paths

Rating System	Prescriptive compliance path	Performance compliance path
LEED-NCv2.2, LEED-CSv2.0	<ol style="list-style-type: none"><li>1. Comply with prescriptive measures of Advanced Energy Design Guide for Small Office Buildings 2004; or</li><li>2. Comply with prescriptive measures in the Advanced Buildings™ Core Performance Guide; or</li><li>3. Comply with Basic Criteria and Prescriptive Measures of Advanced Buildings Benchmark™ Version 1.1 (for projects registered before June 26, 2007)</li></ol>	Conduct Whole Building Energy Simulation, using following referenced standards: <ol style="list-style-type: none"><li>1. Building Performance Rating Method in ASHRAE 90.1-2004, Appendix G and addenda; or</li><li>2. California Title 24-2005, Part 6; or</li><li>3. Oregon Energy Code 2005, Chapter 13, and Appendix L of State Energy Efficiency Design (SEED) program</li></ol>
LEED for Schools	<ol style="list-style-type: none"><li>1. Comply with prescriptive measures in the Advanced Buildings™ Core Performance Guide</li><li>2. Comply with prescriptive measures in the Advanced Energy Design Guide for K-12 Schools</li></ol>	

# CHAPTER 2.

## ENERGY PERFORMANCE COMPLIANCE PATH REQUIREMENTS

Project teams pursuing a LEED rating can achieve Energy and Atmosphere (EA) Credit 1, Optimize Energy Performance, through the Energy Performance Compliance Path provided 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 key reports reviewed for this credit; and
- Significant and relevant Credit Interpretation and Rulings (CIRs) published by USGBC.

### 2.1. Referenced Standards

ASHRAE 90.1–2004 is the technical standard referenced as a basis for energy performance credits within LEED New Construction (NC) v2.2, LEED Core & Shell (CS) v2.0, and LEED for Schools. 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. Other referenced standards are California Title 24–2005 and Oregon Energy Code 2005. Projects in California that elect to conduct a whole-building energy simulation for EA Credit 1 may use Title 24 to determine the energy savings. Similarly, projects in Oregon may use the building energy performance rating method in Oregon Energy Code 2005.

#### 2.1.1. ASHRAE 90.1–2004

ASHRAE Standard 90.1 is an industry-accepted standard that provides minimum requirements for the energy-efficient design of commercial buildings and criteria for determining compliance with these requirements. The Performance Rating mMethod 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, 2004). This manual is written for users with intermediate or advanced understanding of ASHRAE Appendix G and will therefore not address every detail of ASHRAE Standard 90.1.

**Note:** *Projects using Appendix G also need to comply with all the minimum requirements noted in ASHRAE 90.1 Standard. All LEED projects must comply with the mandatory provisions in ASHRAE 90.1 Standard: 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 90.1–2004, 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 90.1–2004 Addenda. Project teams are permitted to use addenda within the most recent supplement of the referenced ASHRAE standard, as well as any approved addenda published in between supplements.

**Note:** *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.*

A list of Appendix G addenda that affect achievement of EA Credit 1 is provided in Appendix A ASHRAE Standard 90.1–2004, Addenda Guidance.

## 2.1.2. Oregon Energy Code 2005

Developed by Oregon Department of Energy, Oregon Energy Code 2005 is included in Chapter 13 of the Oregon Structural Specialty Code. The energy code provisions are mandatory for all heated and/or cooled residential and commercial construction, including state-owned and state-operated buildings that are constructed, altered, or repaired. The energy conservation requirements are a mandatory statewide minimum that cannot be modified by local government without state approval.

Projects using Oregon Energy Code must use the Building Modeling Guidelines detailed in Appendix L of the State Energy Efficiency Design (SEED) Program Guidelines to determine the energy savings.<sup>1</sup> The modeling requirements in the Oregon Building Energy Performance Rating Method are similar to those in ASHRAE 90.1–2004, Appendix G.

## Equivalency to ASHRAE 90.1–2004

Oregon Energy Code 2005 is deemed equivalent to ASHRAE 90.1–2004 by USGBC for projects in Oregon, provided the mandatory provisions of ASHRAE 90.1–2004 are met. This equivalency is for the purpose of certification of EA Prerequisite 2 and EA Credits 1, 2, and 6. Projects do not need to provide justification or support of Oregon Energy Code 2005 equivalence when applying for LEED-NCv2.2, LEED CSv2.0, or LEED for Schools v2.0 certification.

## 2.1.3. California Title 24–2005

Title 24, Part 6, of the California Code of Regulations represents the Energy Efficiency Standards for Residential and Nonresidential Buildings, established in response 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-NCv2.2, LEED CSv2.0, and LEED for Schools v2.0 is Title 24–2005.

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 (which include 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 document will therefore not address detailed modeling requirements of Title 24 but instead summarize its major differences with ASHRAE 90.1–2004, Appendix G.

<sup>1</sup> SEED is the Oregon State Energy Efficiency Design program. SEED was established in 1991 by an Oregon law that directs state agencies to work with the Oregon Department of Energy to ensure cost-effective energy conservation measures (ECMs) are included in new and renovated public buildings.

## Equivalency to ASHRAE 90.1-2004

Title 24–2005 is deemed to be directly equivalent to ASHRAE 90.1–2004 by USGBC for projects in California for the purpose of certification of EA Prerequisite 2 and EA Credits 1, 2, and 6. Projects within California may still elect to use ASHRAE 90.1–2004 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-NCv2.2, LEED-CSv2.0, or LEED for Schools certification.

## 2.2. Energy Modeling Requirements

The methodology described in ASHRAE 90.1–2004 (Appendix G), California Title 24–2005, and Oregon Energy Code 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 and LEED for Schools are identical to LEED-NC except as noted in this table.

**Table 2.1.** Comparison of Modeling Requirements for ASHRAE 90.1-2004, California Title 24, and Oregon Energy Code

ASHRAE 90.1-2004		Oregon Energy Code 2005		California Title 24-2005	
Baseline Case	Proposed Case	Baseline Case	Proposed Case	Baseline Case	Proposed Case
<b>Schedule of Operation</b>					
Same as proposed design.  Exception: Schedule may differ from proposed design if proposed design is implementing some nonstandard efficiency measures.	Use actual operating schedule.  Exception: Schedules can be modified to model nonstandard efficiency measures such as lighting controls, natural ventilation, demand control ventilation, or service water heating load reductions. When differing schedule is modeled for demand control ventilation in proposed case, baseline case should be modeled with ASHRAE 62.1-2004 minimum values.	Same as ASHRAE 90.1-2004.	Same as ASHRAE 90.1-2004.	Same as proposed design.  Automatically modeled in compliance mode.	Default Title 24 schedules used for heating, cooling, fans, lighting, receptacle loads, etc.
<b>Orientation</b>					
Simulations with 4 orientations are required (0°, 90°, 180°, and 270°). Self-shading is ignored in baseline model.	Model building orientation as designed.	Same as proposed design. Simulations of 4 orientations are not required.	Same as ASHRAE 90.1-2004.	Same as proposed design.  Automatically modeled in compliance mode. Simulations of 4 orientations are not required.	Model building orientation as designed.

**Table 2.1.** Comparison of Modeling Requirements for ASHRAE 90.1-2004, California Title 24, and Oregon Energy Code (continued)

ASHRAE 90.1-2004		Oregon Energy Code 2005		California Title 24-2005	
Baseline Case	Proposed Case	Baseline Case	Proposed Case	Baseline Case	Proposed Case
<b>Building Envelope</b>					
<p>Model building envelopes using Table G3.1.5.</p> <p>New buildings:</p> <p>Model above-grade walls, roof, and floor assemblies using lightweight assembly types per G3.1.5(b). Match values with appropriate assembly maximum U-factors in Tables 5.5.1-5.5-8.</p> <p>Building should be modeled so it does not shade itself.</p> <p>Existing buildings:</p> <p>Model building envelope using preretrofit envelope parameters.</p> <p>Existing buildings with less than 50% renovations do not have to be rotated.</p>	<p>Building components must be modeled as shown in architectural drawings, or as built for existing building envelopes. Model any exceptions using Table G3.1.5.</p> <p>Mandatory provisions in Section 5.4 must be met.</p>	<p><b>New buildings:</b></p> <p>Model above-grade walls, roof, and floor assemblies using lightweight assembly types and match values with appropriate assembly maximum U-factors in Table 4.1 and 4.2 of Appendix L.</p> <p><b>Existing buildings:</b></p> <p>For envelope components not being modified, reflect existing conditions; for envelope components being modified, model according to code requirements described in Section 4.2 of Appendix L.</p>	<p>Building components must be modeled as shown in architectural drawings or as built for existing building envelopes. Model any exceptions following Section 3.4 of Appendix L.</p> <p>Mandatory provisions in Section 5.4 of ASHRAE 90.1-2004 must be met.</p> <p>Parameters relating to unmodified existing conditions or to future building components must be identical for both baseline and proposed building.</p>	<p>Automatically modeled in Compliance Mode 2</p> <p>Major difference from ASHRAE 90.1-2004:</p> <p>Assembly U-values typically higher than default ASHRAE assembly U-values, especially for wall assemblies.</p> <p>Same framing type typically used in Baseline and Proposed cases.</p> <p>All west-facing glazing that is greater than 40% of wall area must be modeled as opaque surfaces, even if overall window-to-wall ratio is less than 40%.</p>	<p>Building components must be modeled as shown in architectural drawings or as built for existing building envelopes.</p>
<p>Match percentage of vertical fenestration in proposed design, or use 40% of gross wall area, whichever is smaller.</p> <p>Distribute windows uniformly in horizontal bands across 4 orientations.</p> <p>Fenestration U-factor must match requirements in Tables 5.5.1-5.5.8 for applicable vertical glazing percentage for Ufixed. Use SHGCall for all windows.</p>	<p>Model fenestration location and its properties as shown on architectural drawings.</p>	<p>Maximum allowed window-to-wall ratio varies by climate zone (40% for Zone 1 and 33% for Zone 2).</p> <p>Orientation of each window surface must be the same as in the proposed design.</p> <p>Vertical fenestration U-factor and SHGC must match requirements in Table 4.7 for applicable vertical glazing percentage.</p>	<p>Same as ASHRAE 90.1-2004.</p>		
<p>Do not model exterior shading devices.</p> <p>Do not model manually controlled interior shading devices, such as blinds or curtains.</p>	<p>Permanent shading devices may be modeled.</p> <p>Manually controlled interior shading devices should not be modeled.</p> <p>Automatically controlled interior shades or blinds can be modeled.</p>	<p>Same as ASHRAE 90.1-2004.</p>	<p>Same as ASHRAE 90.1-2004.</p>		
<p>Model all roof surfaces with reflectivity of 0.30.</p>	<p>If proposed roof has solar reflectance greater than 0.70 and emittance greater than 0.75, model reflectivity as 0.45; otherwise, model reflectivity as 0.30.</p>	<p>Same as ASHRAE 90.1-2004.</p>	<p>Same as ASHRAE 90.1-2004.</p>		

**Table 2.1.** Comparison of Modeling Requirements for ASHRAE 90.1-2004, California Title 24, and Oregon Energy Code (continued)

ASHRAE 90.1-2004		Oregon Energy Code 2005		California Title 24-2005	
Baseline Case	Proposed Case	Baseline Case	Proposed Case	Baseline Case	Proposed Case
<b>Lighting Systems</b>					
<p><b>LEED NC projects:</b> Model lighting using building area (Section 9.5) or space-by-space (Section 9.6) method.</p> <p>Include exterior lighting power allowance (Section 9.4.5).</p> <p><b>LEED CS projects:</b> Model lighting power in core and shell areas as determined by space type classification in Table 9.6.1.</p> <p>For tenant spaces model separate electric meter for lighting in core building and tenant spaces.</p>	<p>Model proposed design with installed lighting power density and account for all installed lighting.</p> <p>Exceptions: For multifamily living units, hotel-motel guestrooms, and other spaces where lighting systems are connected via receptacles and are not shown or provided for on building plans, assume identical lighting power for proposed and baseline building designs, but exclude these loads when calculating baseline building performance and proposed building performance.</p> <p>Mandatory provisions in Section 9.4 must be met.</p> <p><b>LEED CS projects:</b> Same as LEED NC for areas where lighting system has been designed.</p> <p>For areas where no lighting system has been specified, model these spaces identically in both cases as minimally standard compliant according to building area method.</p> <p>Model separate electric meters for lighting in core building and tenant spaces.</p>	<p><b>LEED NC projects:</b> Model lighting using Tenant space (Section 1313.4.1) or space-by-space (Section 1313.4.2) methods.</p> <p>Include exterior lighting energy identical to proposed design.</p> <p><b>LEED CS projects:</b> Same as ASHRAE 90.1-2004.</p>	<p>Model proposed design with installed lighting power density and account for all installed lighting.</p> <p>Mandatory provisions in Section 9.4 of ASHRAE 90.1-2004 must be met.</p> <p>Exterior lighting energy must be documented.</p>	<p>Automatically modeled in Compliance Mode.2</p> <p><b>Major difference from ASHRAE 90.1-2004:</b> Exterior lighting and unconditioned lighting must be manually added to the analysis by multiplying total power with equivalent full-load hours (EFLHs).</p> <p>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.</p> <p>Title 24 also provides allowance for specific applications in 2005 BEES Table 147-B. Credit may not be taken for improved efficiency.</p> <p><b>LEED CS projects:</b> Same as ASHRAE 90.1-2004.</p>	<p>Model lighting system as designed.</p> <p><b>Major difference from ASHRAE 90.1-2004:</b> 0.20 W/sf portable lighting must be modeled in open office spaces whose portable lighting design is not completed.</p> <p>Different lighting power savings allowance: 10% to 20% for occupancy sensors.</p> <p>Exterior lighting and unconditioned lighting must be manually added to analysis by multiplying total power times equivalent full-load hours (EFLHs).</p> <p><b>LEED CS projects:</b> Same as ASHRAE 90.1-2004.</p>
Do not model automatic lighting controls.	Credit can be taken for automatic lighting controls fitted in addition to mandatory provision under Section 9.4.1.	Same as ASHRAE 90.1-2004.	Credit can be taken for automatic lighting controls not required by code and for daylight utilization when not required by Section 1313.3.1.3.		
Lighting exempted from interior lighting power allowance is classified as process energy and must be identical to proposed case.	Lighting exempted from interior lighting power allowance should be modeled as process energy.	Same as ASHRAE 90.1-2004.	Same as ASHRAE 90.1-2004.		

**Table 2.1.** Comparison of Modeling Requirements for ASHRAE 90.1-2004, California Title 24, and Oregon Energy Code (continued)

ASHRAE 90.1-2004		Oregon Energy Code 2005		California Title 24-2005	
Baseline Case	Proposed Case	Baseline Case	Proposed Case	Baseline Case	Proposed Case
<b>HVAC System Selection</b>					
<p>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.</p> <p><b>Exceptions:</b></p> <ol style="list-style-type: none"> <li>1. Use additional system types for nonpredominant conditions if conditions apply to area greater than 20,000 sf.</li> <li>2. Use same baseline HVAC system type for entire building except for areas where occupancy, loads or schedules differ significantly from rest of building, or areas with varying pressurization, cross-contamination requirements (G3.1.1).</li> </ol>	<p>Proposed design HVAC system type and quantities should reflect actual design, except where either heating system or cooling system has not been specified. In such cases proposed design should assume electric heating or must include cooling system. modeled identically to baseline cooling system.</p> <p>Mandatory provisions in Section 6.4 must be met.</p> <p><b>LEED CS projects:</b> Model building system as described in design documents. This should be whole building model inclusive of both core and shell, and tenant space scope.</p> <p>If HVAC system is not yet designed, use same HVAC system as baseline case.</p>	<p>Determine HVAC system type using actual building area, usage, number of floors, occupancy (residential or nonresidential), and heating fuel source per Table 4.9 of Appendix L.</p> <p>If no active heating or cooling system has been modeled in proposed design, no heating or cooling system should be modeled in baseline. Or model cooling system based on exception to Section L4.3.1.</p> <p>Dedicated systems by floor or by zone, depending on system type (Section L4.3.2.1).</p>	<p>Proposed design HVAC system type and quantities should reflect actual design.</p> <p>If no active heating system and or cooling has been planned, do not model heating or cooling system in proposed design model.</p> <p>Mandatory provisions in Section 5.4 of ASHRAE 90.1-2004 must be met.</p> <p><b>LEED CS projects:</b> Same as ASHRAE 90.1-2004.</p>	<p>Automatically modeled in Compliance Mode.</p> <p><b>Major difference from ASHRAE 90.1-2004:</b> Baseline HVAC system is selected based on number of floors, occupancy type, proposed design HVAC system type (multi- or single zone) and heating fuel.</p> <p>No credit or penalty for efficient duct design and low fan static pressure, unless maximum requirements are exceeded.</p> <p>No credit or penalty for limiting pump head.</p> <p>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).</p>	<p>Proposed design HVAC system type and quantities should reflect actual design.</p> <p><b>Major difference from ASHRAE 90.1-2004:</b> 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).</p>
HVAC equipment capacities for baseline system should be oversized 15% for cooling and 25% for heating	Should reflect actual design capacities and system efficiencies.	Same as ASHRAE 90.1-2004.	Same as ASHRAE 90.1-2004.		
Unmet load hours should not be greater than 300 hours. Also, unmet load hours should not differ by more than 50 hours between two cases.	Unmet load hours should not be greater than 300 hours. Also, unmet load hours should not exceed by more than 50 hours between two cases.	Unmet load hours should not differ by more than 50 hours between two cases.	Same as baseline case.		
<p>Outdoor ventilation rates should be identical to proposed case. If IEQ Credit 2 is pursued, increased ventilation rates should be included in both cases.</p> <p><b>Exceptions:</b> When demand-control ventilation is modeled in proposed design and its use is not required by Section 6.4.3.8.</p>	Should reflect actual design outdoor ventilation rates.	<p>Outdoor ventilation rates should be identical to proposed case.</p> <p><b>Exceptions:</b> When demand-control ventilation is modeled in proposed design and its use is not required by code.</p>	Should reflect actual design outdoor ventilation rates.		

