LEED Building Design and Construction
Activity #6 – Energy and Atmosphere (EA)
Before completing this Activity Read: Reference Guide for Building Design and Construction v4 – Pages 318-465

Note the following abbreviations are used in this activity:

NC	LEED BD+C: New Construction and Major Renovation
CS	LEED BD+C: Core and Shell Development
S	LEED BD+C: Schools
R	LEED BD+C: Retail
DC	LEED BD+C: Data Centers
WDC	LEED BD+C: Warehouses and Distribution Centers
HOS	LEED BD+C: Hospitality
HC	LEED BD+C: Healthcare

Although the LEED BD+C reference guide does not number the LEED prerequisites and credits, for this exercise they have been numbered in the order presented in the credit category.

Fill-In, Multiple Choice, Matching

1. Test your knowledge of how well you know the names of the credits for the Energy and Atmosphere (EA) credit category:

LEED BD+C: NC, CS, S, R, DC, WDC, HOS, HC	
Credit	Name
P1	Fundamental Commissioning and Verification
P2	Minimum Energy Performance
P3	Building-Level Energy Metering
P4	Fundamental Refrigerant Management
C1	Enhanced Commissioning
C2	Optimize Energy Performance
C3	Advanced Energy Metering
C4	Demand Response
C5	Renewable Energy Production
C6	Enhanced Refrigerant Management
C7	Green Power and Carbon Offsets

2. Match the intent shown below to the prerequisite or credit:

LEED BD+C: NC, CS, S, R, DC, WDC, HOS, HC

Credit	ANS	Credit	ANS
EA– P1	E	EA – C3	H
EA – P2	G	EA – C4	C
EA – P3	H	EA – C5	I
EA – P4	A	EA – C6	F
EA – C1	J	EA – C7	D
EA – C2	B		

	INTENT
A	To reduce stratospheric ozone depletion.
B	To achieve increasing levels of energy performance beyond the prerequisite standard to reduce environmental and economic harms associated with excessive energy use.
C	To increase participation in demand response technologies and programs that make energy generation and distribution systems more efficient, increase grid reliability, and reduce greenhouse gas emissions.
D	To encourage the reduction of greenhouse gas emissions through the use of grid-source, renewable energy technologies and carbon mitigation projects.
E	To support the design, construction, and eventual operation of a project that meets the owner's project requirements for energy, water, indoor environmental quality, and durability.
F	To reduce ozone depletion and support early compliance with the Montreal Protocol while minimizing direct contributions to climate change.
G	To reduce the environmental and economic harms of excessive energy use by achieving a minimum level of energy efficiency for the building and its systems.
H	To support energy management and identify opportunities for additional energy savings by tracking building-level energy use.
I	To reduce the environmental and economic harms associated with fossil fuel energy by increasing self-supply of renewable energy.
J	To further support the design, construction, and eventual operation of a project that meets the owner's project requirements for energy, water, indoor environmental quality, and durability.

3. List the areas that are addressed by the Energy and Atmosphere (EA) category:
   1. Energy use Reduction
   2. Energy-efficient design strategies
   3. Renewable Energy Sources

4. Accounting for approximately 40% of the total energy used today, buildings are significant contributors to these problems.

5. Energy efficiency in a green building starts with a focus on design that reduces overall energy needs, such as building orientation and glazing selection, and the choice of climate-appropriate building materials.

6. List strategies that could help to reduce a building's energy use:
   1. passive heating and cooling
   2. natural ventilation
   3. high-efficiency HVAC systems partnered with smart controls

7. The commissioning process is critical to ensuring high-performing buildings.

8. Projects can contribute to increasing the electricity grid's efficiency by enrolling in a demand response program.

9. EA Prerequisite Fundamental Commissioning and Verification requirements:
   Commissioning Process Scope
   Complete the following commissioning (Cx) process activities for mechanical, electrical, plumbing, and renewable energy systems and assemblies, in accordance with ASHRAE

Guideline 0-2005 and ASHRAE Guideline 1.1 - 2007 for HVAC&R Systems, as they relate to energy, water, indoor environmental quality, and durability.

Requirements for exterior enclosures are limited to inclusion in the Owner's Project Requirements (OPR) and basis of design (BOD), as well as the review of the OPR, BOD and project design. NIBS Guideline 3-2012 for Exterior Enclosures provides additional guidance.

Develop the OPR.
Develop a BOD.

The Commissioning Authority (CxA) must do the following:
Review the OPR, BOD, and project design.
Develop and implement a Cx Plan.
Confirm incorporation of Cx requirements into the construction documents.
Develop construction checklists.
Develop a system test procedure.
Verify system test execution.
Maintain an issues and benefits log throughout the Cx process.
Prepare a final Cx process report.
Document all findings and recommendations and report directly to the owner throughout the process.

The review of the exterior enclosure design may be performed by a qualified member of the design or construction team (or an employee of that firm) who is not directly responsible for design of the building envelope.

Commissioning Authority
By the end of the design development phase, engage a commissioning authority with the following qualifications.
The CxA must have documented commissioning process experience on at least two building projects with a similar scope of work. The experience must extend from early design phase through at least 10 months of occupancy;
The CxA may be a qualified employee of the owner, an independent consultant, or an employee of the design or construction firm who is not part of the project's design or construction team, or a disinterested subcontractor of the design or construction team.

For projects smaller than 20,000 square feet (1 860 square meters), the CxA may be a qualified member of the design or construction team. In all cases, the CxA must report his or her findings directly to the owner.

Project teams that intend to pursue EA Credit Enhanced Commissioning should note a difference in the CxA qualifications: for the credit, the CxA may not be an employee of the design or construction firm nor a subcontractor to the construction firm.

