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## **Purpose**

The use of the U.S Green Building Council's (USGBC) LEED rating system to recognize the energy performance of buildings and facilities continues to grow at a rapid pace. Building energy performance constitutes the largest point-earning component within LEED, and CHP can help projects maximize the number of points earned.

The purpose of this paper is to summarize how CHP is treated under the LEED Building Design + Construction: New Construction (LEED BD+C: New Construction) rating system to provide information for projects seeking to use CHP to earn LEED points. The paper focuses on projects where the CHP outputs (electricity and thermal) are contained within the project boundary (i.e., CHP outputs are not part of a district energy system), but does briefly discuss the treatment of exported electricity. The paper addresses the Energy & Atmosphere (EA): Minimum Energy Performance requirement and the EA: Optimize Energy Performance credit since these have the greatest relevance to CHP within the EA credit category.<sup>1,2</sup> Information for both LEED v4 and LEED v2009 is presented.<sup>3</sup>

This paper constitutes the first effort by the EPA CHP Partnership (CHPP) to document CHP treatment under LEED. The long-term goal is to document how CHP is treated under all LEED rating systems. Treatment of CHP in district energy applications may also be explored.<sup>4</sup>

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<sup>1</sup> Other EA credits may also relate to CHP [e.g., Demand Response (LEED v4), Renewable Energy Production (LEED v4), Enhanced Refrigerant Management (LEED v4)]. Future research may explore to what extent these credits (and non-EA credits) relate to CHP.

<sup>2</sup> In both LEED v4 and LEED v2009, Minimum Energy Performance is required of all projects seeking certification. Optimize Energy Performance is a credit and allows projects to earn points. In LEED v4 and LEED v2009, Minimum Energy Performance is known as Energy & Atmosphere Prerequisite 2 (EAp2). In LEED v4, Optimize Energy Performance is known as Energy & Atmosphere Credit 2 (EAc2), and in LEED v2009, it is known as Energy & Atmosphere Credit 1 (EAc1).

<sup>3</sup> The USGBC membership voted to adopt LEED v4 on July 2, 2013. The rating system, including reference guides, was launched at the 2013 Greenbuild International Conference & Expo. Project teams will be allowed to register for either LEED v4 or LEED 2009 until June 1, 2015, after which only LEED v4 will be available. Projects registered under LEED 2009 will be allowed to complete the certification process under that system as long as they do so before it "sunset," which could happen as late as 2021, according to precedents.

<sup>4</sup> Future research may address the treatment of CHP by other tools such as the Green Globes certification program and Portfolio Manager.

## Research Conducted

Research conducted to date has focused on the treatment of CHP in the LEED v4 and LEED v2009 BD+C: New Construction rating systems. EPA CHPP reviewed the following resources:

- LEED credit language for EA: Minimum Energy Performance and EA: Optimize Energy Performance for both LEED v4 and LEED v2009 [available at: <http://www.usgbc.org/credits/new-construction/v4/energy-%26-atmosphere> (LEED v4) and <http://www.usgbc.org/credits/new-construction/v2009/energy-%26-atmosphere> (LEED v2009)].
- LEEDuser ([www.leeduser.com](http://www.leeduser.com)).
- USGBC’s *Methodology for Modeling Combined Heat & Power for EAp2/c1 in LEED 2009* (available at: <http://www.usgbc.org/resources/methodology-modeling-combined-heat-amp-power-eap2c1-leed-2009>).<sup>5</sup>
- USGBC Credit Interpretation Requests relevant to CHP.

EPA CHPP also spoke with the following:

- Stakeholders involved with LEED project certification.
- USGBC staff, Green Building Certification Institute (GBCI) staff, and LEED Energy & Atmosphere Technical Advisory Group members.
- People involved with projects where CHP is being used to help earn LEED points.

## Importance of the Energy & Atmosphere: Optimize Energy Performance Credit

The EA Optimize Energy Performance credit is the maximum LEED point-earning credit (in all categories).