**Table 2.1.** Comparison of Modeling Requirements for ASHRAE 90.1-2004, California Title 24, and Oregon Energy Code (continued)

ASHRAE 90.1-2004		Oregon Energy Code 2005		California Title 24-2005	
Baseline Case	Proposed Case	Baseline Case	Proposed Case	Baseline Case	Proposed Case
<b>HVAC System Selection (continued)</b>					
Operate fans continuously when spaces are occupied and cycle them during unoccupied hours. Baseline system fan supply air volume should be based on a supply-air-to-room-air temperature difference of 20°F. 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.	Should reflect actual fan operation, fan supply rate and fan motor horse power. Fans should operate continuously during occupied periods and cycle to meet load during unoccupied periods. <b>Exception:</b> Fans may cycle during occupied periods where no heating and/or cooling system has been designed but is being modeled.	Operate fans continuously when spaces are occupied and cycle them during unoccupied hours. Baseline system fan supply air volume should be based on supply-air-to-room-air temperature difference of 20°F, or required ventilation air or makeup air, whichever is greater. Heating only systems shall be based on supply-air-to-room-air temperature difference of 300F, or required ventilation air or makeup air, whichever is greater. Use this supply air volume to calculate supply fan power for baseline system design (L4.3.2.8). Return and exhaust fans shall not be modeled, except for exhaust fans serving unconditioned spaces (L4.3.2.9 and 10).	Should reflect actual fan operation, fan supply rate and fan motor horse power. Operate fans on when spaces are occupied and cycle them during unoccupied hours. (Section 3.12.1 of Appendix L and Exceptions to section).		
Fan energy must be modeled separately from cooling system.	Should reflect actual design.	Same as ASHRAE 90.1-2004.	Same as baseline case.		
Model economizers and exhaust air energy recovery systems when required for given climate zones and system parameters.	Should reflect actual design.	Conditions for economizer use and for exhaust air heat recovery differ slightly from ASHRAE 90.1-2004, see Sections L4.3.2.7 and 4.3.2.11.	Should reflect actual design.		
Follow HVAC system-specific requirements (chillers, boilers and heat pumps) as indicated in G3.1.3.	System specific requirements should reflect actual design. <b>LEED CS projects:</b> Reflect actual design, or if system-specific requirements are not specified, HVAC system must be identical to baseline case system.	Follow HVAC system-specific requirements (chillers, boilers and heat pumps) as indicated in L4.3.3.	System specific requirements should reflect actual design. <b>LEED CS projects:</b> Same as ASHRAE 90.1-2004.		

**Table 2.1.** Comparison of Modeling Requirements for ASHRAE 90.1-2004, California Title 24, and Oregon Energy Code (continued)

ASHRAE 90.1-2004		Oregon Energy Code 2005		California Title 24-2005	
Baseline Case	Proposed Case	Baseline Case	Proposed Case	Baseline Case	Proposed Case
<b>Process Energy</b>					
Process loads must be identical to proposed building except as specifically authorized by rating authority (see USGBC CIRs for process energy). <b>LEED CS projects:</b> Model separate meters for tenant receptacle loads and process loads. Use same values for receptacle loads as used in proposed building.	Process loads must be identical to baseline building. Process energy use should be 25% of Baseline building performance. If not, provide documentation to substantiate lower value. <b>LEED CS projects:</b> Tenant spaces Model separate meters for tenant plug loads. Use values indicated in Table G-B to model tenant plug loads or provide documentation for modeled loads.	Same as ASHRAE 90.1-2004.	Process loads must be identical to baseline building. Process energy use should be 25% of Baseline building performance unless justified. Credit may be taken for automatic receptacle-based occupant sensing control systems, by reducing the equipment power or schedules by 15%. <b>LEED CS projects:</b> Same as ASHRAE 90.1-2004		Process loads must be identical to baseline building. Process energy use should be 25% of Baseline building performance. If not, provide documentation to substantiate lower value. <b>LEED CS projects:</b> Same as ASHRAE 90.1-2004.
<b>Energy Rates</b>					
Use same rates for both baseline and proposed building.	Rates from local utility schedules are default option. State average energy prices published by EIA for commercial building customers can be used in absence of local utility rate schedule. <b>LEED CS projects:</b> Tenant spaces Energy-using components are metered and apportioned and/or billed to tenant.	Use same rates for both baseline and proposed building.	Rates from local utility schedules are default option. State average energy prices established by Oregon Department of Energy may be used. <b>LEED CS projects:</b> Same as ASHRAE 90.1-2004.		Rates from local utility schedules are default option. State average energy prices published by EIA for commercial building customers can be used in absence of local utility rate schedule. <b>LEED CS projects:</b> Same as ASHRAE 90.1-2004.
<b>Service Hot Water System</b>					
Service hot water must use same energy sources as proposed building. System-related specific parameters must be modeled as indicated in Table G3.11.	Must be modeled to reflect actual system installed or designed. Mandatory provisions in Section 7.4 must be met.	Service hot water must use same energy sources as proposed building. System-related specific parameters must be modeled as indicated in Section 4.4 of Appendix L.	Must be modeled to reflect actual system installed or designed. Mandatory provisions in Section 7.4 of ASHRAE 90.1-2004 must be met.		Must be modeled to reflect actual system installed or designed. <b>Major difference from ASHRAE 90.1-2004:</b> 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.

**Note:** EIA = Energy Information Administration, U.S. Department of Energy

IEQ = Indoor Environmental Quality credit category in LEED rating systems

SHGC = solar heat gain coefficient

## 2.3. Simulation Software

### 2.3.1. ASHRAE Standard 90.1–2004 Requirements for Qualified Simulation Software

ASHRAE 90.1–2004 G2.2.1 requires that the qualified simulation program be approved by the rating authority (USGBC in this case) and be able to 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 ASHRAE 90.1–2004, Appendix G, Section 3.

The simulation program must be able to either directly determine the proposed energy use and code baseline energy use or 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, substituting a thermodynamically similar component model that can approximate the expected performance of the component is also allowed, as stated in Table G3.1.13.

Commonly used modeling software packages for ASHRAE 90.1–2004 include DOE-2-based modeling programs (eQuest, EnergyPro, and VisualDOE), HAP, TRACE, Energy-10, EnergyPlus, and IES. Brief descriptions of these programs are presented in Appendix B, Commonly Used Energy Simulation Software.

Energy modeling software packages take different approaches to building the ASHRAE 90.1–2004 Appendix G baseline model. In some cases, the baseline building is automatically defined by the software, based on the proposed design inputs; in other cases, the user is prompted to build the ASHRAE 90.1–2004 model using predefined baseline input parameters built into the software program; in still other cases, the user must build the baseline model from scratch. In all cases, the project team is encouraged to compare the baseline inputs in the software package against the baseline requirements of ASHRAE 90.1–2004 Appendix G to confirm conformance to the Appendix G requirements before submitting modeling results for the preliminary LEED review.

**Note:** *USGBC does not certify or formally approve simulation software packages either for compliance with ASHRAE 90.1–2004 G2.2 or to confirm their capabilities to generate the ASHRAE 90.1–2004 Appendix G baseline model. It is the responsibility of the project team to document that the inputs for any software package conform to the baseline and proposed case modeling requirements listed in ASHRAE 90.1–2004 Appendix G, in accordance with the LEED EA Prerequisite 2 submittal requirements.*

### 2.3.2. Oregon Energy Code Qualified Simulation Software

Appendix L of SEED Modeling Guidelines requires that the qualified simulation program be approved by the SEED Program Evaluator. The requirements for qualified simulation software are the same as ASHRAE 90.1–2004 except for the following:

- Oregon Energy Code qualified simulation software must be able to explicitly model fenestration shading and all code baseline building characteristics specified in Section 4, Calculation of Code Baseline Energy Cost.

- Oregon Energy Code does not require that qualified simulation software be able to explicitly model part-load performance curves for mechanical equipment.

Qualified simulation software programs include, but are not limited to, DOE-2-based programs, BLAST, and EnergyPlus.

### 2.3.3. California Title 24 Qualified Simulation Software

California's current state-approved energy compliance software programs for use with the Title 24 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). These programs can automatically generate the energy budget for the standard design and calculate the energy use of the proposed design after the proposed design inputs are complete. However, some postprocessing or additional software modules may be needed to address the additional energy consumption required for LEED documentation (e.g., unconditioned lighting, exterior lighting, process loads) and to convert the metric from TDV energy to cost.

## 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 some of the key output report parameters critical to the quality control process for credit compliance. The summary output reports include 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 Key Output Reports

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

The BEPS and BPU 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. The reports also display the percentage of hours that any system zone is outside of throttling range and the percentage of hours that any plant load is not satisfied. The difference between the two reports is that the BEPS report summarizes the energy use in the units of MBtu (million Btu), while the BPU report presents the energy use 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 BPU 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 in the BEPS report 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 exact location is not available, an alternative file for the closest available location is typically considered appropriate. If the selected weather file is not from the closest available location—for example, because of altitude differences or a 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. See whether the site Energy Use Intensity (EUI) is reasonable for the building type and climate. The Commercial Buildings Energy Consumption Survey (CBECS) database and the EnergyStar Target Finder database can be used for this purpose.
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 design 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. See whether the energy cost per unit floor area is reasonable for the building type and climate (see number 4 under Figure 2.1).

**Figure 2-1. Sample BEPS and BEPU Reports from eQuest<sup>2</sup>**

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
EMI ELECTRICITY MBTU	0.0	0.0	315.4	0.0	54.3	0.0	7.3	66.2	0.0	0.0	0.0	0.0	679.3
FMI 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 36.6 MBTU/SQFT-YR GROSS-AREA 36.6 MBTU/SQFT-YR NET-AREA  
 TOTAL SOURCE ENERGY 2273.04 MBTU 90.9 MBTU/SQFT-YR GROSS-AREA 90.9 MBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTILING 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
EMI ELECTRICITY KWH	69.0	0.0	92425.0	0.0	15924.0	0.0	2145.0	19393.0	0.0	0.0	0.0	0.0	199042.0
FMI NATURAL-GAS THERM	0.0	0.0	0.0	1944.0	0.0	0.0	0.0	0.0	0.0	0.0	406.0	0.0	2351.0

TOTAL ELECTRICITY 199042.0 KWH 7.962 KWH /SQFT-YR GROSS-AREA 7.962 KWH /SQFT-YR NET-AREA  
 TOTAL NATURAL-GAS 2351.0 THERM 0.094 THERM /SQFT-YR GROSS-AREA 0.094 THERM /SQFT-YR NET-AREA

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

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

2 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](http://doe2.com/download/eQUEST/DOE22Reports-and-QC_2001-06-07.zip)

**Figure 2-2.** Sample ES-D Report from eQuest<sup>3</sup>

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	EMI	199042. KWH	12737.	0.0640	YES
PSE Gas 31 NRes After 10-9-1993	NATURAL-GAS	FMI	2351. THERM	2698.	1.1477	YES
				=====		
				15435.		
				ENERGY COST/GROSS BLDG AREA:	0.42	
				ENERGY COST/NET BLDG AREA:	0.42	

## 2.4.2. Title 24 Key Output Reports

As noted in Section 2.3.3, current state-approved energy compliance software programs for use with California Title 24 are EnergyPro and eQuest Compliance Module. Both are DOE-2-based software. These programs can generate DOE-2 reports and Title 24 report forms summarizing the modeling inputs and outputs.

Among the Title 24 report forms generated by EnergyPro, the PERF-1, UTIL-1, and ECON-1 reports are the key report forms required as backup documentation for EA Credit 1. DOE-2 outputs may be used to complete the EA Credit 1 Template and as additional backup documentation.

The PERF-1 report provides summaries of Title 24 time-dependent valuation (TDV) energy consumption by end use, lighting power density, envelope inputs, and HVAC inputs for both the proposed design and the baseline cases.

The 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 the ECON-1 report.

The 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

Four important summary output files produced by HAP are:

- The Annual Cost Summary Report lists the total energy cost and the energy cost by end use.
- The Energy Cost Budget by System Component report summarizes the total energy use, end uses, and energy use intensity (energy use per unit floor area and cost per unit floor area).
- Unmet load reports are provided by HAP for all plants and systems.
- Version 4.4 and later versions of the HAP program tailor the output to the requirements defined in ASHRAE Standard 90.1–2004, Appendix G, and provides a Summary Report that mimics the format and content of the LEED NCv2.2 EA Credit 1 Submittal Template.

<sup>3</sup> DOE-2.2 Reports and Modeling Quality Control Concepts, available at: [http://doe2.com/download/eQUEST/DOE22Reports-and-QC\\_2001-06-07.zip](http://doe2.com/download/eQUEST/DOE22Reports-and-QC_2001-06-07.zip)

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

- The *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.
- The *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.
- The *Zone Temperature Report* and *Unmet Load Report* for air systems and the *Unmet Load Report* for plants provide the raw data that are the basis for LEED unmet load hours reported on the LEED EA Credit 1 summary report.
- The *Monthly Energy Use by Component* report lists monthly energy use for end-use categories (e.g., total indoor fan kWh) on a building-wide basis. This information is helpful for understanding the relative energy consumption of major energy end uses.
- The *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.

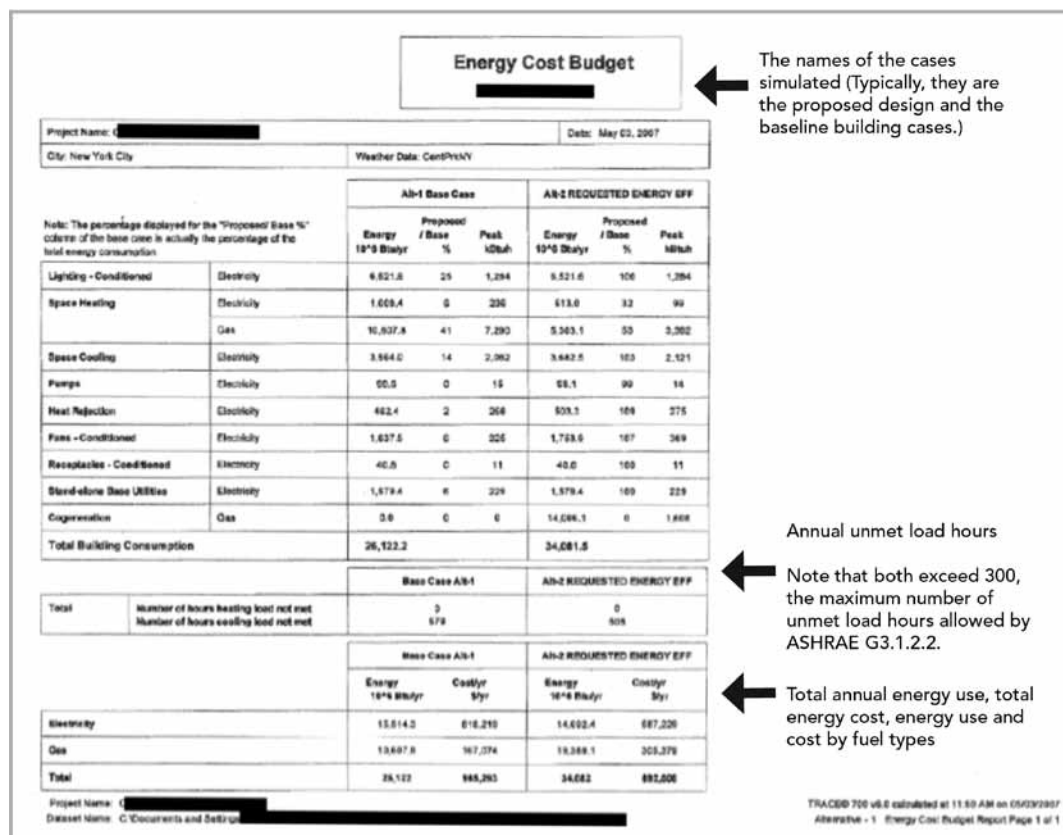
## 2.4.4. TRACE Output Reports

The most important TRACE summary output files are the Energy Cost Budget report and the Energy Consumption Summary report.