Current Facilities Requirements and Operations and Maintenance Plan
Prepare and maintain a current facilities requirements and operations and maintenance plan that contains the information necessary to operate the building efficiently. The plan must include the following:
a sequence of operations for the building;
the building occupancy schedule;

equipment run-time schedules;
setpoints for all HVAC equipment;
set lighting levels throughout the building;
minimum outside air requirements;
any changes in schedules or setpoints for different seasons, days of the week, and times of day;
a systems narrative describing the mechanical and electrical systems and equipment;
a preventive maintenance plan for building equipment described in the systems narrative; and
a commissioning program that includes periodic commissioning requirements, ongoing commissioning tasks, and continuous tasks for critical facilities.

Data Centers only
For small projects with computer room peak cooling loads less than 2,000,000 Btu/h (600 kW) or a total computer room peak cooling load less than 600,000 Btu/h (175 kW), the CxA may be a qualified employee of the design or construction team.

10. List the benefits of a properly executed Cx process that clearly expresses the owner's project requirements:
    1. fewer change orders
    2. fewer corrective actions while on-site
    3. improved planning and coordination
    4. reduced energy consumption
    5. overall lower operating costs

11. Another potential benefit of Cx is occupants' health and comfort because of better temperature and ventilation control.

12. The qualified commissioning authority (CxA) chosen to represent the owner's needs should be brought in early in the design process.

13. The OPR must include all systems to be commissioned plus the building envelope, even if full envelope commissioning is not pursued.

14. The review should be conducted on mid design documents so that the project team has time to make any necessary changes.

15. List examples of what might warrant an update to the OPR:
    1. design changes
    2. value engineering modifications
    3. new or reassigned team members
    4. updated operating conditions

16. In general, contractors are responsible for filling out the checklists and returning them to the CxA.

17. The CxA should report any noncompliance to the owner and project team for them to help resolve.

18. The CxA generally oversees the testing; the contractors execute the testing.

19. List what the CxA should provide information on the process and requirements for:
    1. installation verification (construction) checklists
    2. Functional Performance tests
    3. Issues log
    4. Team meetings
    5. Contractor and subcontractor participation of Cx team
    5. Schedule

20. An acceptable sampling rate is "10 or 10%," meaning that for multiple units of the same type with the same components and sequences (e.g., fan coil units or variable air volume systems), the commissioning team may test only 10 units or 10% of the units, whichever is greater.

21. List what the CxA should include in the Cx report:
    1. Summary of cx process and results
    2. project directory
    3. Cx process overview
    4. OPR
    5. BOD
    6. Submittals
    7. Design review log
    8. Cx specifications
    9. List of systems Cx
    10. Installation verification checklists
    12. Functional performance tests
    13. Issues log, detailing open and closed issues

22. Efficient operations can be defined as the controlling of equipment such that it uses the minimum amount of energy or water to maintain setpoints and comfort levels.

23. List the systems that must be commissioned:
    1. Mechanical, including HVAC & R and Controls
    2. Plumbing, including domestic Hot Water, pumps, controls
    3. Electrical, including service, distribution, lighting and controls
    4. Renewable Energy Systems

24. The envelope must be covered in the OPR and BOD, but full envelope commissioning is not required unless the project team pursues EA credit Enhanced Commissioning Option 2.

25. List the Systems that are not required to be commissioned under this prerequisite but may be added to the Cx scope at the request of the owner:

1. Envelope
2. Life Safety
3. Communications and data
4. Fire protection and Fire Alarm
5. Process equipment

26. Complete Table 1. Who can be the CxA?

Table 1. Who can be the CxA?

Can ...	Who is ...	Be CxA for ...	
		fundamental Cx?	Enhanced Cx?
an employee of the architecture or design firm	A member of the design team (e.g., a project architect, engineer, or energy modeler who is also the HVAC designer)	NO, unless project is under 20,000 ft²	NO
	Not a member of the design team (e.g., a LEED administrator or energy modeler who is not participating in the design)	Yes	NO
a subconsultant to the architecture or engineering firm	a member of the design team (e.g., a project engineer subcontracted to the architect)	NO, unless project is under 20,000 ft²	NO
	not a member of the design team (e.g., a LEED administrator, Cx specialist, energy modeler)	Yes	Yes
an employee or subcontractor of the general contractor or construction manager	a member of the construction team	NO, unless project is under 20,000 ft²	NO
	not a member of the construction team	Yes	No
an employee of the owner or an independent consultant contracted to the owner		Yes	Yes

27. The OPR details the functional requirements as well as the expectations of the building's use and operation.

28. List what the OPR might include:
    1. Key project requirements
    2. Occupant requirements
    3. Budget considerations and limitations
    4. Target goals
    5. Performance criteria
    6. Operations and maintenance requirements

29. The design team must document the basis of design before any contractor submittals for commissioned equipment or systems are approved.

30. List what the BOD might include:
    1. systems and assemblies
    2. Performance criteria and assumptions
    3. Descriptions
    4. Governing codes and standards
    5. Owner directives
    6. Design development guidelines
    7. Revision history

31. List what is included in the Cx plan program overview:
    1. Goals and objectives
    2. General project information
    3. Systems to be commissioned

32. List what the Cx plan describes about the Cx team:
    1. Team members, roles, and responsibilities
    2. Communication protocol, coordination, meetings, and mangement

33. List what the Cx plan summarizes about the process activities:
    1. Reviewing the OPR
    2. Reviewing the BOD
    3. Developing systems functional test procedures
    4. Verifying system performance
    5. Reporting deficiencies and resolution process
    6. Accepting the building systems

34. List what is useful for including in the design review log:
    1. Date of the review
    2. Drawing number or page where issue was found

3. comments
4. Party responsible for addressing the issue
5. Response
6. Date the issue was closed

35. List the sections the functional performance test typically reports on:
    1. Date and time of test
    2. Individuals present during testing
    3. Visual inspections observations
    4. Sensor checks
    5. Device checks
    6. Operating mode tests
    7. Results

36. EA Prerequisite Minimum Energy Performance requirements:
    Option 1. Whole-Building Energy Simulation
    Demonstrate an improvement of 5% for new construction, 3% for major renovations, or 2% for core and shell projects in the proposed building performance rating compared with the baseline building performance rating.