- ➔ Achieving all of the available Optimize Energy Performance credits would represent 45 percent (LEED v4) and 47.5 percent (LEED v2009) of the points needed to earn certification at the “LEED Certified” level.

CHP’s efficiency and cost saving benefits can greatly contribute to a project’s ability to earn points under this credit.

Table 1 illustrates the importance of this credit in both LEED v4 and LEED v2009.

**Table 1: Importance of Energy & Atmosphere: Optimize Energy Performance**

LEED Version	Total Number of Points Available	Total Number of Points Needed to Earn LEED Certified*	Total Number of Optimize Energy Performance Points Available
LEED v4	110	40	18 (16 for Schools; 20 for Healthcare)
LEED v2009	110	40	19

\*LEED Certified is the lowest level that can be achieved under LEED. LEED Silver is earned with 50 points; LEED Gold is earned with 60 points; LEED Platinum is earned with 80 points.

<sup>5</sup> LEED’s methodology for modeling CHP is not expected to change between LEED v2009 and LEED v4.

## Summary of the Energy & Atmosphere: Minimum Energy Performance Prerequisite<sup>6</sup>

The Minimum Energy Performance prerequisite (EAp2) must be met by all projects seeking LEED certification. LEED provides three compliance pathways for meeting EAp2 (certain compliance pathways—Options 2 and 3—are available only for certain building types, but Option 1 is available to all building types). However, only Option 1 is likely to be considered for buildings with CHP systems as it allows projects with CHP to earn the most points for the increased efficiency available with CHP under the Optimize Energy Performance credit.

Projects with CHP are not precluded from using Options 2 or 3 to comply with EAp2, but it is unlikely that these options will be followed given that their use for EAp2 also requires their use under the Optimize Energy Performance credit, where few points can be earned using these options.

### **Option 1: Whole Building Energy Simulation (Performance-based)**

- LEED v4
    - Projects must demonstrate savings of 5% (new construction), 3% (major renovations), and 2% (cores and shell) in the proposed building (the “Design Building”) compared to a baseline case meeting the minimum requirements of ASHRAE 90.1-2010 (the “Baseline Building”). This is done by creating a computer model following rules described in Appendix G of ASHRAE 90.1-2010.
  - LEED v2009
    - Projects must demonstrate savings of 10% (new construction) or 5% (major renovations) in the proposed building (the “Design Building”) compared to a baseline case meeting the minimum requirements of ASHRAE 90.1-2007 (the “Baseline Building”). This is done by creating a computer model following rules described in Appendix G of ASHRAE 90.1-2007.
  - The model described in Appendix G (Performance Rating Method [PRM]) of ASHRAE 90.1 is based on cost performance of the building (e.g., the above-referenced 5% savings for new construction under LEED v4 are based on cost rather than on energy savings or emissions savings).
  - The compliance path (i.e., option) chosen for EAp2 must also be used to earn points under the Optimize Energy Performance credit. This is important because there are a significantly fewer points available under Optimize Energy Performance for the prescriptive paths—Option 2 has a maximum of 6 points available under LEED v4 and 1 point under LEED v2009; Option 3 has a maximum of 3 points available (Option 3 is only available under LEED v2009).
  - Of the three options, only Option 1 allows a project to use Option 1 under the Optimize Energy Performance credit, with the potential to earn 18 points under LEED v4 and 19 points under LEED v2009. Use of Option 2 or 3 to meet EAp2 limits the potential points that can be earned under the credit from zero to six points (depending on the Option and the version of the rating system).
  - Some building types may not have a choice and may have to comply with Option 1—both Options 2 and 3 are prescriptive compliance paths that are only available to specific building types and sizes.
- ➔ The U.S. Green Building Council has produced a guidance document presenting a methodology for incorporating CHP into the simulation required through Option 1: *Methodology for Modeling Combined Heat & Power for EAp2/c1 in LEED 2009* (onsite systems only)<sup>7</sup>