The Energy Cost Budget report (Figure 2.3) compares the energy use and cost of the proposed design 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					
	Elect Cons. (kWh)	Gas Cons. (kBtu)	% of Total Building Energy	Total Building Energy (kBtu/yr)	Total Source Energy* (kBtu/yr)
<b>Primary heating</b>					
Primary heating	15,556	10,607,841	40.8 %	10,691,905	11,328,538
Other Htg Accessories	455,586		6.0 %	1,555,257	4,066,257
<b>Heating Subtotal</b>	<b>471,544</b>	<b>10,607,841</b>	<b>46.8 %</b>	<b>12,247,221</b>	<b>15,394,772</b>
<b>Primary cooling</b>					
Cooling Compressor	1,040,816		12.0 %	3,052,302	10,667,073
Towers/Cond Fans	135,474		1.6 %	462,372	1,367,255
Condenser Pump	26,174		0.4 %	59,872	268,747
Other Ctg Accessories	3,414		0.0 %	11,022	34,900
<b>Cooling Subtotal</b>	<b>1,205,878</b>		<b>15.8 %</b>	<b>4,125,568</b>	<b>12,378,537</b>
<b>Auxiliary</b>					
Supply Fans	479,767		6.3 %	1,627,512	4,913,027
Pumps			0.0 %	0	0
Stand-alone Rose Utilities	462,747		6.1 %	1,578,255	4,738,541
<b>Aux Subtotal</b>	<b>942,514</b>		<b>12.3 %</b>	<b>3,216,867</b>	<b>9,651,567</b>
<b>Lighting</b>					
Lighting	1,910,819		15.0 %	6,521,615	19,886,856
<b>Receptacle</b>					
Receptacles	11,800		0.2 %	40,681	121,755
<b>Cogeneration</b>					
Cogeneration			0.0 %	0	0
<b>Totals</b>					
<b>Totals**</b>	<b>4,545,952</b>	<b>10,607,841</b>	<b>100.0 %</b>	<b>25,122,186</b>	<b>37,713,836</b>

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 IESVE-Navigator for ASHRAE 90.1 are designed to mirror the format required for EA Credit 1 submissions. They are made available in an interactive html format to facilitate completion of the LEED credit form and supporting documentation. The reports also include a checklist of the requirements for LEED NC v2009 Credit EA 1, Option 1: Performance Rating Method:

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 or 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 method 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 design and baseline in terms of end use by fuel type (kBtu) and demand (MBH), plus annual totals and percentage 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**



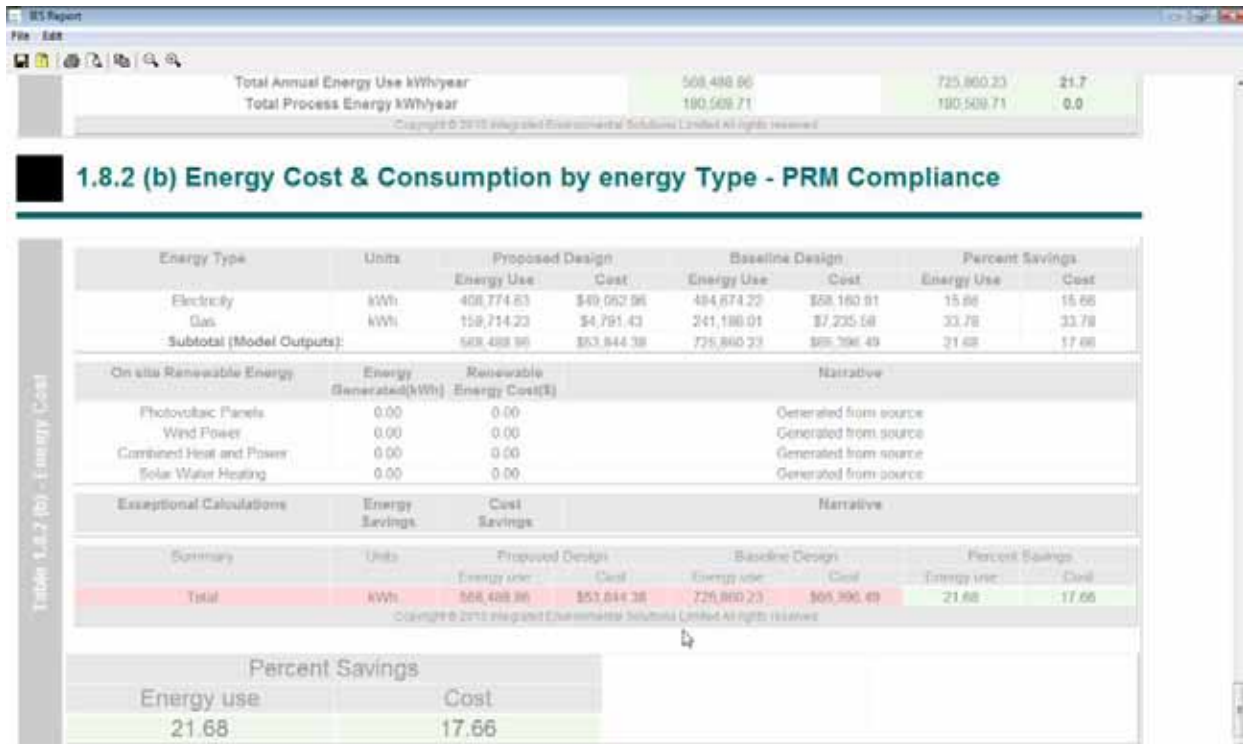
# 1.8.2 Performance Rating Table - PRM Compliance

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	17.57	Demand MBH	18.45	4.8
Space Heating (Fossil Fuel)	No	Gas	Energy use kBtu	116,267.03	Energy use kBtu	124,966.21	7.0
			Demand MBH	104.35	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	3,308.46	-94.3
			Demand MBH	4.26	Demand MBH	2.35	-81.5
Fans Interior	No	Electricity	Energy use kBtu	19,766.38	Energy use kBtu	13,833.80	-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	32,196.44	Energy use kBtu	32,196.44	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		301,044.21	0.2
Total Process Energy kBtu/year				32,196.44		32,196.44	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

- 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 percentage loading for various run times.
- Monthly and annual energy and demand by equipment or end use.
- Project review showing building weather, exposures, area, r-values, glass area, occupancy, HVAC equipment, end-use data, water heating data, and water usage.
- Energy cost report showing monthly and annual kW, energy, and electricity costs, plus monthly and annual other fuel usage and associated costs.

## 2.5. Credit Interpretations and Rulings

LEED prerequisites and credits are not always easily applied to all projects. In cases where the applicant feels they need more information on how to meet the credit intent for their particular project circumstances, project teams can submit a Credit Interpretation Request (CIR) to seek administrative and technical guidance. This section describes the CIRs regarding EA Credit 1 under LEED NCv2.2, LEED CSv2.0, and LEED for Schools that were submitted prior to June 26, 2009, and appear in the online CIR database. CIRs for all rating systems generated in response to requests submitted after June 26, 2009, are project specific and do not appear in the CIR database and are not cited in Table 2.2.

**Note:** All CIRs referenced below are for the LEED-NCv2.2 rating system, EAc1, unless otherwise noted.

**Table 2.2.** Summary of Major EA Credit 1 CIRs, through June 26, 2009.

Topic	Rating System and CIR date	Summary	Description
<b>HVAC system</b>			
Baseline HVAC system	NCv2.2 8/26/2008, 4/23/2008	Clarifies how to determine baseline HVAC system(s) for building eligible for more than one system type.	CIR dated 8/26/2008 states that 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: "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."
			CIR dated 4/23/2008 confirms that when conditions do not vary per exceptions to G3.1.1, project teams must use single baseline system type for entire building. However, if project includes multiple detached buildings, each building can use different system type; this is addressed in Chapter 4 of document.
Baseline HVAC system serving high process load spaces	NCv2.2 3/23/2007	Clarifies use of exception to G3.1.1 to document baseline and achieve greater energy savings from single-zone systems in high process load areas.	CIR allows projects to demonstrate substantial energy savings for well-designed HVAC system serving high process load spaces based on following exception to G3.1.1: "Any space that has high occupancy or process loads including peak thermal 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	NCv2.2 8/13/2007	Clarifies how to document energy savings from HVAC systems controlled by occupancy sensors.	ASHRAE 90.1-2004, 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, CIR clarifies that it is acceptable to use 10% power adjustment indicated in table 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. In this case, Exceptional Calculation Method should be used, consistent with CIR dated 6/7/2001.
Hospitals and laboratory baseline HVAC system	NCv2.2 8/16/2007	Clarifies how baseline HVAC systems may be modeled for spaces with pressurization and air change requirements.	Pressurization and air change requirements of health care facilities fall under Exception (c) of G3.1.1, which indicates that packaged single-zone systems (System 3 or 4) may be used as baseline system. Ruling acknowledges that, without reheat, single-zone, constant-volume system is unable to meet temperature and humidity control requirements typical for hospitals and laboratories. It requires that project teams follow Appendix G and model these spaces with pressurization control requirements with packaged single-zone systems in baseline building. Humidity control requirements should be modeled same as in proposed building, even if that requires modeling reheat with that system type.
	NCv2.2 8/16/2007, 8/13/2007, 3/4/2008	Allows health care and laboratory projects to apply Appendix AC and ASHRAE 90.1-2007, Appendix G 3.1.2.9, to document baseline fan power.	Rulings acknowledge that fan power is not adequately addressed by ASHRAE 90.1-2004 for health care and laboratory applications. Appendix G, Section 3.1.2.9, in ASHRAE 90.1-2004 does not give credit for air pressure drops associated with cooling coils, preheat coils, multiple filter stages, air blenders, extensive sound attenuation, humidifiers, and exhaust bio-safety cabinets that may be used in health care facilities and laboratories and contribute to excessive fan energy. To avoid penalizing such facilities, rulings allow laboratory and hospital projects to use Addendum AC and apply changes to Appendix G, Section 3.1.2.9, that are published in 2007 version of standard. Addendum AC adds pressure drop credits for fan systems that include evaporative cooling, sound attenuation, ducted returns, filtration, and return or exhaust airflow control devices. These credits are in Table 6.5.3.1.1B of this addendum.  In addition, rulings clarify that projects may not use Labs21 "Laboratory Modeling Guidelines using ASHRAE 90.1-2004 Appendix G" as compliance path for modeling laboratories.
Fume hoods	NCv2.2 8/13/2007	Allows use of ASHRAE 90.1-2004, Addendum AC, and ASHRAE 90.1-2007, Appendix G, to demonstrate savings from laboratory exhaust systems.	Addendum AC modifies fan power allowance in Section 6 of ASHRAE standard and includes exemption for fans exhausting air from fume hoods. When these fans are exempted, allowed horsepower for entire system must be reduced by adjustment factor contained in addendum.

**Table 2.2.** Summary of Major EA Credit 1 CIRs, through June 26, 2009. (continued)

Topic	Rating System and CIR date	Summary	Description
<b>HVAC system (continued)</b>			
Natural ventilation	NCv2.2 3/22/2007	Describes requirements for documenting energy savings from natural ventilation.	<p>Submittals for natural ventilation savings will be evaluated on case-by-case basis and should include following information:</p> <ul style="list-style-type: none"> <li>• Detailed project description;</li> <li>• Clear identification of areas taking credit for natural ventilation;</li> <li>• Detailed description or references that document modeling algorithms and/or methodology for natural ventilation portion of energy model;</li> <li>• All thermostat, fan, infiltration, and other appropriate schedules for naturally ventilated areas;</li> <li>• Documentation to demonstrate that range of unmet load hours is similar for both proposed and baseline buildings, to ensure that savings are not claimed for hours outside control parameters;</li> <li>• Documentation to demonstrate that the operational schedule for natural ventilation system aligns with anticipated occupants' behavior and</li> <li>• Exceptional calculations to document manual control features (for case-by-case review).</li> </ul>
<b>Lighting system</b>			
Manual lighting controls	NCv2.2 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, only automated lighting controls are eligible for energy savings credit. CIR confirms that 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	NCv2.2 10/24/2008	Clarifies use of the Exceptional Calculation Method to document higher savings from automatic lighting controls.	For automatic lighting controls, ASHRAE 90.1-2004, Appendix G, Table G3.2, Power Adjustment Percentages for Automatic Lighting Controls, defines default percentages of savings that can be claimed. CIR clarifies that project teams are allowed to claim greater savings for use of automatic lighting controls than default savings percentage, based on statement in ASHRAE 90.1-2004, 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 (USGBC in this case). CIR requires that schedule change and energy savings be modeled and submitted as Exceptional Calculation Method with documentation that supports proposed lighting schedule.
Lighting in multilevel residential buildings	NCv2.2 3/23/2007	Describes specific requirements for modeling lighting in multilevel residential buildings.	<p>All common areas and support areas, including circulation, lounges, and lobbies, should be included in lighting power density calculations and modeled in both proposed design and baseline cases.</p> <p>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 the Exceptional Calculation Methodology.</p>

**Table 2.2.** Summary of Major EA Credit 1 CIRs, through June 26, 2009. (continued)

Topic	Rating System and CIR date	Summary	Description
<b>Process Energy</b>			
Process loads	NCv2.2 3/23/2007	Describes methodology for documenting process energy savings from efficient hard-wired lighting in residential living units.	<p>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.</p> <p>Lighting credit can be taken only in rooms where permanently installed hard-wired lighting fixtures meet illumination requirements for space.</p> <p>CIR 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.</p>
	NCv2.2 3/4/2008, 5/27/2008	Clarifies some specific process load situations.	<p>According to definition of process energy, CIR dated 3/4/2008 clarifies that energy use by personal cooling and heating systems is not considered process energy.</p> <p>Also, CIR dated 5/27/2008 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 submittal template Tables 1.8.1 and 1.8.2.</p>
	NCv2.2 01/07/2009, 10/24/2008 and 3/23/2007	Confirms that process loads must be included in simulations.	CIRs confirm that process loads for entire facility must be included in both design case and baseline model. This reinforces ASHRAE 90.1-2004, Appendix G 1.2, requirements that both proposed building performance and baseline building performance include all end-use load components.
Process energy use reduction	NCv2.2 10/24/2008, 10/3/2008, 8/13/2007, 2/26/2007	Defines the Exceptional Calculation Method to document process energy use reduction.	<p>Process load reduction must be documented by an Exceptional Calculation Methodology, as described in ASHRAE 90.1-2004, Appendix G2.5. For example, all four CIRs 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 design and baseline cases.</p> <p>CIR dated 10/24/2008 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 case, supported by following:</p> <ul style="list-style-type: none"> <li>• 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);</li> <li>• List of modifications that make new equipment more efficient;</li> <li>• Detailed utility bills from comparison facility for reference; and</li> <li>• Operation schedules for facility and equipment.</li> </ul>
	NCv2.2 8/13/2007	Describes requirements for documenting process energy savings from appliances.	CIR requires that to document process energy savings from energy-efficient appliances, actual measured energy use data be obtained from both baseline and proposed equipment. Project teams can conduct studies themselves or cite studies of identical equipment.

**Table 2.2.** Summary of Major EA Credit 1 CIRs, through June 26, 2009. (continued)

Topic	Rating System and CIR date	Summary	Description
<b>Process Energy (continued)</b>			
	NCv2.2 10/24/2008	Prohibits floor area reductions when modeling automated mechanical storage-and-retrieval systems.	Automated mechanical storage-and-retrieval systems used in refrigerated warehouses eliminate use of fork lifting, thus potentially reducing aisle size. However, CIR clarifies that reduction in floor area for proposed design is not permissible under Table G3.1.1 of Baseline Building Performance in ASHRAE 90.1-2004, Table G3.1.1 requires that baseline building be modeled with identical conditioned floor area as proposed design.
	NCv2.2 5/27/2008	Defines specific requirements for documenting waste energy recovery from process loads.	<p>CIR addresses facility that uses large process heating and cooling plants to test HVAC equipment. Subsequent heating and cooling energy created from tested equipment is captured and reused by process heating and cooling plants. CIR defines specific modeling approach for using waste energy recovery for systems. There requirements are summarized as follows:</p> <ul style="list-style-type: none"> <li>• Tested equipment should be modeled using identical types, quantities, efficiencies, controls, and pump power in baseline and proposed cases.</li> <li>• 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.</li> <li>• 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.</li> </ul> <p>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.</p>
Data center	NCv2.2 1/14/2009, 11/11/2008	Describes requirements for documenting process energy savings from use of server virtualization technique.	Data centers may use server virtualization technique to reduce energy consumption. Server visualization techniques replace multiple servers with one large, high-performance server that runs multiple "virtual" servers. To account for savings from technology, CIR requires use of the 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.
	NCv2.2 11/11/2008	Prohibits use of ASHRAE 90.1-2007 Exceptional Calculation Method baseline for documenting process energy savings in data centers.	<p>To document process energy savings through Exceptional Calculation Method, the baseline definition of data center building should not be based on ASHRAE 90.1-2007, as outlined in Environmental Performance Criteria (EPC) Guide for New Data Centers, draft based on LEED NCv2.2, September 3, 2008.</p> <p>Baseline needs additional justification and EPC Guide for New Data Centers can be used as support, but case needs to stand on its own.</p>
Refrigerated warehouse	NCv2.2 1/12/2009	Clarifies that refrigerated warehouses should be modeled as energy neutral.	ASHRAE 90.1-2004 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, CIR requires that refrigerated warehouse portion of project be modeled as energy neutral.

**Table 2.2.** Summary of Major EA Credit 1 CIRs, through June 26, 2009. (continued)

Topic	Rating System and CIR date	Summary	Description
<b>Tenant requirements</b>			
Energy efficiency measures in tenant guidelines	CSv2.0 4/24/2008, 10/24/2008	Clarifies what efficiency improvements in tenant guidelines can be included in proposed model.	Whether energy efficiency measure 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, as clarified by CIR dated 4/24/2008. Efficiency improvements mandated by tenant requirements can be included in proposed model. In addition, per LEED-CS errata 11/2007 and CIR dated 10/24/2008, efficiency requirements must be strictly enforced and be part of tenant lease.
Process energy use in future build-out	NCv2.2 08/07/2007	Requires process energy use in future build-outs to be included in simulations.	Process energy use in future build-out should be included in simulations. LEED CSv2.0 Reference Guide provides guidance on how to address future build-out spaces.
<b>Use of ASHRAE 90.1-2007, Appendix G</b>			
Use of ASHRAE 90.1-2007, Appendix G	4/23/2008	Allows use of ASHRAE 90.1-2007, Appendix G.	It is acceptable to use ASHRAE 90.1-2007, Appendix G, in place of ASHRAE 90.1-2004, Appendix G, if energy simulation follows language of 2007 Appendix G in its entirety.