    Calculate the baseline building performance according to ANSI/ASHRAE/IESNA Standard 90.1-2010, Appendix G, with errata (or a USGBC-approved equivalent standard for projects outside the U.S.), using a simulation model.

    Projects must meet the minimum percentage savings before taking credit for renewable energy systems. The proposed design must meet the following criteria:
    - compliance with the mandatory provisions of ANSI/ASHRAE/IESNA Standard 90.1-2010, with errata (or a USGBC-approved equivalent standard for projects outside the U.S.);
    - inclusion of all energy consumption and costs within and associated with the building project; and
    - comparison against a baseline building that complies with Standard 90.1-2010, Appendix G, with errata (or a USGBC-approved equivalent standard for projects outside the U.S.).

    Document the energy modeling input assumptions for unregulated loads. Unregulated loads should be modeled accurately to reflect the actual expected energy consumption of the building.

    If unregulated loads are not identical for both the baseline and the proposed building performance rating, and the simulation program cannot accurately model the savings, follow the exceptional calculation method (ANSI/ASHRAE/IESNA Standard 90.1–2010, G2.5). Alternatively, use the COMNET Modeling Guidelines and Procedures to document measures that reduce unregulated loads.

    Retail only
    For Option 1, Whole-Building Energy Simulation, process loads for retail may include refrigeration equipment, cooking and food preparation, clothes washing, and other major support appliances. Many of the industry standard baseline conditions for commercial kitchen equipment and refrigeration are defined in Appendix 3, Tables 1–4. No additional documentation is necessary to substantiate these predefined baseline systems as industry standard.

OR

Option 2. Prescriptive Compliance: ASHRAE 50% Advanced Energy Design Guide

Comply with the mandatory and prescriptive provisions of ANSI/ASHRAE/IESNA 90.1-2010, with errata (or a USGBC-approved equivalent standard for projects outside the U.S.).

Comply with the HVAC and service water heating requirements, including equipment efficiency, economizers, ventilation, and ducts and dampers, in Chapter 4, Design Strategies and Recommendations by climate Zone, for the appropriate ASHRAE 50% Advanced Energy Design Guide and climate zone:

- ASHRAE 50% Advanced Energy Design Guide for Small to Medium Office Buildings, for office buildings smaller than 100,000 square feet (9290 square meters);
- ASHRAE 50% Advanced Energy Design Guide for Medium to Large Box Retail Buildings, for retail buildings with 20,000 to 100,000 square feet (1860 to 9290 square meters);
- ASHRAE 50% Advanced Energy Design Guide for K-12 School Buildings; or
- ASHRAE 50% Advanced Energy Design Guide for Large Hospitals. Over 100,000 square feet (9290 square meters)

For projects outside the U.S., consult ASHRAE/ASHRAE/IESNA Standard 90.1-200, Appendixes B and D, to determine the appropriate climate zone.

Option 3. Prescriptive Compliance: Advanced Buildings™ Core Performance™ Guide

Comply with the mandatory and prescriptive provisions of ANSI/ASHRAE/IESNA Standard 90.1-2010, with errata (or USGBC approved equivalent standard for projects outside the U.S.).

Comply with Section 1: Design Process Strategies, Section 2: Core Performance Requirements, and the following three strategies from Section 3: Enhanced Performance Strategies, as applicable. Where standards conflict, follow the more stringent of the two. For projects outside the U.S., consult ASHRAE/ASHRAE/IESNA Standard 90.1-2010, Appendixes B and D, to determine the appropriate climate zone.

3.5 Supply Air Temperature Reset (VAV)
3.9 Premium Economizer Performance
3.10 Variable Speed Control

To be eligible for Option 3, the project must be less than 100,000 square feet (9290 square meters).

Note: Healthcare, Warehouses or Laboratory projects are ineligible for Option 3.

Data Centers

Whole-Building Energy Simulation

Demonstrate a 5% improvement in the proposed performance rating over the baseline performance rating. To determine total energy cost savings, create two models, one for building energy cost and the other for IT equipment energy cost. Calculate the baseline building performance according to ANSI/ASHRAE/IESNA Standard 90.1-2010, Appendix G, with errata (or a USGBC-approved equivalent standard for projects outside the U.S.), using a simulation model for the whole building and data center modeling guidelines.

Determine the power utilization effectiveness (PUE) value of the proposed design.

For this prerequisite, a minimum of 2% of the 5% energy savings must come from building power and cooling infrastructure.

Projects must meet the minimum percentage savings before taking credit for renewable energy systems.

The proposed design must meet the following criteria:

- compliance with the mandatory provisions of ANSI/ASHRAE/IESNA Standard 90.1-2010, with errata (or a USGBC-approved equivalent standard for projects outside the U.S.);
- inclusion of all energy consumption and costs within and associated with the building project; and
- comparison against a baseline building that complies with ANSI/ASHRAE/IESNA Standard 90.1-2010, Appendix G, with errata (or a USGBC-approved equivalent standard for projects outside the U.S.), and data center modeling guidelines.

For data centers, regulated energy includes cooling units for computer and data processing rooms, critical power conditioning equipment, critical distribution equipment, heat rejection plants, and mechanical and electrical support rooms.

Include in process loads both the unregulated load and the IT equipment load. The IT load comprises critical systems and electrical power transformation, which may include servers, storage and networking power use, and operations affecting monthly server CPU utilization percentages.

Develop two sets of IT load models using two scenarios, one at the maximum estimated IT load rating and the second at the startup IT rating expected at the time of commissioning.

Document the energy modeling input assumptions for unregulated loads. Unregulated loads should be modeled accurately to reflect the actual expected energy consumption of the building.

