



**ADVANCED ENERGY MODELING FOR LEED
ONLINE TRAINING COURSE**

KRISHNAJI PAWAR, LEED AP BD+C, GSAS CGP, ISO 14001:2015, GCP
ENERGY SPECIALIST CURRICULUM





**ENERGY PERFORMANCE COMPLIANCE
HVAC SYSTEM
FOR ENERGY PROFESSIONALS**

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WHAT SHOULD YOU LEARN



Energy Performance
Compliance Path:
documentation Checklist



ENERGY PERFORMANCE COMPLIANCE PATH: DOCUMENTATION CHECKLIST

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

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 90.1-2016+ can use the table as a guide to perform quality assurance for completeness and accuracy. The inputs are found in the LEED Online credit form and energy modeling summary reports.

The most common errors are for projects using ASHRAE 90.1-2016+, Appendix G. For projects using California Title 24, the baseline input is automatically generated by the simulation software and is therefore not separately included in this section.



OUTPUT QUALITY CONTROL CHECKLIST

The next step is to determine whether the outputs comply with the referenced standard's requirements and LEED requirements, such as unmet load hours, process energy use, and exceptional calculations. Table 3.2 presents a checklist to help teams and reviewers confirm that the requirements have been met and the output values reported in the LEED credit form are consistent with the simulation output reports. The checklist applies to projects using ASHRAE 90.1-2016+ and California Title 24-2019, Part 6.

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 90.1-2016+ and California Title 24.



Table 3.1. Input Quality Control Checklist

TOPIC	CHECK	ERRORS	RESOURCES
Primary system type	<div><div>☐ Verify that HVAC system type selected for baseline is correct.</div><div>☐ Verify that both heating and cooling systems have been modeled for proposed design. For heated-only storage spaces, verify that baseline system type has been modeled using system types 10 or 11 from ASHRAE 90.1-2016+ Addendum dn, or types 9 or 10 from ASHRAE 90.1-2010, where all relevant requirements of system type have been applied (this optional compliance path allows proposed case system to be modeled as designed rather than with both heating and cooling).</div></div>	<div><div>☐ Baseline building is modeled with wrong HVAC system (e.g., Title 24 project baseline system is not consistent with system missing from 10, 10, 10).</div><div>☐ Baseline HVAC systems use both fossil fuel and electricity when exception is to G3.1.1 is not applicable.</div><div>☐ Baseline HVAC system is modeled using "Electric and Other" heating source classification when fossil fuel is used in conjunction with electricity to heat spaces in proposed case (the heating type should be hybrid).</div><div>☐ Baseline HVAC system type includes makeup air units or outside air handler when baseline system should be modeled with outside air required directly to air handlers. (Exceptions are allowed for residential buildings in hot, humid climates where dedicated outside air system is necessary to maintain humidity requirements in baseline case mode. The total fan power for baseline case for fan coils plus dedicated outside air system should still be same as if project were modeled with outside air required directly to air handlers.)</div><div>☐ Heating source of proposed case with fossil fuel (preheat is not treated as hybrid if heating source of rest of building is electricity).</div><div>☐ Baseline HVAC system for retrofitted building is modeled as existing condition rather than HVAC system required by tables G3.1.1A, and G3.1.1B.</div><div>☐ No heating or cooling system is modeled in proposed case for conditioned spaces.</div></div>	<div><div>☐ ASHRAE 90.1-2016+, Table G3.1.10, and Table G3.1.1(b)</div></div>