# CHAPTER 3.

## ENERGY PERFORMANCE COMPLIANCE PATH DOCUMENTATION AND REVIEW

The purpose of this section is to help LEED users document the energy modeling compliance path. The section focuses on documentation requirements for EA Credit 1 and guidance on the quality control process that project teams can adopt for verifying the energy savings demonstrated on the LEED Online Submittal Template. Detailed technical and procedural guidance for verifying energy savings, including common errors made in EA Credit 1 applications, is included.

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**

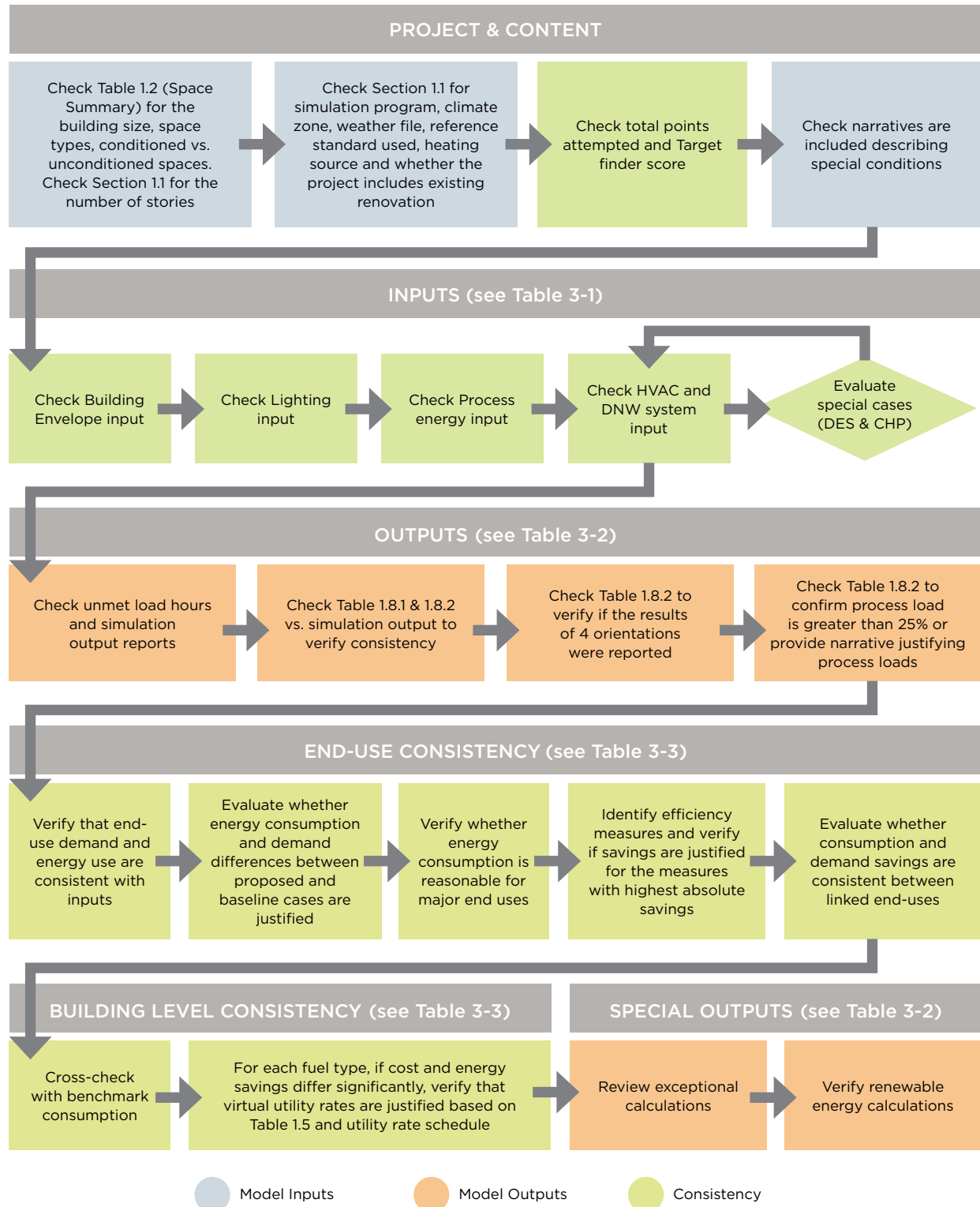
#### **3.1.1. LEED Submittal Template**

The LEED submittal template is the primary document required for EA Credit 1. To verify energy performance, the submittal template must be completed with the required information and a sufficient level of detail. This expectation for LEED EA Credit 1 applications has been described in Appendix C, Annotated LEED EA Credit 1 Submittal template. The annotated sample Submittal Template which includes descriptions of the required content for applicants using ASHRAE 90.1–2004 but can also serve as 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 Submittal Template, applicants must provide building-level simulation output reports and utility rate schedules, as shown in Appendix B. The required building-level reports were introduced in Chapter 2 for several representative types of simulation software. For example, BEPS, BEPU, and ES-D reports are required for projects using DOE-2–based software. The USGBC 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 issues found 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 90.1–2004 can use the table as a guide to perform quality assurance for completeness and accuracy. The inputs are found in the LEED Online submittal template and energy modeling summary reports.

The most common errors are for projects using ASHRAE 90.1–2004, Appendix G. Although not noted in the table, many of these errors are often seen for Oregon Energy Code 2005 projects as well. 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. However, common errors identified for the baseline case include incorrect modeling of the lighting space functions and mixing the Complete Building and Area Category methods.

### **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 submittal template are consistent with the simulation output reports. The checklist applies to projects using ASHRAE 90.1–2004 and California Title 24.

### 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 90.1–2004, California Title 24, and the Oregon Energy Code.

**Table 3.1.** Input QC Checklist

Topic	Check	ASHRAE 90.1-2004 common errors	Resources
<b>General information</b>			
Simulation program	Verify that approved energy simulation software has been used.	<ul style="list-style-type: none"> <li>Using unqualified simulation software, e.g. using Energy-10 for buildings with more than 2 thermal zones or larger than 10,000 sf.</li> </ul>	ASHRAE 90.1-2004, Appendix G, Section G 2.2
Weather file and climate zone	Verify that correct weather file and climate zone have been used.	<ul style="list-style-type: none"> <li>n/a</li> </ul>	n/a
Referenced standard	Verify that approved referenced standard has been used.	<ul style="list-style-type: none"> <li>Using referenced standard other than ASHRAE 90.1-2004 for project not located in California or Oregon.</li> </ul>	n/a
New construction percentage	Verify reported percentage of new construction consistent with LEED Online project summary.	<ul style="list-style-type: none"> <li>Reporting different percentages on submittal template and LEED Online.</li> </ul>	n/a
Target finder score	Confirm that Target Finder Score is provided. If not provided, check Table 1.2 of EA Credit 1 submittal template to verify project's primary occupancy.	<ul style="list-style-type: none"> <li>Not providing Target Finder Score even though project has Target Finder standard occupancy type.</li> </ul>	Target Finder Web site
<b>Space summary</b>			
Building floor area	Verify that building floor area is consistent with other credits. Verify conditioned area with IEQ Prerequisite 1. Consider $\pm 10\%$ variance to account for built-up area.	<ul style="list-style-type: none"> <li>Building floor area is inconsistent with other credits.</li> </ul>	n/a
<b>Building envelope</b>			
Existing building	Verify baseline energy modeling approach for existing building renovation.	<ul style="list-style-type: none"> <li>Baseline building shell of existing construction is not modeled as it exists prior to any revisions.</li> </ul>	ASHRAE 90.1-2004, Table G3.1, Section 5(f)
Opaque assemblies	Verify that opaque envelope input reflects correct assembly construction and U-values.	<ul style="list-style-type: none"> <li>Incorrect envelope constructions are modeled in baseline building (e.g., exterior walls not modeled with lightweight, steel-framed assemblies).</li> </ul>	ASHRAE 90.1-2004, Table G3.1, Section 5(b)
Fenestration	Verify that fenestration area modeled for baseline meets referenced standard requirements.	<ul style="list-style-type: none"> <li>Baseline vertical fenestration exceeds 40% of gross above-grade wall.</li> </ul>	ASHRAE 90.1-2004, Table G3.1, Section 5(c)
	Verify that Baseline and Proposed design U-values reflect assembly U-values.	<ul style="list-style-type: none"> <li>Proposed design uses center-of-glass U-values rather than whole window assembly U-values (including frame).</li> <li>Baseline building adds frame conductance to prescriptive Baseline assembly U-values.</li> <li>Not applying Ufixed for all windows in baseline.</li> <li>Addendum A or ASHRAE 90.1-2007, Appendix G, is not used, but Baseline case windows are not modeled uniformly.</li> </ul>	
	Verify that Solar Heat Gain Coefficient (SHGC) input is correct for baseline.	<ul style="list-style-type: none"> <li>Using SHGCnorth for north windows in Baseline.</li> </ul>	
Shading devices	Verify that proposed design includes correct type of shading devices.	<ul style="list-style-type: none"> <li>Proposed design models manually controlled shading devices, such as blinds.</li> </ul>	ASHRAE 90.1-2004, Table G3.1, Section 5, Exception (d)
	Verify that baseline building includes no shading devices	<ul style="list-style-type: none"> <li>Baseline building includes shading devices.</li> </ul>	

**Table 3.1.** Input QC Checklist (continued)

Topic	Check	ASHRAE 90.1-2004 common errors	Resources
<b>Building envelope (continued)</b>			
Cool roofs	Verify that proposed cool roof is modeled with appropriate reflectance from Table G3.1, Section 5, Exception (C).	<ul style="list-style-type: none"> <li>Proposed roof modeled with rated reflectance greater than 0.45.</li> </ul>	ASHRAE 90.1-2004, Table G3.1, Section 5, Exception (c)
<b>Lighting</b>			
Interior Lighting Power Density (LPD)	Verify that consistent calculation methodology is used for baseline design.	<ul style="list-style-type: none"> <li>Baseline Design LPD applies multiple Building Area Methods to single building without complying with applicable exceptions.</li> </ul>	ASHRAE 90.1-2004, Table G3.1, Section 6
	Verify that Baseline building LPD used for energy model meets ASHRAE requirements.	<ul style="list-style-type: none"> <li>Baseline building LPD does not follow Table 9.6.1 or Table 9.6.2.</li> <li>Incorrect additional LPD allowance for accent, display, and/or task lighting is modeled in Baseline case.</li> <li>For existing building renovation, proposed lighting retrofits are greater than 50%, but Baseline lighting systems are modeled as existing conditions.</li> </ul>	ASHRAE 90.1-2004, Sections 9.6.1, 9.6.2
Lighting controls	Verify that lighting control inputs are consistent with ASHRAE requirements.	<ul style="list-style-type: none"> <li>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.</li> <li>Proposed design adjusts lighting power for use of occupancy sensors in spaces where occupancy sensors are required by Section 9.4.1.2(a).</li> <li>Baseline building includes controls in addition to mandatory control requirements that are incorporated by lighting schedules.</li> <li>Proposed design claims lighting control credit for use of manual controls.</li> <li>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.</li> <li>Space function is inconsistent with space type is selected for determination of Baseline lighting power allowance.</li> </ul>	ASHRAE 90.1-2004, Table G3.2, Table G3.1, Sections 6, 9.4.1.2
Lighting schedules	Verify that lighting schedule has been correctly modeled for residential buildings.	<ul style="list-style-type: none"> <li>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 design case and/or baseline case.</li> </ul>	NCv2.2 CIR dated 3/23/2007
Exterior Lighting	Verify that baseline exterior lighting power has been correctly calculated.	<ul style="list-style-type: none"> <li>Baseline lighting power is not calculated per ASHRAE Table 9.4.5.</li> <li>Proposed lighting power is inconsistent with that reported in documentation for SS Credit 8.</li> <li>Nontradable surfaces are not modeled with lesser of nontradable surface and installed lighting power for each nontradable surface, as required.</li> </ul>	ASHRAE 90.1-2004, Table 9.4.5

**Table 3.1.** Input QC Checklist (continued)

Topic	Check	ASHRAE 90.1-2004 common errors	Resources
<b>Process loads</b>			
Process lighting	Verify that qualified process lighting is reported.	<ul style="list-style-type: none"> <li>Regulated lighting use is incorrectly reported as process lighting.</li> </ul>	ASHRAE 90.1-2004, Exceptions to 9.2.2.3
Other process loads	Verify that all process loads are reported identically for Proposed design and baseline building and that all end-use load components within and associated with building are modeled.	<ul style="list-style-type: none"> <li>Receptacle and other miscellaneous loads are not same in baseline and proposed designs.</li> <li>Process loads, such as cooking equipment and elevator, are omitted from baseline and proposed design models.</li> </ul>	ASHRAE 90.1-2004, Table G3.1, Section 12, and Table G3.1
<b>HVAC system</b>			
Primary system type	Verify that correct HVAC system type is selected for baseline.	<ul style="list-style-type: none"> <li>Baseline building is modeled with wrong HVAC system or incorrectly applies Addendum A.</li> <li>Baseline HVAC systems use both fossil fuel and electricity.</li> <li>Software work-arounds are used incorrectly (e.g., baseline uses alternative system to model System 6, Packaged VAV with PFP boxes in eQuest).</li> <li>Addendum A changes to square footage determination of HVAC system type are not applied when other Addendum A provisions are included in energy model.</li> <li>Baseline HVAC system is mapped using "Electric and Other" heating source classification when fossil fuel heating is present in proposed case.</li> <li>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.</li> <li>Preheat (when present) is not modeled identically for Baseline and Proposed case</li> </ul>	ASHRAE 90.1-2004, Tables G3.1.1A, G3.1.1B
	Verify that both heating and cooling systems have been modeled for proposed design.	<ul style="list-style-type: none"> <li>No heating or cooling system is modeled in proposed design case for conditioned spaces.</li> </ul>	ASHRAE 90.1-2004, Table G3.1, Section 10, and Table G3.1, Section 1(b)
Additional system type	Verify that baseline additional system type meets requirements in Exceptions to G3.1.1.	<ul style="list-style-type: none"> <li>Baseline incorrectly includes additional type(s) of systems.</li> </ul>	ASHRAE 90.1-2004, exceptions to G3.1.1
Fan volume	Verify that baseline fan volume has been sized correctly.	<ul style="list-style-type: none"> <li>Proposed and Baseline buildings show equal fan supply volumes instead of following ASHRAE airflow rate sizing guidelines.</li> <li>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 20°F as required.</li> <li>Fan volume in proposed design is autosized, not using design conditions.</li> </ul>	G3.1.2.8
Fan power	Verify that baseline fan power has been calculated correctly.	<ul style="list-style-type: none"> <li>Baseline fan power does not conform to Table G3.1.2.9.</li> <li>Proposed and baseline buildings show equal fan power instead of following ASHRAE fan power calculations.</li> <li>Additional fan power allowance is claimed in baseline for return, exhaust, or relief fans.</li> <li>Addendum AC is used without indication that it is being used or indication of parameters used to define A (pressure adjustment).</li> </ul>	ASHRAE 90.1-2004, G3.1.2.9.