If unregulated loads are not identical for both the baseline and the proposed building performance rating, and the simulation model cannot accurately model the savings, follow the exceptional calculation method (ANSI/ASHRAE/ IESNA Standard 90.1-2010, G2.5) to document measures that reduce unregulated loads.

37. List the benefits of identifying an energy goal for the project early in the design process:
    1. Help prioritize efficiency strategies
    2. integrate systems
    3. reduce first costs
    4. improve building performance

38. List the two approaches projects can take to comply with EA Prerequisite Minimum Energy Performance:
    1. Performance
    2. Prescriptive

39. For EA Prerequisite Minimum Energy Performance, Option 3, the energy performance target must be established using ENERGY STAR's Target Finder and must be greater than a score of 90.

40. Energy costs offset by on-site renewable energy systems do not count toward energy savings for compliance with the prerequisite. Renewable energy may be included in the model for achievement of points under the related credit.

41. Determining the right climate zone for the project is essential, since the requirements are specific to each climate zone. ASHRAE 90.1-2010 defines eight climate zones (Miami is in climate zone 1; Anchorage is in climate zone 8) and three climate types: A (moist), B (dry), and C (marine).

42. To find the project's climate zone and type, consult ASHRAE 90.1-2010, Appendix B, for the appropriate State and County. If the project's County is not listed, use the climate zone listed for the State as a whole.

43. List the name of each of the options for EA Prerequisite Minimum Energy Performance:

    Option 1. Whole-Building Energy Simulation

    Option 2. Prescriptive Compliance: ASHRAE 50% AEDG

    Option 3. Prescriptive Compliance: Advanced Buildings Core Performance Guide

44. EA Prerequisite Building-Level Energy Metering requirements:

    NC, S, R, DC, WDC, HOS, HC

    Install new or use existing building-level energy meters, or submeters that can be aggregated to provide building level data representing total building energy consumption (electricity, natural gas, chilled water, steam, fuel oil, propane, biomass, etc). Utility-owned meters capable of aggregating building-level resource use are acceptable.

    Commit to sharing with USGBC the resulting energy consumption data and electrical demand data (if metered) for a five-year period beginning on the date the project accepts LEED certification. At a minimum, energy consumption must be tracked at one-month intervals.

    This commitment must carry forward for five years or until the building changes ownership or lessee.

    CS

    Install new or use existing base building-level energy meters, or submeters that can be aggregated to provide base building-level data representing total building energy consumption (electricity, natural gas, chilled water, steam, fuel oil, propane, etc.). Utility-owned meters capable of aggregating base building-level resource use are acceptable.

    Commit to sharing with USGBC the resulting energy consumption data and electrical demand data (if metered) for a five-year period beginning on the date the project accepts LEED certification or typical occupancy, whichever comes first. At a minimum, energy consumption must be tracked at one-month intervals.

    This commitment must carry forward for five years or until the building changes ownership or lessee.

45. List the sources of energy supplied by a utility company or campus plant that must be metered:

    1. Electricity
    2. Natural gas, propane, fuel oil, diesel fuel, other fossil fuels
    3. Biofuels
    4. District chilled water, steam, and hot water

46. If all energy provided to the building is supplied by one or more utility companies and the utility meters provide monthly consumption data, those meters meet the prerequisite requirements.

47. Begin tracking energy use when the project achieves LEED certification or at occupancy, whichever occurs first.

48. Utility-provided meters are typically regulated by code or law to establish their accuracy. Utility meters are often called "revenue-grade" because their measurement results directly in a charge to the customer.

49. EA Prerequisite Fundamental Refrigerant Management requirements:
Do not use chlorofluorocarbon (CFC)-based refrigerants in new heating, ventilating, air-conditioning, and refrigeration (HVAC&R) systems. When reusing existing HVAC&R equipment, complete a comprehensive CFC phase-out conversion before project completion. Phase-out plans extending beyond the project completion date will be considered on their merits.

    Existing small HVAC&R units (defined as containing less than 0.5 pound [225 grams] of refrigerant) and other equipment, such as standard refrigerators, small water coolers, and any other equipment that contains less than 0.5 pound (225 grams) of refrigerant, are exempt.

50. Production of CFCs was phased out in industrialized nations that signed the Montreal Protocol before December 1995 and in most other countries by 2010.

51. Though both hydrochlorofluorocarbons (HCFCs) and CFCs contribute to ozone depletion, only CFCs must be addressed to meet this prerequisite.

52. EA Credit Enhanced Commissioning requirements:
Implement, or have in place a contract to implement, the following commissioning process activities in addition to those required under EA Prerequisite Fundamental Commissioning and Verification.

    Commissioning Authority
    The CxA must have documented commissioning process experience on at least two building projects with a similar scope of work. The experience must extend from early design phase through at least 10-months of occupancy;
    The CxA may be a qualified employee of the owner, an independent consultant, or a disinterested subcontractor of the design team.

    Option 1. Enhanced Systems Commissioning (3-4 points)
    Path 1: Enhanced Commissioning (3 points)
    Complete the following commissioning process (CxP) activities for mechanical, electrical, plumbing, and renewable energy systems and assemblies in accordance with ASHRAE Guideline 0-2005 and ASHRAE Guideline 1.1-2007 for HVAC&R systems, as they relate to energy, water, indoor environmental quality, and durability.

    The commissioning authority must do the following:
    Review contractor submittals.
    Verify inclusion of systems manual requirements in construction documents.
    Verify inclusion of operator and occupant training requirements in construction documents.
    Verify systems manual updates and delivery.
    Verify operator and occupant training delivery and effectiveness.
    Verify seasonal testing.
    Review building operations 10 months after substantial completion.
    Develop an on-going commissioning plan.

    Include all enhanced commissioning tasks in the OPR and BOD.

OR
Path 2: Enhanced and Monitoring-Based Commissioning (4 points)
Achieve Path 1.

AND
Develop monitoring-based procedures and identify points to be measured and evaluated to assess performance of energy - and water -consuming systems.