Table 3.1. Input Quality Control Checklist			
HVAC System +			
TOPIC	CHECK	ERRORS	RESOURCES
Additional system type	Verify that baseline additional system type meets requirements in exceptions to G3.1.1.	Baseline incorrectly includes additional types of systems.	ASHRAE 90.1-2016+, Exceptions to G3.1.1
Thermal blocks	Verify that thermal blocks are appropriately modeled.	Proposed case spaces served by single-zone systems are modeled with multiple thermal blocks. Proposed case HVAC zones are not defined consistently with HVAC design drawings.	ASHRAE 90.1-2016+, Table G3.1.7 and 8
Equipment capacity	Verify that proposed case equipment capacities are modeled as designed and baseline case equipment capacities are modeled per G3.1.2.2.	Proposed case equipment capacities are not modeled as designed, or are increased to meet requirement for unmet load hours in G3.1.2.2 without a quality check for causes of high unmet load hours. The baseline equipment capacities are not based on long-term and are oversized by 20% for heating and 15% for cooling. Baseline capacities are oversized at both system and plant levels. Auto-sizes is performed for baseline case in energy model, but cooling degree day and heating degree day schedules are not defined correctly, leading to significant additional oversizing. Energy simulation reports show no equipment operating hours above 80% part-load range for cooling or above 70% part-load range for heating.	ASHRAE 90.1-2016+, G3.1.2.2

Table 3.1. Input Quality Control Checklist			
HVAC System +			
TOPIC	CHECK	ERRORS	RESOURCES
Fan volume	Verify that baseline fan volume has been sized correctly.	Proposed and baseline buildings show equal fan supply volumes instead of following ASHRAE airflow rate zoning guidelines. Baseline case is sized using supply air-to-room-air temperature difference from proposed case, and not using supply air-to-room-air temperature difference of 20°F as required. Fan volume in proposed design is auto-sized, not using design conditions.	ASHRAE 90.1-2016+, G3.1.2.8
Fan power	Verify that baseline fan power has been calculated correctly.	Baseline fan power does not conform to G3.1.2.9. Insufficient information is provided regarding fan pressure requirements to confirm whether fan power has been calculated correctly. Proposed and baseline buildings show equal fan power instead of following ASHRAE fan power calculations. Additional fan power allowance is claimed in baseline for return, exhaust, or relief fans. Baseline fan power is calculated incorrectly in simulation software with automated baseline.	ASHRAE 90.1-2016+, G3.1.2.9.

Table 3.1. Input Quality Control Checklist			
HVAC System +			
TOPIC	CHECK	ERRORS	RESOURCES
Exhaust air energy recovery	Verify that exhaust energy recovery has been modeled in baseline building where required, and that it is modeled appropriately in proposed case when included in proposed design.	Baseline building omits exhaust air energy recovery when required. Heat recovery system omits bypass of outside economizer - Baseline case energy recovery efficiency is not modeled in accordance with G3.1.2.10. Proposed case energy recovery efficiency is not modeled as designed. Proposed case energy recovery bypass is not modeled as designed. Baseline and proposed case ventilation rates are not modeled with zero flow during unoccupied periods, or modeled identically between two cases where health or safety regulations mandate an alternative minimum flow during unoccupied periods.	ASHRAE 90.1-2016+, G3.1.2.10
Economizer control	Verify that economizers are properly included or excluded in baseline building.	Economizer type and/or control is incorrectly modeled in baseline building. Economizer high limit shutdown is not in accordance with Table G3.1.2.6B.	ASHRAE 90.1-2016+, G3.1.2.6, G3.1.2.7

Table 3.1. Input Quality Control Checklist			
HVAC System +			
TOPIC	CHECK	ERRORS	RESOURCES
Ventilation	☑ Verify that ventilation is appropriately modeled in baseline and proposed cases.	<ul style="list-style-type: none">Outdoor air is not modeled with identical flow in baseline and proposed case models (except for demand control ventilators).Outdoor air is modeled with same design ventilation percentage instead of same ventilation within baseline and proposed cases.Outdoor air systems in both cases are not modeled with same outside airflow when fans are cycled on to meet unoccupied setback temperatures, except where health or safety regulations mandate an alternative minimum flow during unoccupied periods.When infiltration rates are modeled differently between baseline and proposed cases, differences are not justified using extended calculation method and/or there is no provision for compensating building to confirm infiltration rates are consistent with design intent and energy model results.	☑ ASHRAE 90.1–2016+, G3.1.2.4
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">Baseline case is not modeled using minimum outdoor air rates required by ASHRAE 90.1–2016+ whenever credit is taken for demand control ventilation in proposed case.Demand control ventilation is not included in baseline building when its use is required for high-occupancy areas by ASHRAE 90.1–2016+, Section 6.4.3.9 Ventilation Controls for High-Occupancy Areas.	☑ ASHRAE 90.1–2016+, G3.1.2.5