**Table 3.1.** Input QC Checklist (continued)

Topic	Check	ASHRAE 90.1-2004 common errors	Resources
<b>HVAC system (continued)</b>			
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.	<ul style="list-style-type: none"> <li>• Baseline building omits exhaust air energy recovery when required.</li> <li>• Heat recovery system omits bypass of air-side economizer.</li> <li>• Baseline case energy recovery efficiency is not modeled in accordance with G3.1.2.10.</li> <li>• Proposed case energy recovery efficiency is not modeled as designed.</li> <li>• Proposed case energy recovery bypass is not modeled as designed.</li> <li>• Baseline and proposed case ventilation rates are not modeled with zero flow during unoccupied periods.</li> </ul>	ASHRAE 90.1-2004, G3.1.2.10
Economizer control	Verify that economizers are properly included or excluded in baseline building.	<ul style="list-style-type: none"> <li>• Economizer type and/or control is incorrectly modeled in baseline building.</li> <li>• Economizer high limit shutoff is not in accordance with Table G3.1.2.6C.</li> </ul>	ASHRAE 90.1-2004, G3.1.2.6, G3.1.2.7
Ventilation	Verify that ventilation is appropriately modeled in baseline and proposed cases.	<ul style="list-style-type: none"> <li>• Outdoor air is modeled with same design ventilation percentage instead of same ventilation rates in baseline and proposed cases.</li> <li>• Baseline case uses 30% minimum flow ratio rather than required 0.4 cfm/sf.</li> </ul>	
Demand control ventilation	Verify that demand control ventilation has been excluded or included in baseline building and modeled appropriately.	<ul style="list-style-type: none"> <li>• Demand control ventilation is not included in baseline building when its use is required for high-occupancy areas by ASHRAE 90.1-2004, Section 6.4.3.8 Ventilation Controls for High-Occupancy Areas.</li> <li>• Outside airflow is not modeled as zero during unoccupied periods.</li> </ul>	ASHRAE 90.1-2004, G3.1.2.5
	Verify that demand control ventilation is correctly modeled in Proposed design case.	<ul style="list-style-type: none"> <li>• Insufficient information is provided regarding demand control ventilation in proposed design case.</li> <li>• Demand control ventilation is modeled for credit, and Baseline case ventilation rates are not modeled with ASHRAE 62.1-2004 values. (These values should be used in Baseline case if credit is taken for demand control ventilation in Proposed case design.)</li> </ul>	n/a
Unitary equipment cooling/heating efficiency	Verify that equipment efficiencies of proposed design and baseline building meet referenced standard's requirements.	<ul style="list-style-type: none"> <li>• Proposed building HVAC equipment does not meet mandatory minimum efficiencies listed in Tables 6.8.1A through 6.8.1G.</li> <li>• Baseline building HVAC equipment is modeled as other than minimum efficiencies listed in Tables 6.8.1A through 6.8.1G.</li> <li>• Baseline system capacities are omitted in submittal template to verify efficiencies listed.</li> <li>• Cooling efficiencies do not break out cooling efficiency separately from fan power, or EER is modeled for cooling efficiency component only.</li> </ul>	ASHRAE 90.1-2004, Table G3.1, Section 10
System-specific information	Verify that system-specific HVAC system requirements are met for baseline.	<ul style="list-style-type: none"> <li>• Baseline heat pumps allow electric backup heat to operate above 40°F.</li> <li>• Baseline fan systems (System 5 through 8) omit supply temperature reset.</li> <li>• Fan-powered VAV boxes are modeled for Systems 5 and 7.</li> <li>• Multiple zones are modeled under single-zone system type, and reheat is modeled (Systems 1, 2, 3, and 4).</li> </ul>	ASHRAE 90.1-2004, G3.1.3.1, G3.1.3.12, G3.1.3.13, G3.1.3.14

**Table 3.1.** Input QC Checklist (continued)

Topic	Check	ASHRAE 90.1-2004 common errors	Resources
<b>HVAC system (continued)</b>			
Chiller parameters	Verify number, type, and capacity of chillers in baseline.	<ul style="list-style-type: none"> <li>• Baseline has incorrect number and/or type of chillers.</li> <li>• Baseline chiller capacities are equal to proposed design chiller capacities instead of following ASHRAE system sizing guidelines.</li> </ul>	ASHRAE 90.1-2004, 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.	<ul style="list-style-type: none"> <li>• Baseline chilled water loops are modeled with incorrect pumping energy and/or incorrect configuration (e.g., modeled as primary-only loops).</li> <li>• Baseline chilled water loops are modeled with incorrect temperature settings.</li> <li>• Baseline chilled water loops omit supply temperature reset.</li> <li>• Different number of primary chilled water pumps is modeled than chillers.</li> </ul>	ASHRAE 90.1-2004, G3.1.3.8, G3.1.3.9, G3.1.3.10
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.	<ul style="list-style-type: none"> <li>• Baseline condenser water loops are modeled with incorrect pumping energy.</li> <li>• Baseline condenser water loops are modeled with incorrect temperature settings.</li> <li>• Baseline condenser water loops omit wet bulb reset controls.</li> <li>• A different number of condenser water pumps is modeled than chillers</li> <li>• Baseline cooling tower fans are not modeled as 2-speed.</li> <li>• Baseline cooling tower fans are not modeled as axial fans with 38.2 gpm/hp.</li> </ul>	ASHRAE 90.1-2004, G3.1.3.11
Boiler parameters	Verify that number, type, and capacity of boilers for baseline meet referenced standard's requirements.	<ul style="list-style-type: none"> <li>• Baseline building includes incorrect number of boilers.</li> <li>• Baseline boiler capacities are equal to proposed design boiler capacities instead of following ASHRAE system sizing guidelines.</li> </ul>	ASHRAE 90.1-2004, 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.	<ul style="list-style-type: none"> <li>• Baseline hot water loops are modeled with incorrect pumping energy and/or incorrect loop configuration (e.g., modeled as primary-secondary loops).</li> <li>• Baseline hot water loops are modeled with incorrect temperature settings.</li> <li>• Baseline hot water loops omit supply temperature reset.</li> </ul>	ASHRAE 90.1-2004, 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 followed USGBC guidance.	<ul style="list-style-type: none"> <li>• Project registered after 5/28/2008 does not follow USGBC modeling guidance for treatment of district thermal energy.</li> <li>• Project registered before 5/28/2008 models on-site boilers for systems using purchased hot water or steam in Baseline building, contrary to ASHRAE requirements.</li> </ul>	USGBC Guidance and ASHRAE 90.1-2004, G3.1.1.1
Cooling tower parameters	Verify that baseline cooling tower is modeled per referenced standard's requirements.	<ul style="list-style-type: none"> <li>• Baseline building includes incorrect type of cooling tower and/or fan control.</li> <li>• * Baseline building models condenser water temperatures incorrectly.</li> </ul>	ASHRAE 90.1-2004, G3.1.3.11

**Table 3.1.** Input QC Checklist (continued)

Topic	Check	ASHRAE 90.1-2004 common errors	Resources
Service hot water system			
Service hot water system	Verify that service hot water system is modeled if system has been specified or planned.	<ul style="list-style-type: none"><li>Service hot water system is not included in either building.</li><li>Separate hot water heater system in Baseline building is not modeled when Proposed building combines space heating with service hot water heating.</li></ul>	ASHRAE 90.1-2004, Table G3.1, Section 11, Section 6.5.6.2
	Verify that condenser heat recovery for service hot water heating is modeled in baseline building where required.	<ul style="list-style-type: none"><li>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 aseline case.</li><li>Baseline case includes incorrect condenser heat recovery inputs.</li></ul>	
Energy type summary			
Energy rates	Check that actual rates of purchased energy or state average energy prices are reported.	<ul style="list-style-type: none"><li>Both actual rates and state average energy prices are used.</li></ul>	ASHRAE 90.1-2004, G2.4

**Table 3.2:** Output QC Checklist

Topic	Check	Common errors	Resources
Unmet load hours	Verify that unmet load hours of both Proposed design and Baseline buildings meet requirements. (Projects using Title 24 and EnergyPro need not report unmet load hours in EA Credit 1 submittal template.)	<ul style="list-style-type: none"> <li>Proposed and/or Baseline buildings have more than maximum 300 hours of unmet load.</li> <li>Unmet load hours of proposed baseline building exceed unmet load hours of baseline case by more than 50 hours.</li> <li>Worst-case zone instead of entire building is used to comply with these requirements.</li> <li>Typical causes for high unmet load hours:</li> <li>Zones are inappropriately modeled, resulting in lack of separation between perimeter and core spaces, or between perimeter spaces facing different directions.</li> <li>Internal heat conduction properties are modeled incorrectly for adjacent spaces with varying temperature setpoints or temperature setpoint schedules.</li> <li>High internal loads are mistakenly applied.</li> <li>Spaces with high loads are not modeled with correct system capacity and/or airflow.</li> <li>Supply air temperature resets are modeled incorrectly.</li> <li>Morning warm-up period is inadequate.</li> <li>Outside air schedules are not set to zero when fans cycle on at night.</li> <li>Multiple zones are modeled under single-zone system, particularly when electric resistance heating is primary or supplemental heating source.</li> <li>Airflow at zone level is inadequate.</li> <li>Capacities and flow rates from central plant equipment are inadequate.</li> <li>Central plant loops are off during calls for heating and/or cooling.</li> <li>Electric resistance heating is not modeled for heat pump units when outdoor temperature drops below 40°F.</li> </ul>	ASHRAE 90.1-2004, G3.1.2.2

**Table 3.2:** Output QC Checklist (continued)

Topic	Check	Common errors	Resources
Renewable energy	Verify that renewable energy reported in Table 1.6 of submittal template is consistent with EA Credit 2.	<ul style="list-style-type: none"> <li>Renewable energy reported is inconsistent with EA Credit 2.</li> <li>Renewable energy does not include backup calculations or narrative describing calculation methodology in EA Credit 1 or EA Credit 2.</li> </ul>	n/a
	Verify that amount of renewable energy generated is reasonable, cross-checking information provided by EA Credit 2.	<ul style="list-style-type: none"> <li>Renewable energy generated is inconsistent with power input.</li> <li>Calculations to justify renewable energy generation are omitted.</li> </ul>	National Renewable Energy Laboratory (NREL), PV Watts Calculator
Exceptional calculation method	Verify validity of exceptional calculation methodology.	<ul style="list-style-type: none"> <li>Defensible baseline is not established.</li> <li>Calculations and theoretical or empirical information supporting accuracy of methodology are omitted.</li> <li>Methodology for exceptional calculations for measures such as refrigeration, heat recovery, and process load savings is incorrect.</li> </ul>	ASHRAE 90.1-2004, G2.5
Simulation output	Verify consistency between energy consumption and cost simulation outputs and values reported in EA Credit 1 submittal template.	<ul style="list-style-type: none"> <li>Energy use and/or cost values reported in Tables 1.8.1 and 1.8.2 of submittal template are inconsistent with simulation output</li> </ul>	n/a
	Verify that process energy costs represent not less than 25% of baseline total energy cost.	<ul style="list-style-type: none"> <li>Process energy cost represents less than 25% of baseline total energy cost, and supporting documentation substantiating low process energy inputs is missing.</li> </ul>	LEED-NCv2.2, CSv2.0, and LEED for Schools 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.	<ul style="list-style-type: none"> <li>Envelope elements are not correctly modeled.</li> </ul>	n/a
	If California Title 24-2005 is referenced, check UTIL-1 report to verify that EnergyPro was run in compliance mode.	<ul style="list-style-type: none"> <li>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.</li> </ul>	USGBC guidelines for LEED-NC and LEED-CS; California Title 24-2005, 11/19/2007
	If California Title 24-2005 is referenced, check UTIL-1 report to verify that EnergyPro was run in compliance mode.	<ul style="list-style-type: none"> <li>Consumption and cost values for electricity or natural gas vary by more than 10%, and narrative providing demand and utility tariff is not provided.</li> </ul>	USGBC guidelines for LEED-NC and LEED-CS; California Title 24-2005, 11/19/2007

**Table 3.3. Output-Input Consistency QC Checklist\***

Topic	Check	Comments
<b>End-use level energy demand, consumption, and savings</b>		
Interior and Exterior Lighting Power	Calculate lighting demand for both cases with average lighting power densities reported in Table 1.4, and verify consistency with lighting power demand reported in Table 1.8.2.  Verify consistency of exterior lighting demand of both cases reported in Table 1.8.2 with lighting power in Table 1.4.	<ul style="list-style-type: none"> <li>Calculate lighting demand based on building floor area provided in Table 1.2 and lighting power density input in Table 1.4.</li> </ul> $\text{Lighting Demand} = \text{Average Lighting Power Density} \times \text{Building Floor Area}$
	Determine whether any differences can be justified based on lighting control credits.	<ul style="list-style-type: none"> <li>Lighting schedule differences and daylighting, occupancy sensor, and other controls can account for differences in lighting power.</li> </ul>
Interior and Exterior Lighting Consumption	Verify that Equivalent Full Load Hours (EFLHs of both cases based on lighting energy use and demand reported in Table 1.8.2.	<ul style="list-style-type: none"> <li>Calculate interior lighting EFLHs of proposed design:</li> </ul> $\text{EFLHs} = \frac{\text{Lighting Energy Use}}{\text{Lighting Power}}$
	Determine whether any differences in EFLHs can be justified based on lighting control credits.	<ul style="list-style-type: none"> <li>Proposed design EFLHs can be reduced by lighting controls, such as daylighting controls, and reduced lighting schedules.</li> </ul>
	If project references California Title 24-2005, verify that exterior lighting and unconditioned space lighting have been added to results reported in Tables 1.8.1 and 1.8.2.	<ul style="list-style-type: none"> <li>Both buildings may incorrectly omit exterior and unconditioned lighting energy use.</li> </ul>
	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.	<ul style="list-style-type: none"> <li>Multiply installed wattages by average annual operating hours, then divide by 1,000 to obtain annual energy consumption.</li> <li>Multiply average annual energy consumption by average electricity cost to obtain annual energy cost.</li> </ul>
Cooling equipment efficiency	Confirm whether average efficiency of cooling equipment correlates (within reasonable margin) with IPLV reported in Table 1.4.	<ul style="list-style-type: none"> <li>Use output of total ton-hours (or million Btu) of cooling and total kWh of cooling energy use to calculate cooling equipment average efficiency.</li> </ul> $\text{Average Efficiency (kW/ton)} = \frac{\text{Input kWh}}{\text{Output Ton-Hours}}$
	Identify any parameters that may result in variance.	<ul style="list-style-type: none"> <li>Chillers operating mostly at full load show different IPLV from 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).</li> </ul>
Fan and pump power	Verify that fan and pump demand reported in Tables 1.8.1 and 1.8.2 is consistent with fan and pump power reported in Table 1.4.	<ul style="list-style-type: none"> <li>Demand reported in Table 1.8.1 and 1.8.2 should not be greater than total power reported in Table 1.4.</li> </ul> $\text{Input kW} = \frac{\text{Output Hp} \times 0.746}{\text{Efficiency}}$
	Verify that differences in fan and pump energy consumption versus demand between baseline and proposed cases can be justified.	<ul style="list-style-type: none"> <li>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.</li> </ul>
System demand	Verify that system demand reported in Tables 1.8.1 and 1.8.2 is consistent with demand calculated with system capacities and efficiencies reported in Table 1.4 of the Template, particularly for cooling system.	<ul style="list-style-type: none"> <li>If cooling is provided only by chillers, project's cooling demand can be calculated with following equation:</li> </ul> $\text{Cooling Demand (ton-hours)} = \frac{\text{Chiller Capacity (tons)}}{\text{Chiller Efficiency (kW/ton)}}$

**Table 3.3.** Output-Input Consistency QC Checklist\* (continued)

Topic	Check	Comments
Energy consumption by end-use	Verify that energy consumption by end use is reasonable for project's climate zone based on inputs provided	<ul style="list-style-type: none"> <li>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).</li> </ul>
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.	<p><b>Envelope Energy Efficiency Measures:</b></p> <ul style="list-style-type: none"> <li>Determine whether building is internally or externally load dominated.</li> <li>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.</li> </ul> <p><b>Exhaust air heat recovery:</b></p> <ul style="list-style-type: none"> <li>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.</li> </ul> <p><b>Ground-source heat pumps:</b></p> <ul style="list-style-type: none"> <li>If no supplemental fossil fuel boiler, expect to see significant heating energy savings in cold climates associated with electric resistance heating.</li> <li>Expect to see increased pump power in most cases.</li> <li>Verify that modeled efficiency curves and loop temperatures are consistent with actual design.</li> </ul> <p><b>Variable refrigerant volume systems:</b></p> <ul style="list-style-type: none"> <li>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.</li> <li>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).</li> </ul> <p><b>Variable-speed drives:</b></p> <ul style="list-style-type: none"> <li>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.</li> <li>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.</li> </ul> <p><b>Variable-Speed (VSD) Chillers:</b></p> <ul style="list-style-type: none"> <li>Depending on control methods, VSD Chillers can save 50%–60% of cooling energy. This level of savings requires control strategy that usually operates chillers at 35%–50% load. Also, this level of savings is typically associated with chilled water and condenser water reset controls.</li> </ul> <p><b>Reduced Domestic Hot Water (DHW) Flow:</b></p> <ul style="list-style-type: none"> <li>Calculations reflecting reduced flow should not affect standby loss calculations; energy savings equal to flow reduction are unlikely.</li> <li>Calculations reflecting savings should account for percentage of hot water versus cold water flow to fixtures.</li> </ul> <p><b>Condensing boilers:</b></p> <ul style="list-style-type: none"> <li>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 130°F or below. The baseline curve should also be carefully scrutinized to verify that the Average Fuel Utilization Efficiency (AFUE) is consistent with the average efficiency reported for the baseline case.</li> </ul> <p><b>Increased CHW delta-T:</b></p> <ul style="list-style-type: none"> <li>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.</li> </ul>

**Table 3.3.** Output-Input Consistency QC Checklist\* (continued)

Topic	Check	Comments
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.	<ul style="list-style-type: none"> <li>Cooling and heat rejection should reflect similar savings unless  <b>Exception:</b>            If the control strategies for heat rejection vary between the baseline and proposed case, differences may be justified. (e.g., difference may occur if wet bulb temperature is reset to 60°F versus 70°F or design temperature is 75°F versus 85°F, or water-side economizer is used).</li> </ul>
	Calculate approximate expected proposed design fan energy savings of VAV systems and verify consistency with percentage savings reported in Table 1.8.2.	<ul style="list-style-type: none"> <li>After normalizing fan power, VAV system fan energy savings should align with cooling (and to lesser extent heating) energy savings.</li> </ul> $\text{Approximate Expected Proposed Design Fan Energy Savings} = 1 - \left[ 100\% - \% \text{ of Proposed Design Fan Demand Savings} \right] \times \left[ 100\% - \% \text{ of Proposed Design Cooling Energy Savings} \right]$ <p><b>Exception:</b> Cooling equipment efficiency measures that improve cooling performance at part load would not be reflected in fan savings.</p>
	Verify cooling energy savings or heating energy increase versus lighting or process power density reduction.	<ul style="list-style-type: none"> <li>Cooling savings should occur with lighting or process power density reductions.  <b>Exception:</b>            Projects with economizer controls will not reflect maximum savings associated with loads reductions.</li> <li>Heating energy increase should occur with lighting or process power density reductions.</li> </ul>
<b>Building-level energy consumption and cost</b>		
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.	<ul style="list-style-type: none"> <li>The Commercial Buildings Energy Consumption Survey (CBECS consumption and expenditures tables, available at <a href="http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html">http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html</a>).</li> <li>Check the Commercial End-Use Survey (CEUS data, available at <a href="http://www.energy.ca.gov/ceus/">http://www.energy.ca.gov/ceus/</a>).</li> </ul>
Virtual energy rates	Determine whether differences in virtual energy rates are justified based on utility rate information provided.	<ul style="list-style-type: none"> <li>Calculate virtual energy rates for each type of fuel by dividing total cost by total use.</li> <li>Higher virtual rates are seen when peak demand charges are high and demand by end-use are high.</li> <li>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.</li> </ul>
	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 the tariff, not based on a virtual rate comprised mostly of monthly meter fees.	<ul style="list-style-type: none"> <li>Gas rate is calculated based on a virtual rate comprised mostly of monthly meter fees.</li> </ul>

\* Tables referenced in this checklist are in the EA Credit 1 submittal template.