Include the procedures and measurement points in the commissioning plan. Address the following:
roles and responsibilities;
measurement requirements (meters, points, metering systems, data access);
the points to be tracked, with frequency and duration for trend monitoring;
the limits of acceptable values for tracked points and metered values (where appropriate, predictive algorithms may be used to compare ideal values with actual values);
the elements used to evaluate performance, including conflict between systems, out-of-sequence operation of systems components, and energy and water usage profiles;
an action plan for identifying and correcting operational errors and deficiencies;
training to prevent errors;
planning for repairs needed to maintain performance; and
the frequency of analyses in the first year of occupancy (at least quarterly).

Update the systems manual with any modifications or new settings, and give the reason for any modifications from the original design.

AND/OR
Option 2. Envelope Commissioning (2 Points)

Fulfill the requirements in EA Prerequisite Fundamental Commissioning and Verification as they apply to the building's thermal envelope in addition to mechanical and electrical systems and assemblies.

Complete the following commissioning process (CxP) activities for the building's thermal envelope in accordance with ASHRAE Guideline 0-2005 and the National Institute of Building Sciences (NIBS) Guideline 3-2012, Exterior Enclosure Technical Requirements for the Commissioning Process, as they relate to energy, water, indoor environmental quality, and durability.

Commissioning authority must complete the following:
Review contractor submittals.
Verify inclusion of systems manual requirements in construction documents.
Verify inclusion of operator and occupant training requirements in construction documents.
Verify systems manual updates and delivery.
Verify operator and occupant training delivery and effectiveness.
Verify seasonal testing.
Review building operations 10 months after substantial completion.
Develop an on-going commissioning plan.

Data Centers only
Projects that select Option 1 must complete the following commissioning process.

For small projects with peak cooling loads less than 2,000,000 Btu/h (600 kW), or a total computer room peak cooling load less than 600,000 Btu/h (175 kW), the CxA must perform the following activities:

conduct at least one commissioning verification review of the owner's project requirements, basis of design, and design documents before mid-construction documents development; back-check the review comments in all subsequent design submissions; and conduct an additional full verification review at 95% completion of the design documents and basis of design.

For projects with peak cooling loads 2,000,000 Btu/h (600 kW) or more, or a total computer room peak cooling load 600,000 Btu/h (175 kW) or more, the CxA must conduct at least three verification reviews of the basis of design:
one verification review of design documents before the start of design development;
one verification review of design documents before mid-construction documents; and
one final verification review of 100% complete design documents, verifying achievement of the owner's project requirements and adjudication of previous review comments.

53. Monitoring-based commissioning (MBCx) gives the building owner, operators, and the CxA a continual stream of information that helps them identify operational issues as they occur, thereby saving time, money, and energy consumption over the lifetime of the building.

54. Complete Table 1. Commissioning activities

Table 1. Commissioning activities

Phase	Cx task	Responsible party	Cx	Enhanced Cx	MBCx	BECx
Predesign	Develop OPR	owner	X	X	X	X
Schematic design	Develop BOD, including envelope requirements	Design Team	X	X	X	X
	Include general monitoring, metering, and trending requirements	Design Team			X	
Design	Engage CxA	Owner	X	X	X	X
Documents	Develop initial commissioning plan	CxA	X	X	X	X
	Include monitoring requirements, equipment	CxA			X	
	Include envelope requirements	CxA				X
	Conduct OPR, BOD, and design document review	CxA, owner, design team	X	X	X	X
	Prepare systems manual outline	CxA, owner		X	X	X
	Include monitoring requirements, equipment	CxA, owner			X	
	Include envelope requirements	CxA, owner				X
	Document training requirements	CxA, owner		X	X	X
	Update OPR and BOD as necessary	CxA, owner, design team	X	X	X	X

Phase	Cx task	Responsible party	Cx	Enhanced Cx	MBCx	BECx
Construction Documents	Issue Cx specifications for inclusion in bid/permit documents	CxA	X	X	X	X
	Include enhanced Cx requirements	CxA		X	X	X
	Include monitoring-based Cx requirements	CxA			X	
	Include envelope based Cx requiremetns	CxA				X
	Update OPR and BOD as necessary	CxA, owner, design team	X	X	X	X
	Conduct design review (recommended)	CxA, design team	X	X	X	X
Construction	Update OPR and BOD as necessary	CxA, owner, design team	X	X	X	X
	Perform prefunctional inspections	CxA	X	X	X	X
	Complete submittal reviews concurrently with or before acceptance by design team	CxA		X	X	X
	Update OPR, BOD, Cx plan and systems manual as necessary	CxA	X	X	X	X
	Issue owner's training requirements	CxA, contractor		X	X	X
	Issue construction checklists	CxA	X	X	X	X
	Issue functional performance test scripts for contractor review	CxA, contractor	X	X	X	X
	Issue/review verified TAB report	Contractor, CxA	X	X	X	X
	Issue/review completed construction checklists	Contractor, CxA	X	X	X	X
	Execute functional performance tests	CxA, contractor	X	X	X	X
	Document issues in issues log	CxA	X	X	X	X
	Compile final systems manual	CxA		X	X	X
	Complete final commissioning report	CxA	X	X	X	X
	Verify training plan has been implemented	CxA, contractor, building operators		X	X	X

Phase	Cx task	Responsible party	Cx	Enhanced Cx	MBCx	BECx
Occupancy and operations	Complete Cx report	CxA	X	X	X	X
	Compile operations and maintenance plan	CxA	X	X	X	X
	Compile final systems manual	CxA		X	X	X
	Perform seasonal testing	CxA, contractor, building operators		X	X	X
	Perform 10-month review	CxA, contractor, building operators		X	X	X
	Develop ongoing Cx plan	CxA, building operators		X	X	X

BECx = building envelope commissioning plan
BOD = basis of design
Cx = commissioning process
CxA = commissioning authority
MBCx = monitoring-based commissioning process
OPR = owner's project requirements

55. List the three components of monitoring-based commissioning:
    1. Permanent energy monitoring systems
    2. real-time energy analysis
    3. ongoing commissioning

56. List the activities that MBCx allows the user to do:
    1. track energy consumption
    2. detect faulty equipment operations
    3. identify unusual energy or power consumption patterns as they occur

57. MBCx is most cost-effective when the metering and energy analysis software are integrated into the initial design of a building.