Table 3.1. Input Quality Control Checklist			
HVAC System +			
TOPIC	CHECK	ERRORS	RESOURCES
	☑ (LEED-CS projects only):	<ul style="list-style-type: none">Credit for demand control ventilation has been taken in tenant spaces where CO2 sensors are not installed, but tenant guidelines do not require warrants to install CO2 sensors that interface with building air handlers.	☑ ASHRAE 90.1–2016+, G3.1.2.4
	☑ Verify that demand control ventilation is correctly modeled in proposed design case.	<ul style="list-style-type: none">Insufficient information is provided regarding demand control ventilation in proposed design case.Proposed case minimum outdoor airflow rates at design conditions are not modeled as designed.	NA
Unitary equipment cooling and heating efficiency	☑ Verify that equipment efficiencies of proposed design and baseline building meet referenced standard's requirements.	<ul style="list-style-type: none">Proposed building HVAC equipment does not meet mandatory minimum efficiencies listed in Tables 6.8.1A–6.8.1G.Baseline building HVAC equipment is modeled as other than minimum efficiencies listed in Tables 6.8.1A–6.8.1G.Baseline system capacities are omitted in EQu2 Section 5.4 table to verify efficiencies listed.Cooling efficiencies do not break out cooling efficiency (compressor, fan motor, or BEHR) modeled for cooling efficiency component only.Cooling efficiencies incorrectly break out cooling efficiency separately from fan power using design fan power rather than fan power at AHRF rating conditions.Proposed case part-load performance curves do not appropriately reflect operating parameters of installed ground-source heat pumps or water-source heat pumps.	ASHRAE 90.1–2016+, Table G3.1.10, G3.1.2.1

Table 3.1. Input Quality Control Checklist			
HVAC System +			
TOPIC	CHECK	ERRORS	RESOURCES
System-specific information	☑ Verify that system-specific HVAC system requirements are met for baseline.	<ul style="list-style-type: none">Baseline heat pumps allow electric backup heat to operate above 45°F.Baseline heat pumps are turned off when outdoor air temperature is 45°F or lower rather than operating with supplemental electric resistance heat below 45°F and operating as low as 17°F (low temperature rating condition using heat pump ARI 340/360 test procedures).Baseline fan systems (5–6) omit supply temperature reset.Fan-powered VAV boxes are modeled for systems 5 and 7.Multiple zones are modeled under single-zone system type, and reheat is modeled (systems 1, 2, 3, and 6).Baseline case uses 30% minimum flow ratio rather than required 0.4 cfm/sqft.	☑ ASHRAE 90.1–2016+, G3.1.3.1, G3.1.3.12, G3.1.3.13, G3.1.3.14
Chiller 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">Baseline chilled water loops are modeled with incorrect pumping energy and/or incorrect configuration (e.g., modeled as primary-only loops).Baseline chilled water loops are modeled with incorrect temperature settings.Baseline chilled water loops omit supply temperature reset.Number of primary chilled water pumps modeled is inconsistent with number of chillers.	ASHRAE 90.1–2016+, G3.1.3.8, G3.1.3.9, G3.1.3.10