**Notes:** CBECS = Commercial Buildings Energy Consumption Survey  
 CEUs = Commercial End-Use Survey  
 EFLH = equivalent full-load hours  
 EUI = energy use intensity

# CHAPTER 4.

## ATYPICAL ENERGY SYSTEMS AND SCENARIOS

This section 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 Systems (DES) modeling requirements; and
- Combined Heat and Power (CHP) system modeling requirements.

### 4.1. Exceptional Calculations

Section G2.5 of ASHRAE 90.1–2004 stipulates that when no simulation program can adequately model a design, material, or device, the rating authority (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 submittal template.

Table 4.1 lists examples of energy efficiency measures for which exceptional calculations are required and cites applicable USGBC Credit Interpretations and Rulings (CIRs) with further guidance on the methodology.

**Table 4.1.** CIRs Regarding Exceptional Calculatio

Scenario	CIR
Energy savings from HVAC systems controlled by occupancy sensors	NCv2.2 CIR dated 8/13/2007
Energy savings from natural ventilation	NCv2.2 CIR dated 3/22/2007
Energy savings from automatic lighting controls	NCv2.2 CIR dated 10/24/2008
Process energy use reduction	NCv2.2 CIRs dated 10/24/2008, 10/3/2008, 8/13/2007, 2/26/2007
Process energy savings from efficient hard-wired lighting in residential units	NCv2.2 CIR dated 3/23/2007
Process energy savings in data centers	NCv2.2 CIRs dated 1/14/2009, 11/11/2008

In addition, this manual includes 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 includes guidance on the exceptional calculations section of the LEED submittal template.
- Table 2.2, Summary of EA Credit 1 CIRs, 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, it must use the following equation (provided in the LEED-NCv2.1 CIR dated 9/5/2001 and revised 9/21/06) to determine the appropriate point thresholds for 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 includes 75,000 square feet of existing buildings and 40,000 square feet of new construction, the point thresholds table must be modified as shown in Table 4.2.

**Table 4.2.** Credit EA 1 Point Thresholds for New Construction Plus Renovations to Existing Buildings

New buildings	Existing buildings	Project target	Points
10.5%	3.5%	<b>5.9%</b>	<b>1</b>
14.0%	7.0%	<b>9.4%</b>	<b>2</b>
17.5%	10.5%	<b>12.9%</b>	<b>3</b>
21.0%	14.0%	<b>16.4%</b>	<b>4</b>
24.5%	17.5%	<b>19.9%</b>	<b>5</b>
28.0%	21.0%	<b>23.4%</b>	<b>6</b>
31.5%	24.5%	<b>26.9%</b>	<b>7</b>
35.0%	28.0%	<b>30.4%</b>	<b>8</b>
38.5%	31.5%	<b>33.9%</b>	<b>9</b>
42.0%	35.0%	<b>37.4%</b>	<b>10</b>

**Note:** The EA Credit 1 submittal template automatically calculates the points earned with the revised target point threshold based on the inputs of the new construction percentage in Section 1.1.

## 4.3. Calculations for Multiple Buildings

To receive a single rating for a group of buildings, the project team must calculate the energy performance for each building and then aggregate the results for all the buildings into one performance rating calculation. Each building in the group must still meet EA Prerequisite 2 and may receive its own rating if that is desired. If the performance of a group of buildings is analyzed in one energy model, the calculations are not necessary. Table 4.3 summarizes the methods for obtaining a single EA Credit 1 rating for multiple buildings.

**Table 4.3.** Ways to Obtain Single EA Credit 1 Rating for Multiple Buildings

Performance analysis options	Results used for performance rating calculation	Additional calculations needed
One energy model	Single cost savings	n/a
Multiple energy models	Energy cost results for each building	Aggregate data into one performance rating calculation

## 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.

“Required Treatment of District Thermal Energy,” published on May 28, 2008, by USGBC, clarifies whether and how project teams must account for district energy systems in the prerequisites and credits for LEED NCv2.2, LEED for Schools, LEED for Commercial Interiors v2.0, and LEED for Core & Shell v2.0.

A subsequent document, “Treatment of District or Campus Thermal Energy in LEED V2 and LEED 2009 – Design & Construction,” may be used in lieu of the original document for documenting compliance for projects that include district energy systems.

Any projects that include DES and registered for these rating systems on or after May 28, 2008, are required to follow the guidance from one of these documents. The requirements apply to all DES, whether new or preexisting, and whether owned by the project owner or another entity. 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.

- For the Proposed Building case, the plant capacities (including chiller, boiler, and cooling tower capacities, and circulation loop flow) should be scaled to represent the portion of peak thermal loads contributed by the buildings included in the LEED submittal.
- If the baseline building HVAC system type for the project includes a central plant, the type and number of chillers or boilers modeled for the baseline building must be based on the conditioned floor area for the current LEED submittal. Similarly, the baseline chilled water and hot water pump controls must be modeled based on the conditioned floor area for the current LEED submittal.

Like conventional EA Credit 1 approaches, DES projects can take either a prescriptive or a performance-based approach to calculations. Further information on the energy performance compliance path for DES is provided below. Please note that the energy modeling and documentation guidance on DES in the following section is mandatory only for projects registered after May 28, 2008, but is available as optional guidance to projects registered before that date.

### DES Energy Modeling and Documentation Guidance

*“Required Treatment of District Thermal Energy,” May 28, 2008*

For projects following the performance compliance path, USGBC requires two steps to complete the analysis for EA Credit 1.

#### Step 1: Stand-alone building scenario

- This step documents the performance of the building alone, with upstream equipment modeled as cost neutral. It is used to demonstrate that each building has sufficient savings to achieve the minimum 2 points without implications of DES efficiencies or inefficiencies. If only 2 points are being attempted, then the project team does not need to complete Step 2.

#### Step 2: Aggregate building and DES scenario

- This step documents the combined performance of the building and central plant by including the performance of upstream equipment and can document the achievement of more than 2 points.
- The flow diagram in Figure 4.3 illustrates the general path of analysis for projects with DES.

*“Treatment of District or Campus Thermal Energy in LEED V2 and LEED 2009 – Design & Construction”*

A project team following the performance compliance path can choose one of 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 proposed and baseline buildings for all downstream equipment serviced by district or campus energy systems. This option has point caps (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 point floors (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.

## 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<sub>2</sub> emissions.

USGBC published the “CHP Calculation Methodology for LEED NCv2.2 EA Credit 1” in November 2005. The document provides guidance for treatment of CHP under the energy performance compliance path.

### CHP Energy Modeling and Documentation Guidance

Any CHP system must meet the following two criteria to be eligible for consideration under EA Credit 1:

- The minimum annual CHP system efficiency must be at least 60%. Efficiency is expressed by the following equation:

$$\text{Annual CHP Efficiency} = \frac{\left[ \begin{array}{l} \text{Annual Btu Electrical} \\ \text{Output of Fuel-Driven} \\ \text{Electricity Generator} \end{array} + \begin{array}{l} \text{Annual Thermal} \\ \text{Output} \end{array} \right]}{\text{Annual Btu Fuel Input}}$$

The thermal output used in the calculation must be the reclaimed thermal energy. Heat produced by the generator that is rejected and not recovered cannot be included in this calculation.

- The environmental performance of district CHP systems must be validated by a narrative addressing emissions and showing that the environmental impact of the system is lower than if the building heating and cooling loads were met with a natural gas boiler and electric chillers using electricity from the local grid.

The performance rating method requires hourly calculations for CHP performance, either directly, through simulation of the system, or by manual postprocessing of the hourly simulation results. However, it may be possible to conduct the calculation on a net annual basis if hourly load, demand, and/or utility rate relationships are insignificant.

Detailed energy modeling and documentation requirements for projects choosing the energy performance compliance path are described in the USGBC document referenced above.

# CHAPTER 5.

## RELATED CREDITS

This chapter explains the synergies and overlaps that EA Credit 1 has with EA Credit 2 and EA Credit 6 in the LEED rating systems. It also includes documentation guidance for the two credits.

### 5.1. EA Credit 2, On-Site Renewable Energy

#### 5.1.1. Overview

EA Credit 2 requires that projects using eligible on-site renewable energy systems offset building energy cost by at least 2.5% to achieve the minimum threshold. Building energy cost can be obtained from EA Credit 1 if whole building energy simulation is performed. 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
<ol style="list-style-type: none"><li>Electrical production systems based on<ul style="list-style-type: none"><li>Photovoltaic (PV)</li><li>Wind</li><li>Hydroelectric</li><li>Tidal or wave</li><li>Biofuel</li></ul></li><li>Solar thermal systems</li><li>Geothermal systems that use deep-earth water or steam sources to produce electric power or thermal energy</li></ol>	<ol style="list-style-type: none"><li>Architectural passive design strategies, such as shading and daylighting</li><li>Earth-coupled HVAC systems that do not obtain significant quantities of deep-earth heat, such as ground-source heat pumps</li><li>Green power generated off-site</li></ol>

#### 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:

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

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

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
<b>Energy generated</b>	Estimated by using same simulation tool employed for EA Credit 1 or separate calculation methodology.	Separate calculation methodology.
<b>Utility rate</b>	Actual utility schedule or virtual utility rate.	EIA 2003 Commercial Sector Average Energy Cost by State.
<b>Total energy cost</b>	Total design energy cost of proposed design reported in EA Credit 1 submittal template, Table 1.8.2(b)	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.

**Notes:** EIA = Energy Information Administration, U.S. Department of Energy  
CBECS = Commercial Building Energy Consumption Survey

### 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 Credit 1 submittal template or CBECS data.
- Electricity consumption is used instead of energy cost.

## 5.2. EA Credit 6, Green Power

### 5.2.1. Overview

EA Credit 6 requires that the project obtain no less than 35% of its electricity from renewable sources by engaging in at least a two-year renewable energy contract.

Electricity products certified by the Green-e Program 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 (RECs). The eligible power products are not necessarily Green-e certified but must meet the requirements for Green-e equivalency defined in the CIR dated 3/28/2007. The CIR requires that a project purchasing power that is not Green-e certified document that the renewable supplier has met the Green-e criteria and properly accounted for the eligible renewable resources sold. 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.

### 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:

$$\text{Percentage Green Power} = \frac{\text{Purchased Green Power}^4}{\text{Total Electricity}} \times 100$$

How a project's total electricity use is obtained depends on whether energy simulation is performed for EA Credit 1 (Table 5.3).

<sup>4</sup> Green power purchase cannot be credited to any future projects.

**Table 5.3.** Calculation 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 Credit 1 submittal template, Table 1.8.2(b).	Calculate default total electricity consumption by multiplying median electricity intensity (in kWh/sf) obtained from CBECS database with total building floor area.

**Note:** CBECS = Commercial Building Energy Consumption Survey

### 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 project's total annual electricity consumption or total annual electricity consumption claimed does not match that in the EA Credit 1 submittal template.
- 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 or is for only one year.

# APPENDIX A.

## ASHRAE 90.1-2004 ADDENDA

The ASHRAE 90.1-2004, 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, the USGBC CIR dated 4/23/2008 allows the use of ASHRAE 90.1-2007, Appendix G, which includes all ASHRAE 90.1-2004 addenda and other modifications, in place of ASHRAE 90.1-2004, Appendix G, if the energy simulation follows the language of 2007 Appendix G in its entirety.

**Table A.1. ASHRAE 90.1-2004, Appendix G Addenda**

Appendix G section	Topic	Description	Addendum text
G2.2.4	Simulation program	Addendum a adds new section, G2.2.4, to G2.2 regarding requirements on simulation program.	"The simulation program shall be tested according to ANSI/ASHRAE Standard 140 and the results shall be furnished by the software provider."
G3.1.1	Baseline HVAC system type and description	Addendum U adds requirements to G3.1.1 for modeling Baseline HVAC systems.	"For systems 1, 2, 3, and 4, each thermal block shall be modeled with its own HVAC system. For systems 5, 6, 7, and 8, each floor shall be modeled with a separate HVAC system. Floors with identical thermal blocks can be grouped for modeling purposes."
Table G3.1, Section 1	Proposed model	Addendum a clarifies how to document installed system's power demand and operating schedules for Section G3.1.1 when simulation program doesn't specifically model them.	"Where the simulation program does not specifically model the functionality of the installed system, spreadsheets or other documentation of the assumptions shall be used to generate the power demand and operating schedule of the systems."
Table G3.1 Section 4	Schedules	Addendum ag narrows scope of fans to meet requirements for HVAC fan schedules.	"Schedules for HVAC fans that provide outdoor air for ventilation shall run continuously whenever spaces are occupied and shall be cycled on and off to meet heating and cooling loads during unoccupied hours."
Table G3.1 Section 5	Building envelope: exceptions	Addendum a adds detailed requirements on modeling techniques for uninsulated envelope assemblies in Section G3.1.5. Section G3.1.5 requires that all components of building envelope in proposed design shall be modeled as shown on architectural drawings or as-built for existing building envelope. However, uninsulated assemblies are permitted to differ from architectural drawings.	"(a) All uninsulated assemblies (e.g., projecting balconies, perimeter edges of intermediate floor slabs, concrete floor beams over parking garages, roof parapet) shall be separately modeled using either of the following techniques: 1. Separate model of each of these assemblies within the energy simulation model 2. Separate calculation of the U-factor for each of these assemblies. The U-factors of these assemblies are then averaged with larger adjacent surface using an area-weighted average method. This average U-factor is modeled within the energy simulation model."
Table G3.1 Section 5	Building envelope: baseline building performance	Addendum a modifies requirements on distribution of vertical fenestration in Baseline model.	"(c) Vertical Fenestration. Vertical fenestration ... shall be distributed on each face of the building in the same proportion as in the Proposed Design."
Table G3.1 Section 6	Lighting: proposed building performance	Addendum ae requires that loads of lighting systems connected via receptacles be included in simulations.	"For multifamily living units, hotel/motel guest rooms, and other spaces in which lighting systems are connected via receptacles and are not shown or provided for on building plans, assume identical lighting power for the proposed and Baseline building designs in the simulations." (Addendum A deleted the following: "... but exclude these loads when calculating the baseline building performance and proposed building performance.")

**Table A.1. ASHRAE 90.1-2004, Appendix G Addenda (continued)**

Appendix G section	Topic	Description	Addendum text
G3.1 Section 11	Service hot water systems: baseline building performance	Addendum a adds requirement that if new service hot water system has been specified, system be sized according to provisions of Section 7.2.1.	“(b) Where a new service hot water system has been specified, the system shall be sized according to the provisions of Section 7.2.1, and the equipment shall match the minimum efficiency requirements in Section 7.2.2.”
		Addendum a provides additional detailed guidance on modeling Baseline service hot water systems.	“(g) Service hot water energy consumption shall be calculated explicitly based upon the volume of service hot water required, and the entering make-up water and the leaving service hot water temperatures. Entering water temperatures shall be estimated based upon the location. Leaving temperatures shall be based upon the end use requirements.  “(h) Where recirculation pumps are used to insure prompt availability of service hot water at the end use, the energy consumption of such pumps shall be calculated explicitly.”
		Addendum a allows project teams to claim energy savings in service hot water heating based on water conservation measures and other energy efficiency measures.	“(i) Service water loads and usage shall be the same for both the baseline building design and the proposed design and shall be documented by the calculation procedures described in Section 7.2.1, with the following exceptions:  1. Service hot water usage can be demonstrated to be reduced by documented water conservation measures that reduce the physical volume of service water required. Examples include low-flow shower heads. Such reductions shall be demonstrated by calculations.  2. Service hot water energy consumption can be demonstrated to be reduced by reducing the required temperature of service mixed water, by increasing the temperature, or by increasing the temperature of the entering make-up water. Examples include alternative sanitizing technologies for dishwashing and heat recovery to entering make-up water. Such reductions shall be demonstrated by calculations.  3. Service hot water usage can be demonstrated to be reduced by reducing hot fraction of mixed water to achieve required operational temperature. Examples include shower or laundry heat recovery to incoming cold water supply and reducing the hot water fraction required to meet required mixed water temperature. Such reductions shall be demonstrated by calculations.”
Table G3.1 Section 12	Baseline receptacle and other loads	Addendum a adds requirements on modeling receptacle and other loads and provides guidance on how to estimate process energy savings.	“Other systems, such as motors covered by Section 10, and miscellaneous loads shall be modeled as identical to those in the proposed design including schedules of operations and controls of the equipment. Where there are specific efficiency requirements in Section 10, these systems or components shall be modeled as having the lowest efficiency allowed by those requirements. Where no efficiency requirements exist, power and energy rating or capacity of the equipment shall be identical between the baseline building and the proposed design with the following exception:  “Variations of the power requirements, schedules or control sequences of the equipment modeled in the baseline building from those in the proposed design may be allowed by the rating authority based upon documentation that the equipment installed in the proposed design represents a significant verifiable departure from documented conventional practice. The burden of this documentation is to demonstrate that accepted conventional practice would result in baseline building equipment different from those installed in the proposed design. Occupancy and occupancy schedules may not be changed.”
Table G3.1.1A	Baseline HVAC system types	Addendum a changes all cutoffs of conditioned floor area that are used to determine Baseline HVAC system, from 75,000 sf to 25,000 sf.	(The revised Table G3.1.1A is not included.).