58. EA Credit Optimize Energy Performance requirements:
    NC, CS, S, R, WDC, HOS, HC

    Establish an energy performance target no later than the Schematic design phase. The target must be established as KBtu per square foot-year (kW per square meter-year) of source energy use.

    Choose one of the options below.

    Option 1. Whole-Building Energy Simulation (1–18 points except Schools and Healthcare, 1–16 points Schools, 1–20 points Healthcare)

    Analyze efficiency measures during the design process and account for the results in design decision making. Use energy simulation of efficiency opportunities, past energy simulation analyses for similar buildings, or published data (e.g., Advanced Energy Design Guides) from analyses for similar buildings.

Analyze efficiency measures, focusing on load reduction and HVAC-related strategies (passive measures are acceptable) appropriate for the facility. Project potential energy savings and holistic project cost implications related to all affected systems.

Project teams pursuing the Integrative Process credit must complete the basic energy analysis for that credit before conducting the energy simulation.
Follow the criteria in EA Prerequisite Minimum Energy Performance to demonstrate a percentage improvement in the proposed building performance rating compared with the baseline. Points are awarded according to Table 1.

Complete Table 1. Points for percentage improvement in energy performance

Table 1. Points for percentage improvement in energy performance

New Construction	Major Renovation	Core and Shell	Points (except S, HC)	Points (Healthcare)	Points (Schools)
6%	4%	3%	1	3	1
8%	6%	5%	2	4	2
10%	8%	7%	3	5	3
12%	10%	9%	4	6	4
14%	12%	11%	5	7	5
16%	14%	13%	6	8	6
18%	16%	15%	7	9	7
20%	18%	17%	8	10	8
22%	20%	19%	9	11	9
24%	22%	21%	10	12	10
26%	24%	23%	11	13	11
29%	27%	26%	12	14	12
32%	30%	29%	13	15	13
35%	33%	32%	14	16	14
38%	36%	35%	15	17	15
42%	40%	39%	16	18	16
46%	44%	43%	17	19	--
50%	48%	47%	18	20	--

Retail only
For all process loads, define a clear baseline for comparison with the proposed improvements. The baselines in Appendix 3, Tables 1–4, represent industry standards and may be used without additional documentation. Calculate the baseline and design as follows:

Appliances and equipment. For appliances and equipment not covered in Tables 1–4, indicate hourly energy use for proposed and budget equipment, along with estimated daily use hours. Use the total estimated

appliance/equipment energy use in the energy simulation model as a plug load. Reduced use time (schedule change) is not a category of energy improvement in this credit. Energy Star ratings and evaluations are a valid basis for performing this calculation.

Display lighting. For display lighting, use the space-by-space method of determining allowed lighting power under ANSI/ASHRAE/IESNA Standard 90.1–2010, with errata (or a USGBC-approved equivalent standard for projects outside the U.S.), to determine the appropriate baseline for both the general building space and the display lighting.

Refrigeration. For hard-wired refrigeration loads, model the effect of energy performance improvements with a simulation program designed to account for refrigeration equipment.

Option 2. Prescriptive Compliance: ASHRAE Advanced Energy Design Guide (1–6 points)
To be eligible for Option 2, projects must use Option 2 in EA Prerequisite Minimum Energy Performance.

Implement and document compliance with the applicable recommendations and standards in Chapter 4, Design Strategies and Recommendations by Climate Zone, for the appropriate ASHRAE 50% Advanced Energy Design Guide and Climate zone. For projects outside the U.S., consult ASHRAE/ASHRAE/IESNA Standard 90.1–2010, Appendixes B and D, to determine the appropriate climate zone.

ASHRAE 50% Advanced Energy Design Guide for Small to Medium Office Buildings
Building envelope, opaque: roofs, walls, floors, slabs, doors, and continuous air barriers (1 point)
Building envelope, glazing: vertical fenestration (1 point)
Interior lighting, including daylighting and interior finishes (1 point)
Exterior lighting (1 point)
Plug loads, including equipment and controls (1 point)

ASHRAE 50% Advanced Energy Design Guide for Medium to Large Box Retail Buildings
Building envelope, opaque: roofs, walls, floors, slabs, doors, and vestibules (1 point)
Building envelope, glazing: fenestration - all orientations (1 point)
Interior lighting, excluding lighting power density for sales floor (1 point)
Additional interior lighting for sales floor (1 point)
Exterior lighting (1 point)
Plug loads, including equipment choices and controls (1 point)

ASHRAE 50% Advanced Energy Design Guide for K-12 School Buildings
Building envelope, opaque: roofs, walls, floors, slabs, and doors (1 point)
Building envelope, glazing: vertical fenestration (1 point)
Interior lighting, including daylighting and interior finishes (1 point)
Exterior lighting (1 point)
Plug loads, including equipment choices, controls, and Kitchen equipment (1 point)

ASHRAE 50% Advanced Energy Design Guide for Large Hospitals
Building envelope, opaque: roofs, walls, floors, slabs, doors, vestibules, and continuous air barriers (1 point)
Building envelope, glazing: vertical fenestration (1 point)
Interior lighting, including daylighting (form or nonform driven) and interior finishes (1 point)
Exterior lighting (1 point)
Plug loads, including equipment choices, controls, and Kitchen equipment (1 point)

Retail only
Meet the requirements of Option 2 and comply with the prescriptive measures in Appendix 3, Tables 1–4, for 90% of total energy consumption for all process equipment.