Table 3.1. Input Quality Control Checklist			
HVAC System +			
TOPIC	CHECK	ERRORS	RESOURCES
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"> Baseline chilled water loops are modeled with incorrect pumping energy and/or incorrect configuration (e.g., modeled as primary-only loops). Baseline chilled water loops are modeled with incorrect temperature settings. Baseline chilled water loops omit supply temperature reset. Number of primary chilled water pumps modeled is inconsistent with number of chillers. 	ASHRAE 90.1-2016+, G3.1.3.3, G3.1.3.5, 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"> Baseline condenser water loops are modeled with incorrect pumping energy. Baseline condenser water loops are modeled with incorrect temperature settings. Baseline condenser water loops omit wet bulb reset controls. Number of condenser water pumps modeled is inconsistent with number of chillers. Baseline cooling tower fans are not modeled as 2-speed. Baseline cooling tower fans are not modeled as axial fans with 38.2 gpm/hp. 	ASHRAE 90.1-2016+, G3.1.3.11

Table 3.1. Input Quality Control Checklist			
HVAC System +			
TOPIC	CHECK	ERRORS	RESOURCES
Boiler parameters	Verify that number, type, and capacity of boilers for baseline meet referenced standard's requirements.	<ul style="list-style-type: none"> Baseline building includes incorrect number of boilers. Baseline boiler capacities are equal to proposed design boiler capacities instead of following ASHRAE system sizing guidelines. 	ASHRAE 90.1-2016+, 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"> Baseline hot water loops are modeled with incorrect pumping energy and/or incorrect loop configuration (e.g., modeled as primary-secondary loops). Baseline hot water loops are modeled with incorrect temperature settings. Baseline hot water loops omit supply temperature reset. 	ASHRAE 90.1-2016+, G3.1.3.3, G3.1.3.4, G3.1.3.5
District thermal energy	Verify that projects using district or campus thermal energy have been correctly modeled.	<ul style="list-style-type: none"> For project using DES Guidance v2, average efficiency of proposed case virtual central plant is not modeled following requirements. Project takes credit for efficiency of district energy systems serving project, but does not follow DES Guidance v2 in its energy. Project not using DES Guidance v2 models on-site boilers for systems using purchased hot water or steam in baseline case, contrary to ASHRAE requirements. Project not using DES Guidance v2 does not model cooling energy using purchased energy rates in proposed case and appropriate Appendix. Baseline cooling system in baseline case. 	USGBC DES Guidance v2 and ASHRAE 90.1-2016+, G3.1.1

Table 3.1. Input Quality Control Checklist			
HVAC System +			
TOPIC	CHECK	ERRORS	RESOURCES
Cooling tower parameters	Verify that baseline cooling tower is modeled per referenced standard's requirements.	<ul style="list-style-type: none"> Baseline case includes incorrect type of cooling tower and/or fan control. Baseline case models condenser water temperatures incorrectly. 	ASHRAE 90.1-2016+, G3.1.3.11
Service hot water system	Verify that baseline hot water loop configuration and pump inputs meet referenced standard's requirements.	<ul style="list-style-type: none"> Service hot water system is not included in either baseline or proposed case. Separate hot water heater system in baseline case is not modeled when proposed case combines space heating with service hot water heating. 	ASHRAE 90.1-2016+, Table G3.1.11, Section 6.5.6.2
	Verify that projects using district or campus thermal energy have been correctly modeled.	<ul style="list-style-type: none"> Storage heating volumes modeled for service water heating are inconsistent. Baseline does not conform to values for minimum efficiency required in ASHRAE 90.1-2016+, Table 7.8, for corresponding system type. 	ASHRAE 90.1-2016+, Table 7.8
	If credit is taken for low-flow fixtures, verify calculations.	<ul style="list-style-type: none"> Backup water heating calculations are inconsistent with annual fixture flows shown in WE Credit 3, and/or insufficient information is provided to show that water heating temperature differential and standby losses were appropriately accounted for in calculations. 	ASHRAE 90.1-2016+, Exceptions to Table G3.1.11(i)