**Table A.1.** ASHRAE 90.1-2004, Appendix G Addenda (continued)

Appendix G section	Topic	Description	Addendum text
G3.1.2.2	Equipment capacities	Addendum a adds definition of unmet load hour to Section 3.1.2.2.	"Unmet load hour: an hour in which one or more zones is outside of the thermostat setpoint range."
G3.1.2.9	Supply fan power	Addendum ac changes methodology used to calculate fan power allowance but does not extrapolate to Appendix G of ASHRAE 90.1-2004. These changes are addressed in CIR dated in 8/13/2007.	(The changes are not included because of their length.)
G3.1.3.12	Supply air temperature reset (systems 5 through 8).	Addendum a revises requirements in G3.1.3.12 for supply air temperature reset.	"The air temperature for cooling shall be reset higher by 5°F (2.3°C) under the minimum cooling load conditions."  (Previously, the section stated, "Supply air temperature shall be reset based on zone demand from the design temperature difference to a 10°F (5.6°C) temperature difference under minimum load conditions. Design air flow rates shall be sized for the reset supply air temperature; i.e., a 10°F (5.6°C) temperature difference.")
G3.1.3.13	VAV minimum flow setpoints (systems 5 and 7).	Addendum am adds requirements to G3.1.3.13.	"Minimum volume setpoints for VAV reheat boxes shall be 0.4 cfm/ft <sup>2</sup> of floor area served or the minimum ventilation rate, whichever is larger."
Table G3.1#6 (Baseline)	Portable lighting	Addendum m, Section 9.4.1.4, allows furniture-mounted supplemental task lighting to be excluded from lighting power allowance if separately controlled.	<b>Exceptions to 9.2.2.3:</b>  p. Furniture mounted supplemental task lighting that is controlled by automatic shutoff and complies with 9.4.1.4(d). 9.4.1.4 Additional Control.  d. "Task Lighting – supplemental task lighting, including permanently installed undershelf or undercabinet lighting, shall have a control device integral to the luminaires or be controlled by a wall-mounted control device provided the control device is readily accessible and located so that the occupant can see the controlled lighting."
Table G3.1.2.9	Fan power	Addendum ac	(Please refer to addendum; it allows Baseline fan power to be calculated using different method than G3.1.2.9, which is generally less stringent.)

# 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 1. Several front-end programs have been developed that give DOE-2 a user-friendly input interface and allow formatted output reports. Commonly used DOE-2 based modeling software for the EA Credit 1 performance compliance path using ASHRAE Appendix G includes DOE2.1e (VisualDOE) and eQuest.

eQuest is a free building energy analysis simulation program widely used for LEED projects that follow the energy performance compliance path. 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 can 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.carriercommercial.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 utilization 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 by 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](http://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.

## Energy-10

This program has been developed by the National Renewable Energy Laboratory's (NREL) Center for Building and Thermal Systems. The program can automatically generate base cases and energy-efficient alternative building descriptions and automatically apply energy-efficient features and rank-ordering of results. More information on Energy-10 is available at <http://sbicouncil.org/displaycommon.cfm?anb=1&subarticlebr=112>. Although Energy-10 cannot meet the requirements for qualified simulation program in ASHRAE 90.1–2004 G2.2.1, it is approved by USGBC as qualified simulation software for modeling small commercial and residential buildings that have one or two thermal zones and generally less than 10,000 sf.

## 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. 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 calculations 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 through 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](http://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

## SUBMITTAL TEMPLATE

**Figure C.1.** Section 1.1 of Letter Template: General Information

### Section 1.1 - General Information

Provide the following data for your project

Simulation Program:	EnergyPlus v2.0	Quantity of Stories:	1
Principal Heating Source:	Solar / Site Recovered	Weather File:	Los Angeles, CA TMY2
Energy Code Used:	ASHRAE 90.1-2004 Appendix G	Climate Zone:	3B
New Construction Percent:	100 %	Existing Renovation Percent:	0 %

Enter the Target Finder score for your building from the Energy Star website ([http://www.energystar.gov/index.cfm?fuseaction=target\\_finder.&CFID=154897](http://www.energystar.gov/index.cfm?fuseaction=target_finder.&CFID=154897)). The score has no bearing on the number of EAc1 points earned. Use the following process to evaluate the Target Finder score:

1. Enter the facility information
2. Enter the facility characteristics. Select each primary and secondary space type that applies to the project. Then complete the required information for each space type.
4. Enter the total energy use per energy source for your project based on the totals reflected in the Proposed Design energy simulation output report.

Target Finder Score: 100

**Figure C.2.** Target Finder Primary and Secondary Space Types

[Space Types]

- Primary Space Types ---
  - Office
  - K-12 School
  - Hospital (Acute Care or Children's)
  - Hotel (Economy and Budget)
  - Hotel (Midscale w/o Food and Beverage)
  - Hotel (Midscale w/ Food and Beverage)
  - Hotel (Upscale)
  - Hotel (Upper Upscale)
  - Medical Office
  - Residence Hall/Dormitory
  - Supermarket/Grocery
  - Warehouse (Refrigerated)
  - Warehouse (Unrefrigerated)
  - Courthouse
  - Bank/Financial Institution
  - Retail
- Secondary Space Types ---
  - Other
  - Computer Data Center
  - Parking
  - Swimming Pool

[Space Types]

PRINT

FREQUENTLY ASKED QUESTIONS

Design Energy to the target

Facility Name

State

**Figure C.3.** Section 1.2 of Letter Template: Space Summary

### Section 1.2 - Space Summary

Provide the space summary for your project

(click "CLEAR" to clear the contents of any row All numeric entries must be entered as whole numbers without commas):

<b>Building Use (Occupancy Type)</b>	<b>Conditioned Area (sf)</b>	<b>Unconditioned Area (sf)</b>	<b>Total Area (sf)</b>	
Office	962		962	<input type="button" value="CLEAR"/>
Classroom	1,855		1,855	<input type="button" value="CLEAR"/>
Museum/Display	2,239		2,239	<input type="button" value="CLEAR"/>
Restroom	146	459	605	<input type="button" value="CLEAR"/>
Kitchen	297		297	<input type="button" value="CLEAR"/>
Library	426		426	<input type="button" value="CLEAR"/>
Corridor	310		310	<input type="button" value="CLEAR"/>
Janitor		180	180	<input type="button" value="CLEAR"/>
Retail	410		410	<input type="button" value="CLEAR"/>
IT/Copy Room	196		196	<input type="button" value="CLEAR"/>
Storage	464	279	743	<input type="button" value="CLEAR"/>
<b>Total:</b>	7,305	918	8,223	

**Figure C.4.** Section 1.3 of Letter Template: Advisory Messages

### Section 1.3 - Advisory Messages

Complete the following information from the simulation output files (all entries should be entered as whole numbers, without commas)

	<b>Proposed Building</b>	<b>Baseline Building (0 deg. rotation)</b>	<b>Difference</b>
Number of hours heating loads not met:	1	2	1
Number of hours cooling loads not met:	109	165	56
Number of warning messages:	11,523	11,742	219
Number of error messages:	1	0	1
Number of defaults overridden:	0	0	0

Reporting of unmet load hours without breakdown into heating and cooling hours is allowed.

**Figure C.5.** Section 1.4 of Letter Template: Comparison of Proposed Design versus Baseline Design

**Section 1.4 - Comparison of Proposed Design Versus Baseline Design Energy Model Inputs**

Use **Table 1.4** to document the Baseline and Proposed design energy model inputs for your project. Include descriptions for:

1. Exterior wall, underground wall, roof, floor, and slab assemblies including framing type, assembly R-values, assembly U-factors, and roof reflectivity when modeling cool roofs. (Refer to ASHRAE 90.1 Appendix A)
2. Fenestration types, assembly U-factors (including the impact of the frame on the assembly), SHGCs, and visual light transmittances, overall window-to-gross wall ratio, fixed shading devices, and automated movable shading devices.
3. Interior lighting power densities, exterior lighting power, process lighting power, and lighting controls modeled for credit.
4. Receptacle equipment, elevators or escalators, refrigeration equipment, and other process loads.
5. HVAC system information including types and efficiencies, fan control, fan supply air volume, fan power, economizer control, demand control ventilation, exhaust heat recovery, pump power and controls, and any other pertinent system information. (Include the ASHRAE 90.1-2004 Table G.3.1.1B Baseline System Number).
6. Domestic hot water system type, efficiency and storage tank volume.
7. General schedule information

Documentation should be sufficient to justify the energy and cost savings numbers reported in the Performance Rating Table.

General descriptions for required inputs

**Figure C.6.** Section 1.4 of Letter Template: Comparison of Proposed Design with Baseline Design

Model Input Parameter	Proposed Design Input	Baseline Design Input	
Exterior Wall Construction	R-11 wood frame construction, U-factor = 0.096	R-13 metal-frame construction, U-factor = 0.124	<input type="button" value="CLEAR"/>
Roof Construction	R-19 wood-frame roof: U-factor = 0.051	R-15 built-up Roof: U-factor = 0.063	<input type="button" value="CLEAR"/>
Floor/Slab Construction	Unheated Slab-on-Grade, No Insulation	Unheated Slab-On-Grade, No Insulation	<input type="button" value="CLEAR"/>
Window-to-gross wall ratio	29.6%	29.6% -Same as Proposed	<input type="button" value="CLEAR"/>
Fenestration type	Dual-pane aluminum frame with low-E glass, performance as described below.	N/A	<input type="button" value="CLEAR"/>
Fenestration U-factor	0.59	0.57	<input type="button" value="CLEAR"/>
Fenestration SHGC - Pella Glass, Most Windows	0.39	0.25	<input type="button" value="CLEAR"/>
Fenestration SHGC - PPG Glass - Classroom Glass Doors	0.44	0.25	<input type="button" value="CLEAR"/>
Fenestration Visual Light Transmittance	Pella Glass: 63% PPG Glass: 64%	All Windows modeled same as Proposed Design	<input type="button" value="CLEAR"/>
Shading Devices	Building provides self-shading	None	<input type="button" value="CLEAR"/>
Exhaust Fans	0.2 hp fan in restrooms, janitor's closet, and copy room; operate continuously during occupied hours	Same as ASHRAE Baseline	<input type="button" value="CLEAR"/>
Interior Lighting Power Density (W/sf)	7 Classroom Building: 0.942 Watts/sf installed (0.931 Watts/sf after occupant sensor control credits)	7 Classroom Building: 1.2 Watts/sf (Complete Building Method, School) 2 Admin Building: 1.1 Watts/sf (Complete	<input type="button" value="CLEAR"/>

**Figure C.6.** Section 1.4 of Letter Template: Comparison of Proposed Design with Baseline Design (Continued)

<b>Model Input Parameter</b>	<b>Proposed Design Input</b>	<b>Baseline Design Input</b>	
Daylighting Controls	No daylighting controls Daylighting Controls included in EnergyPlus Model for Most Spaces	No daylighting controls	<input type="button" value="CLEAR"/>
Other Lighting Control Credits	None	None	<input type="button" value="CLEAR"/>
Exterior Lighting Power (kW)	1,004 Watts scheduled with astronomical timeclock	4,881 Watts (all tradable surfaces) scheduled with astronomical timeclock	<input type="button" value="CLEAR"/>
Process Lighting (kW)	0 kW	0 kW	<input type="button" value="CLEAR"/>
Receptacle Equipment Power Density (W/sf)	0.5 W/sf - Unconditioned Spaces 1.0 W/sf - Classroom Building 1.5 W/sf - Administration Building	0.5 W/sf - Unconditioned Spaces 1.0 W/sf - Classroom Building 1.5 W/sf - Administration Building	<input type="button" value="CLEAR"/>
			<input type="button" value="CLEAR"/>
Primary HVAC System Type	The building is naturally ventilated, with no heating, cooling, or supply fans installed in the project. Per I FFD and ASHRAE modeling	Table G3.1.18 System # 4 - Packaged single zone heat pump; one heat pump modeled per building zone	<input type="button" value="CLEAR"/>
Other HVAC System Type	None	None	<input type="button" value="CLEAR"/>
Fan Supply Volume	0 in actual design (modeled with 20 degree delta-T between room air and supply air temperature. Total supply flow modeled = 4,177 cfm	0 degree delta-T between room air and supply air temperature. Total supply flow modeled = 4,746 cfm	<input type="button" value="CLEAR"/>
Fan Power	Same as ASHRAE Standard	0.000734 kW/cfm	<input type="button" value="CLEAR"/>
Economizer Control	None	None	<input type="button" value="CLEAR"/>
Fan Control	Cycled on or off to meet Heating or Cooling Loads per Table G3.1.14 Exception	Continuous	<input type="button" value="CLEAR"/>
Unitary Equipment Cooling Efficiency	12 SEER (default value)	12 SEER	<input type="button" value="CLEAR"/>
Unitary Equipment Heating Efficiency	7.4 HSPF (default value)	7.4 HSPF	<input type="button" value="CLEAR"/>
Domestic Water Heater	Two instantaneous electric heaters in Admin Building (3,500 and 6,000 W). One 66-gal storage electric water heater with 0.98 Energy Factor in	Two instantaneous electric heaters in Admin Building (3,500 and 6,000 W). One 66-gal storage electric water heater with 0.98 Energy Factor in	<input type="button" value="CLEAR"/>
Photovoltaics	Solar panels installed on Classroom Building roof with a South-facing tilt of 16 deg. One 41.58 and one 1.96 kW system are installed with a total	None	<input type="button" value="CLEAR"/>
DHW Flow	2,381 gallons/year (out of 3,516 gal/year total fixture flow). 328 gal/year annual flow to EW1, 613 gal/year annual flow to FW2, 1,441 gal/year	6,306 gallons/year (out of 10,578 gal/year total fixture flow). 1,641 gal/year annual flow to EW1, 963 gal/year annual flow to FW2, 3,703 gal/year	<input type="button" value="CLEAR"/>
			<input type="button" value="CLEAR"/>
			<input type="button" value="CLEAR"/>
			<input type="button" value="CLEAR"/>
			<input type="button" value="CLEAR"/>

**Figure C.7.** Section 1.5 of Letter Template: Energy Type Summary

### Section 1.5 - Energy Type Summary

List the energy types used by your project (i.e. electricity, natural gas, purchased chilled water or steam, etc.) for either the Baseline or Proposed design. Also describe the utility rate used for each energy type (i.e. Feswick County Electric LG-S), as well as the units of energy used, and the units of demand used. (Click "CLEAR" to clear the contents of any row):

TABLE 1.5 - Energy Type Summary				
Energy Type	Utility Rate Description	Units of Energy	Units of demand	
Electricity	SCE GS-2	kWh	kW	<input type="button" value="CLEAR"/>
				<input type="button" value="CLEAR"/>
				<input type="button" value="CLEAR"/>
				<input type="button" value="CLEAR"/>

#### Energy Units:

1 kBtu = 1,000 Btu  
1 kWh = 3,412 kBtu  
1 therm = 100 kBtu

1 MBtu = 1,000 kBtu  
1 MWh = 3,412 kBtu  
1 ton hr = 12 kBtu

#### Demand Units

1 MBH = 1,000 Btu/h  
1 kW = 3,412 MBH  
1 MMBtuh = 1,000 MBH  
1 ton = 12 MBH

**Figure C.8.** Section 1.6 of Letter Template: On-Site Renewable Energy

**Three methods to calculate on-site renewable energy cost**

**Section 1.6 - On-Site Renewable Energy**  
If the project does not include on-site renewable energy, skip to Section 1.7

☒ The project includes On-Site Renewable Energy

How is the on-site renewable energy cost calculated?

☒ This form will automatically calculate the *Renewable Energy Cost* based on the "virtual" energy rate from the proposed design energy model results. This form will subtract the *Renewable Energy Cost* from the proposed design energy model results to calculate the *Proposed Building Performance Rating*. (You do NOT need to fill out the "Renewable Energy Cost" field in Table 1.6 below)

*Renewable Energy Cost* for each on-site renewable source is analyzed separately from the energy model based on local utility rate structures. The *Renewable Energy Cost* for each renewable source is reported in Table 1.6 below, This form will subtract the reported *Renewable Energy Cost* from the proposed design energy model results to calculate the *Proposed Building Performance Rating*.

☐ On-site renewable energy is modeled directly in the energy model. *Renewable Energy Cost* is already credited in the proposed design energy model results (i.e. the energy model already reflects zero cost for on-site renewable energy, and this form will NOT subtract the *Renewable Energy Cost* a second time).

Indicate the on-site renewable energy source(s) used, the backup energy type for each source (i.e. the fuel that is used when the renewable energy source is unavailable - ASHRAE 90.1-2004, Section G2.4), the rated capacity for the source, and the annual energy generated from each source.

TABLE 1.6 - Renewable Energy Source Summary					
Renewable Source	Backup Energy Type	Annual Energy Generated		Rated Capacity	Renewable Energy Cost
Photovoltaic Panels	Electricity	64,095	(kWh)	45.54	

**Figure C.9.** Section 1.7 of Letter Template: Exceptional Calculation Measure Summary

Two methods to determine cost savings  
using exceptional calculations

**Section 1.7 - Exceptional Calculation Measure Summary**  
(If the energy analysis does not include exceptional calculation methods, skip to Section 1.8)

☐ The energy analysis includes exceptional calculation method(s) (ASHRAE 90.1-2004, G2.5)

How is the exceptional calculation measure cost savings determined?

☒ This form will automatically calculate the exceptional calculation measure cost savings based on the "virtual" energy rate from the proposed design energy model results. This form will subtract this cost savings from the proposed design energy model results to calculate the *Proposed Building Performance Rating*.