DATA CENTERS
Whole-Building Energy Simulation
Analyze efficiency measures focused on IT load reduction and HVAC-related strategies (air-side economizers, hot aisle–cold aisle, etc.). Project the potential energy savings and cost implications for all affected systems.

Follow the criteria in EA Prerequisite Minimum Energy Performance to demonstrate a percentage improvement in the proposed performance rating compared with the baseline.

Use energy cost savings from both the building and IT to determine the total percentage reduction.

59. The option pursued in the prerequisite must also be pursued in the Credit.

60. Exemplary Performance
Option 1. New construction, major renovation, and core and shell projects: Achieve at least 54% energy savings.

61. EA Credit Advanced Energy Metering requirements:
NC, S, R, DC, WDC, HOS, HC

Install advanced energy metering for the following:
all whole-building energy sources used by the building; and
any individual energy end uses that represent 10% or more of the total annual consumption of the building.

The advanced energy metering must have the following characteristics.
Meters must be permanently installed, record at intervals of one hour or less, and transmit data to a remote location.
Electricity meters must record both consumption and demand. Whole-building electricity meters should record the power factor, if appropriate.
The data collection system must use a local area network, building automation system, wireless network, or comparable communication infrastructure.
The system must be capable of storing all meter data for at least 36 months.
The data must be remotely accessible.
All meters in the system must be capable of reporting hourly, daily, monthly, and annual energy use.

CORE AND SHELL
Install meters for future tenant spaces so that tenants will be capable of independently metering energy consumption (electricity, chilled water, etc.) for all systems dedicated to their space.
Provide a sufficient number of meters to capture total tenant energy use with a minimum of one meter per energy source per floor.

Install advanced energy metering for all base building energy sources used by the building.

The advanced energy metering must have the following characteristics.
Meters must be permanently installed, record at intervals of one hour or less, and transmit data to a remote location.

Electricity meters must record both consumption and demand. Whole-building electricity meters should record the power factor, if appropriate.
The data collection system must use a local area network, building automation system, wireless network, or comparable communications infrastructure.
The system must be capable of storing all meter data for at least 36 months.
The data must be remotely accessible.
All meters in the system must be capable of reporting hourly, daily, monthly, and _____ energy use.

62. List examples of renewable energy sources that could serve a project:
    1. wind turbines
    2. photovoltaic panels
    3. solar thermal panels
    4. geothermal

63. Identifying major energy end uses is the first step in choosing what to meter.

64. List examples of typical end uses for a commercial office building that may require advanced metering:
    1. Receptacle equipment
    2. Interior lighting
    3. Space heating
    4. Space cooling
    5. Fans
    6. Pumps
    7. Heat rejection
    8. Exterior lighting
    9. Service water heating

65. The owner is responsible for maintaining and calibrating meters according to the manufacturers' recommendations.

66. EA Credit Demand Response requirements:
    Design building and equipment for participation in demand response programs through load shedding or shifting.
    On-site electricity generation does not meet the intent of this credit.

    Case 1. Demand Response Program Available (2 points)
    Participate in an existing demand response (DR) program and complete the following activities. Design a system with the capability for real-time, fully-automated DR based on external initiation by a DR Program Provider. Semi-automated DR may be utilized in practice.

    Enroll in a minimum one-year DR participation amount contractual commitment with a qualified DR program provider, with the intention of multiyear renewal, for at least 10% of the estimated peak electricity demand. Peak demand is determined under EA Prerequisite Minimum Energy Performance.

    Develop a comprehensive plan for meeting the contractual commitment during a Demand Response event.

Include the DR processes in the scope of work for the Commissioning authority, including participation in at least one full test of the DR plan.

Case 2. Demand Response Program Not Available (1 point)
Provide infrastructure to take advantage of future demand response programs or dynamic, real-time pricing programs and complete the following activities.

Install interval recording meters with communications and ability for the building automation system to accept an external price or control signal.

Develop a comprehensive plan for shedding at least 10% of building estimated peak electricity demand. Peak demand is determined under EA Prerequisite Minimum Energy Performance.

Include the DR processes in the scope of work for the commissioning authority, including participation in at least one full test of the DR plan.

Contact local utility representatives to discuss participation in future DR programs.

67. EA Credit Renewable Energy Production requirements:
Use renewable energy systems to offset building energy costs. Calculate the percentage of renewable energy with the following equation:

$$\%\ \text{renewable energy} = \frac{\text{Equivalent cost of usable energy produced by the renewable energy system}}{\text{Total building annual energy cost}}$$

Use the building's annual energy cost, calculated in EA Prerequisite Minimum Energy Performance, if Option 1 was pursued; otherwise use the U.S. Department of Energy's Commercial Buildings Energy Consumption Survey (CBECS) database to estimate energy use and cost.

The use of solar gardens or community renewable energy systems is allowed if both of the following requirements are met.
The project owns the system or has signed a lease agreement for a period of at least 10 years.
The system is located with the same utility service area as the facility claiming the use.

Credit is based on the percentage of ownership or percentage of use assigned in the lease agreement. Points are awarded according to Table 1.

Complete Table 1. Points for renewable energy

Table 1. Points for renewable energy		
Percentage renewable energy	Points (All, except Core and Shell)	Points (Core and Shell)
1%	1	1
3%	--	2
5%	2	3
10%	3	--

68. Excess energy, beyond the building's energy demand at a given point, can be sold to the utility company (net metering).

69. List the allowable sources for renewable energy:
    1. Photovoltaic
    2. Solar thermal
    3. Wind
    4. Biofuel (in some cases)
    5. Low-impact hydroelectricity
    6. Wave and tidal energy
    7. Geothermal energy (in some cases)

70. Some renewable energy systems do not meet the intent of the credit and are not eligible. List strategies that reduce energy consumption but are not eligible renewable energy systems:
    1. architectural features
    2. passive solar
    3. day lighting

71. List the biofuels that are ineligible:
    1. combustion of municipal solid waste
    2. Forest biomass other than mill residue
    3. wood coated with paints, plastics, or laminates
    4. wood Treated for preservation

72. List the ways that the equivalent cost of the usable energy system can be calculated:
    1. Virtual rate
    2. Actual rate plus demand

73. EA Credit Enhanced Refrigerant Management requirements:
    NC, CS, S, DC, WDC, HOS, HC

    Option 1. No Refrigerants or Low-Impact Refrigerants (1 point)

    Do not use refrigerants, or use only refrigerants (naturally occurring or synthetic) that have an ozone depletion potential (ODP) of zero and a global warming potential (GWP) of less than 50.

    OR

    Option 2. Calculation of Refrigerant Impact (1 point)
    Select refrigerants that are used in heating, ventilating, air-conditioning, and refrigeration (HVAC&R) equipment to minimize or eliminate the emission of compounds that contribute to ozone depletion and climate change. The combination of all new and existing base building and tenant HVAC&R equipment that serve the project must comply with the following formula:

    $LCGWP + LCODP \times 10^5 \leq$ 100

RETAIL

Meet Option 1 or 2 for all HVAC systems.

Stores with commercial refrigeration systems must comply with the following.

Use only non-ozone-depleting refrigerants.

Select equipment with an average HFC refrigerant charge of no more than 1.75 pounds of refrigerant per 1,000 Btu/h (2.72 kg of refrigerant per kW) total evaporator cooling load.

Demonstrate a predicted store-wide annual refrigerant emissions rate of no more than 15%. Conduct leak testing using the procedures in GreenChills best practices guideline for leak tightness at installation.

Alternatively, stores with commercial refrigeration systems may provide proof of attainment of EPA GreenChills Silver-level store certification for newly constructed stores.

74. List the main threats to the environment posed by refrigerants:
    1. ozone depletion potential (ODP)
    2. global warming potential (GWP)

75. For any HVAC &R equipment not listed, assume an equipment life of 10 years.

76. Assume that refrigerant leakage rate (Lr) is 2% per year and end-of-life refrigerant loss (Mr) is 10%, for all equipment types. No alternative values may be substituted for these percentages.

77. If a packaged air-conditioning unit uses 7 pounds of refrigerant and its cooling capacity is 5 tons, what is the refrigerant charge (Rc)?

$$R_c = \frac{7\,lb}{4\,lb} = 1.4$$

78. List examples of natural refrigerants:
    1. carbon dioxide
    2. ammonia
    3. water

79. An office project is installing new HVAC-R equipment. The main cooling system will be (2) 200-ton centrifugal Chillers with HCFC-123 and Rc = 1.63 lb/ton. The computer room air conditioning unit will be (1) 10-ton packaged air conditioning unit with HCFC-22 and Rc = 2.3 lb/ton. The manufacturer has also provided a guarantee that the unit has less than 1% per year leakage.

    Calculate the Average Refrigerate Atmospheric Impact. Does this office project comply with EA Credit Enhanced Refrigerant Management?

Inputs									Calculations				
N (Number of Units)	Qunit (Tons)	Refrigerant	GWPr	ODPr	Rc (lb/ton)	Life (yrs)	Lr (%)	Mr (%)	Tr Total Leakage (Lr x Life + Mr)	LCGWP (GWPr x Tr x Rc)/ Life	LCODP x 10^5 100,000 x (ODPr x Tr x Rc)/ Life	Refrigerant Atmospheric Impact = LCGWP + LCODP x 10^5	(LCGWP + LCODP x 10^5) x N x Qunit
2	200	R123	76	0.02	1.63	23	2%	10%	56%	3.0162	79.37	82.4	32,960
1	10	R22	1,780	0.04	2.3	15	2%	10%	40%	109.17	245.3	354.5	3545
Qtotal:	210											Subtotal:	36,505
Average Refrigerant Atmospheric Impact = [∑ (LCGWP + LCODP x 105) x Qunit] / Qtotal: 174													

NO. The average Refrigerant Atmospheric Impact must be ≤100

80. EA Credit Green Power and Carbon Offsets requirements:

Engage in a contract for qualified resources that have come online since January 1, 2005, for a minimum of five years, to be delivered at least annually. The contract must specify the provision of at least 50% or 100% of the project's energy from green power, carbon offsets, or renewable energy certificates (RECs).

Green power and RECs must be Green-e Energy certified or the equivalent. RECs can only be used to mitigate the effects of Scope 2, electricity use.

Carbon offsets may be used to mitigate Scope 1 or Scope 2 emissions on a metric ton of carbon dioxide–equivalent basis and must be Green-e Climate certified, or the equivalent.

For U.S. projects, the offsets must be from greenhouse gas emissions reduction projects within the U.S.

Determine the percentage of green power or offsets based on the quantity of energy consumed, not the cost.

Points are awarded according to Table 1.

Complete Table 1. Points for energy from green power or carbon offsets

Table 1. Points for energy from green power or carbon offsets

Percentage of total energy addressed by green power, RECs and/or offset	Points
50%	1
100%	2

Use the project's annual energy consumption, calculated in EA Prerequisite Minimum Energy Performance, if Option 1 was pursued; otherwise use the U.S. Department of Energy's Commercial Buildings Energy Consumption Survey (CBECS) database to estimate energy use.

Core and Shell Only

A core and shell building's energy is defined as the energy usage of the core and shell floor area as defined by the Building Owners and Managers Association (BOMA) standards, but not less than 15% of the project's floor area.

Green power and RECs must be Green-e Energy certified or the equivalent.

Carbon offsets must be Green-e Climate certified or the equivalent. Unlike RECs and purchased green power, carbon offsets can be used toward both electric and nonelectric energy use.

Net-zero buildings—those anticipated to consume zero net energy on an annual basis—are eligible to achieve 2 points under this credit without purchasing any additional renewable energy, RECs, or carbon offsets, provided the project does not sell any RECs associated with the on-site renewable energy production.