☐ Exceptional calculation measure cost for each exceptional calculation measure is analyzed based on local utility rate structures. The cost savings for each exceptional calculation is reported below. This form will subtract the reported exceptional calculation cost savings from the proposed design energy model results to calculate the *Proposed Building Performance Rating*.

For each exceptional calculation method employed, document the predicted energy savings by energy type, the energy cost savings (if option 2 above is selected), and a narrative explaining the exceptional calculation method performed, and theoretical or empirical information supporting the accuracy of the method. Reference any applicable Credit Interpretation Rulings. [Note: if an end-use has an energy loss rather than an energy savings, enter it as a negative number]

Exceptional Calculation Measure Short Description:			Section G2.5 & Reference Guide p. 176	<input type="button" value="CLEAR"/>
Energy Type(s)	Annual Energy Savings by Energy Type	Annual Cost Savings	Exceptional Calculation Measure Narrative:	
-		\$1,000		
-				
-				
-				

**Figure C.10.** Section 1.8 of Letter Template: Table 1.8.1, Baseline Performance

**Section 1.8 - Performance Rating Method Compliance Report (Option 1 Compliance Only)**

In **Table 1.8.1**, list each energy end use for your 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. In **Table 1.8.1(b)** indicate the total baseline energy cost for each energy type for all four Baseline Design orientations. If either the baseline or proposed design uses more than one energy type for a single end use (i.e. electric resistance reheat, and central natural gas heating), enter each energy type as a separate end use (i.e. *Heating - Electric*, and *Heating - NG*).

Fill out the Proposed Design energy consumption and peak demand for each end use in **Table 1.8.2**. In **Table 1.8.2 (b)** indicate the total proposed energy cost for each energy type. [Note: Process loads for the proposed design must equal those listed in the Baseline design. Any process load energy savings for the project must be reported in Section 1.7.]

(Click "CLEAR" to clear the contents of any end use)



Instructions on how to document Section 1.8

**Table 1.8.1 - Baseline Performance - Performance Rating Method Compliance**  
See Document Description Log for standard report names

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 Design
Interior Lighting	<input type="checkbox"/>	Electricity	Energy Use (kWh) Demand (kW)					<input type="button" value="CLEAR"/>

**Table 1.8.1(b) - Baseline Energy Costs**

Energy Type	Baseline Cost (0° rotation)	Baseline Cost (90° rotation)	Baseline Cost (180° rotation)	Baseline Cost (270° rotation)	Baseline Building Performance
Electricity					
Natural Gas					
Total Baseline Costs:					

**Figure C.11.** Section 1.8 of Letter Template: Table 1.8.2, Performance Rating Table and Energy Cost Consumption by Energy Type Table

Automatically populated

End Use	Process?	Proposed Design Energy Type	Proposed Design Units	Proposed Building Results	Baseline Building Units	Baseline Building Results	Percent Savings
Interior Lighting		Electricity	Energy Use (kWh)		Energy Use (kWh)		0 %
			Demand (kW)		Demand (kW)		0 %

Peak demand for each end-use must be reported.

Energy Type	Proposed Design		Baseline Design		Percent Savings	
	Energy Use	Cost	Energy Use	Cost	Energy Use	Cost
Electricity	0 kWh		0 kWh		0 %	0 %
Natural Gas	0 therms		0 therms		0 %	0 %
	0		0		0 %	0 %
	0		0		0 %	0 %
Subtotal (Model Outputs):	0 (kBtu/year)		0 (kBtu/year)		0 %	0 %
On-Site Renewable Energy	Energy Generated	Renewable Energy Cost				
Automatically populated from Table 1.6						
Exceptional Calculations	Energy Savings	Cost Savings				
Automatically populated from Section 1.7						
	Proposed Design		Baseline Design		Percent Savings	
	Energy Use	Cost	Energy Use	Cost	Energy	Cost
Total:	0 (kBtu/year)	0	0 (kBtu/year)		0 %	0 %

**Figure C.12.** Documentation Description Log of Letter Template

In the text box below, please reference the file name of each uploaded file (e.g. simulationsummary.pdf)

DOE2/cQUEST/VisualDOE - BEPS, BEPU, ES-D reports  
 EnergyPlus - Annual Building Utility Performance Summary (ABUPS) - show energy consumption by end-use; System Summary - shows hours of unmet load; (Unknown) - shows annual energy cost by fuel source  
 EnergyPro: Title 24 reports - PERF-1, ECON-1, & UTIL-1 reports; also a DOE2 based program so .sim file contains BEPS, BEPU, & ES-D reports  
 HAP: Annual Cost Summary; Unmet Load reports for all plants and systems; Systems Energy Budget by Energy Source  
 Trace: Energy Cost Budget/PRM Summary, Energy Consumption Summary Reports, Performance Rating Method Details  
 Utility rate schedules

Required supplemental documentation (important simulation output report and utility rate schedules)

# 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 in some cases. 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 Exceptional Calculation Methodology. According to 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 opening the windows has 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 62.1–2004, 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. In all cases, the buildings are designed to facilitate cross-ventilation, with windows low on the walls for drawing air in, and windows and vents high in 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 55–2004, 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.

**Table D.1.** Energy Model Descriptio

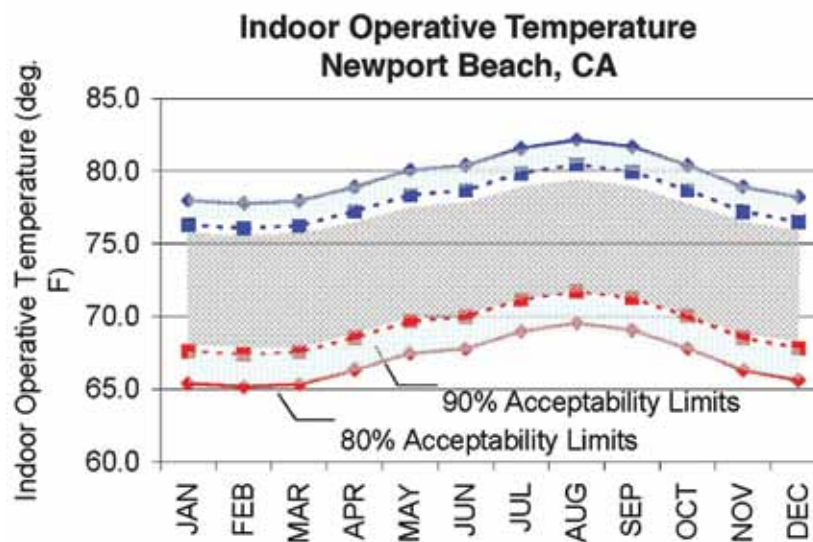
Model		Description	EAc1 LOL Template inputs
Baseline	B	Follows Appendix G	Baseline for Table 1.8.2
Proposed Case without NV	P1	Proposed case model with systems identical to Baseline model; natural ventilation not modeled	Proposed case for Table 1.8.2. and baseline for ECM Section 1.7
Proposed Case: comfort analysis model	P2	Proposed case model with operable windows and vents; NV ON year-round during occupied periods	Analysis model; NV schedule developed based on hourly results of this model (results not listed in EAc1 template)
Proposed Case with NV	P3	Proposed Case for ECM	Proposed Case for ECM Section 1.7

**Note:** ECM = Exceptional Calculation Methodology  
NV = natural ventilation

The Baseline case (B) was modeled using all input parameters required by ASHRAE 90.1–2004, Appendix G, Table G3.1.1B System 4: Packaged single-zone heat pump; one heat pump modeled per building space.

The Proposed Case without NV (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 in the proposed case were modeled as cycling on and off to meet heating and cooling loads during all hours in the proposed case, and were modeled as operating continuously during occupied hours in the Baseline Base (per the exception shown in ASHRAE 90.1–2004, 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 55–2004 for buildings in this location having natural ventilation (meaning the setpoints for both the Baseline and the Proposed models were changed each month to reflect ASHRAE–55 acceptability limits for that month). Figure D.1 shows these temperature setpoints graphically.

**Figure D.1.** Temperature Setpoints Based on ASHRAE–55 80% Acceptability Limits



Fan efficiency is identical for the baseline and proposed cases and complies 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 the CIR:

- 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:
  - 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.

- 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.
- If natural ventilation alone does not reduce the unmet load hours below the levels allowed by ASHRAE 90.1–2004 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):

Table D.2. Summary of HVAC Modeling Parameters				
	B	P1	P2	P3
Heating	ASHRAE Table G3.1.1B	Identical to B; no natural ventilation	Only NV; no mechanical system	Hybrid system; schedule adjusted to include NV
Cooling	ASHRAE Table G3.1.1B	Identical to B; no natural ventilation	Only NV; no mechanical system	Hybrid system; schedule adjusted to include NV
Fans: power	ASHRAE	Fan power per unit flow (kWh / cfm) identical to B; total fan power will vary	No fans modeled	Fan power per unit flow (kWh / cfm) identical to B; total fan power will vary
Fans: schedule	On during occupied hours	As per Exception G3.1.4, cyclic on and off to meet heating and cooling loads	NA	As per Exception G3.1.4, cyclic on and off to meet heating and cooling loads
Infiltration	ASHRAE	Identical to baseline	Natural ventilation	Developed based on P2 simulation hourly results
Windows	Appendix G, non-operable	Non-operable	Operable during occupied hours, closed at nights and unoccupied hours	Operable; openable during occupied hours, closed at nights and unoccupied hours

**Table D.3. Energy Savings by End Use (kWh/yr)**

Model	B	P1	P3	Notes
	Baseline for Table 1.8.2	Proposed for Table 1.8.2	ECM Model	Since there is no HVAC system in the proposed case, P1 fan flow must be calculated in the same way as the baseline, using a 20° temperature differential between the supply air and room air temperature. Since the baseline and P1 have substantially different heating and cooling loads because of the efficient envelope and lighting design, the fan flows will also vary to meet varying loads. Hence fan flows are significantly reduced in P1 compared with the baseline. Heating, cooling, and fan savings through model P1 should be claimed in Table 1.8.2, and savings due to natural ventilation through model P3 should be claimed in Section 1.7.
Heating	49,653	29,750	12,486	
Cooling	22,014.50	12,419	5,069	
Interior lighting	30,475	18,153	18,153	
Exterior lighting	21,289	4,378	4,378	
Interior equipment	29,347	29,347	29,347	
Exterior equipment	0	0	0	
Fans	11,797.80	4,003	1,611	
Pumps	0	0	0	
Heat rejection	0	0	0	
Humidification	0	0	0	
Heat recovery	0	0	0	
Water systems	1,864	1,294	1,294	
Refrigeration	0	0	0	
Generators	0	0	0	
Total End Uses	166,440	99,344	72,338	
Energy cost	\$24,944	\$16,150	\$12,984	
B, P1		\$8,794		Savings in Table 1.8.2
P1, P2			\$3,166	ECM savings in Section 1.7

## Unmet Load Hours

EnergyPlus reports 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 is 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 any zone in any system was not met. The results from this analysis are shown in Table D.4.

**Table D.4. Unmet Load Hours**

	Cooling	Heating	Total
B	164.5	2	<b>166.5</b>
P1	109	0.5	<b>109.5</b>
P2	75	5	<b>80</b>

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 garage exhaust system for the proposed building is controlled by carbon monoxide sensors located throughout the parking 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.

**Figure D.2.** Baseline Garage Exhaust Fan Day Schedule (Monday-Sunday)

Annual Schedules | Week Schedules | Day Schedules

Currently Active Day Schedule: **Garage Exhaust Fan** Type: Fraction

Day Schedule Name: **Garage Exhaust Fan** Type: **Fraction**

Hourly Values

Mdnt - 1:	0.0000 ratio	8-9 am:	1.0000 ratio	4-5 pm:	1.0000 ratio
1-2 am:	0.0000 ratio	9-10 am:	1.0000 ratio	5-6 pm:	1.0000 ratio
2-3 am:	0.0000 ratio	10-11 am:	1.0000 ratio	6-7 pm:	1.0000 ratio
3-4 am:	0.0000 ratio	11-noon:	1.0000 ratio	7-8 pm:	1.0000 ratio
4-5 am:	0.0000 ratio	noon-1:	1.0000 ratio	8-9 pm:	1.0000 ratio
5-6 am:	1.0000 ratio	1-2 pm:	1.0000 ratio	9-10 pm:	1.0000 ratio
6-7 am:	1.0000 ratio	2-3 pm:	1.0000 ratio	10-11 pm:	1.0000 ratio
7-8 am:	1.0000 ratio	3-4 pm:	1.0000 ratio	11-Mdnt:	1.0000 ratio

## 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.

**Figure D.3.** Proposed Garage Exhaust Fan Day Schedule (Monday-Sunday)

Annual Schedules | Week Schedules | Day Schedules

Currently Active Day Schedule: **Garage Exhaust Fan WD** Type: Fraction

Day Schedule Name: **Garage Exhaust Fan WD** Type: **Fraction**

Hourly Values

Mdnt - 1:	0.0000 ratio	8-9 am:	0.5000 ratio	4-5 pm:	0.5000 ratio
1-2 am:	0.0000 ratio	9-10 am:	0.2000 ratio	5-6 pm:	0.9000 ratio
2-3 am:	0.0000 ratio	10-11 am:	0.2000 ratio	6-7 pm:	0.5000 ratio
3-4 am:	0.0000 ratio	11-noon:	0.2000 ratio	7-8 pm:	0.3000 ratio
4-5 am:	0.0000 ratio	noon-1:	0.5000 ratio	8-9 pm:	0.1000 ratio
5-6 am:	0.3000 ratio	1-2 pm:	0.3000 ratio	9-10 pm:	0.1000 ratio
6-7 am:	0.5000 ratio	2-3 pm:	0.2000 ratio	10-11 pm:	0.1000 ratio
7-8 am:	0.9000 ratio	3-4 pm:	0.2000 ratio	11-Mdnt:	0.1000 ratio

## ECM Savings

Savings are calculated 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 heating water and domestic hot water heat exchangers. Incoming domestic water will run through the cooler and be preheated before entering the hotel DHW 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:

$$1) \quad q = UA\Delta T_{lm}$$

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

Where

$$2) \quad q = 500 \times GPM \times (T_{hot,in} - T_{hot,out})$$

$$3) \quad q = 500 \times GPM \times (T_{cold,out} - T_{cold,in})$$

### ECM Savings

The savings were calculated as BTU 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 was 556 Mlbs of steam, which amounts to an annual dollar savings of \$10,776.

## D.4. Domestic Hot Water Reduction Energy Savings

The energy efficiency measure involves the selection of fixtures with flow restriction to achieve lower flows for hot water usage. The baseline for comparison is the federal maximum flows in the EPACT standard. LEED uses this standard for establishing water savings for the water reduction credit. CIRs indicate that the Exceptional Calculation Method may be used to earn credit for these savings. Table D.5 lists the fixtures for the baseline and design cases.

**Table D.5.** Worksheet for Baseline and Proposed Low-Flow Fixtures

					Baseline case		Design case	
Room	Fixture type	Daily uses	Duration (sec)	FTE	Flow rate (gpm)	Electric heated water usage gal / day	Flow rate (gpm)	Electric heated water usage gal / day
CUP	Conventional lavatory	3	15	1	2.5	28	0.5	6
CUP	Breakroom sink	1	15	1	2.5	9	0.5	2
CUP	Janitor sink	3	15	1	2.5	28	2.5	28
								0
B100	Conventional lavatory	3	15	60	2.5	1688	0.5	338
B100	Breakroom sink	1	15	60	2.5	563	0.5	113
B100	Janitor sink	3	15	1	2.5	28	2.5	28
								0
B200	Conventional lavatory	3	15	40	2.5	1125	0.5	225
B200	Breakroom sink	1	15	40	2.5	375	0.5	75
B200	Janitor sink	3	15	1	2.5	28	2.5	28
								0
B300	Conventional lavatory	3	15	60	2.5	1688	0.5	338
B300	Breakroom sink	1	15	60	2.5	563	0.5	113
B300	Janitor sink	3	15	1	2.5	28	2.5	28
								0
B400	Conventional lavatory	3	15	52	2.5	1463	0.5	293
B400	Breakroom sink	1	15	52	2.5	488	0.5	98
B400	Conventional shower	1	300	20	2.5	3750	1.5	2250
B400	Janitor sink	3	15	1	2.5	28	2.5	28
								0
B500	Conventional lavatory	2	15	45	2.5	844	0.5	169
B500	Breakroom sink	1	15	45	2.5	422	0.5	84
B500	Conventional lavatory	2	15	25	2.5	469	0.5	94
B500	Conventional shower	1	300	25	2.5	4688	1.5	2813
B500	Janitor sink	3	15	1	2.5	28	2.5	28
<b>Total hot water</b>		<b>(gallons/day)</b>				<b>18,328</b>		<b>7,176</b>
<b>Annual hot water usage</b>				<b>gal</b>		<b>4,582,031</b>		<b>1,793,906</b>
<b>Electricity use ( 0.145 kWh/gallons)</b>				<b>kWh</b>		<b>664,394.53</b>		<b>260,116.41</b>
<b>Electricity cost ( \$0.06/kWh)</b>				<b>\$</b>		<b>39,863.67</b>		<b>15,606.98</b>
<b>Electricity cost savings (Baseline - Design case)</b>				<b>\$</b>				<b>24,256.69</b>

## D.5. 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. Based on these findings and the proposed building implementing the WattStopper Card Key system ([seen here](#)), a 45% reduction in the lighting power of the hotel rooms has been applied. In a LEED NCv2.1 CIR dated 5/14/2007 this approach was deemed acceptable. The WattStopper is a very 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.





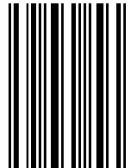


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