### **Option 2: ASHRAE Advanced Energy Design Guides (Prescriptive)<sup>8</sup>**

<sup>6</sup> LEED credit language for Minimum Energy Performance is available at: -

<http://www.usgbc.org/node/2613358?return=/credits/new-construction/v4/energy-%26-atmosphere> (LEED v4) and -  
<http://www.usgbc.org/node/1731017?return=/credits/new-construction/v2009/energy-%26-atmosphere> (LEED v2009). -

<sup>7</sup> Available for download at: <http://www.usgbc.org/resources/methodology-modeling-combined-heat-amp-power-eap2c1-leed-2009>. -

<sup>8</sup> ASHRAE’s Advanced Energy Design Guides are available at: <https://www.ashrae.org/standards-research--technology/advanced-energy-design-guides>. -

- LEED v4
  - Projects must comply with the mandatory and prescriptive provisions of ANSI/ASHRAE/IESNA Standard 90.1–2010, with errata.
  - Projects must 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 Guides are available for:
    - Small to Medium Office Buildings (less than 100,000 square feet)
    - Medium to Large Box Retail Buildings (20,000 to 100,000 square feet)
    - K–12 School Buildings
    - Large Hospitals (over 100,000 square feet)
- LEED v2009
  - Projects must comply with the prescriptive measures of the ASHRAE Advanced Energy Design Guide<sup>9</sup> appropriate to the project scope.
  - Applicable Advanced Energy Design Guides include:
    - Small Office Buildings (less than 20,000 square feet)
    - Small Retail Buildings (less than 20,000 square feet)
    - Small Warehouses and Self Storage Buildings (less than 50,000 square feet)

**Option 3: Advanced Buildings Core Performance Guide (Prescriptive)<sup>10</sup>**

- LEED v4
  - Projects must comply with the mandatory and prescriptive provisions of ANSI/ASHRAE/IESNA Standard 90.1-2010, with errata.
  - Projects must 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:
    - 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.
- LEED v2009
  - Projects must comply with the prescriptive measures identified in the Advanced Buildings™ Core Performance™ Guide (CPG) developed by the New Buildings Institute.
  - The building must meet the following requirements:
    - Less than 100,000 square feet.
    - Comply with Section 1: Design Process Strategies, and Section 2: Core Performance Requirements.
    - Health care, warehouse and laboratory projects are ineligible for this path.

<sup>9</sup> ASHRAE Advanced Energy Design Guides are Available at: <https://www.ashrae.org/standards-research--technology/advanced-energy-design-guides>. -

<sup>10</sup> The Core Performance Guide is available for purchase at: <http://www.advancedbuildings.net/core-performance>. -

## Summary of the Energy & Atmosphere: Optimize Energy Performance Credit <sup>11</sup>

The Optimize Energy Performance credit (EAc2—LEED v4, EAc1—LEED v2009) includes the same compliance pathways as EAp2 (Option 3, however, is not available in LEED v4). Whichever compliance path is chosen for EAp2 is also used to earn points under the Optimize Energy Performance credit:

### **Option 1: Whole Building Energy Simulation (Performance-based)**

- Option 1 is the only option that offers the potential to earn the maximum number of points available for this credit.<sup>12</sup> This requires whole building energy simulation using a computer model.
- As discussed above, to meet the prerequisite, EAp2, the project must reduce energy cost by a minimum percentage compared to a Baseline meeting the minimum requirements of ASHRAE 90.1.
  - LEED v4 – Projects must demonstrate savings of 5% (new construction), 3% (major renovations), and 2% (core and shell) in the proposed building (the “Design Building”) compared to a baseline case meeting the minimum requirements of ASHRAE 90.1-2010 (the “Baseline Building”). This is done using a computer model following rules described in Appendix G of ASHRAE 90.1-2010.
  - LEED v2009 – Projects must demonstrate savings of 10% (new construction) or 5% (major renovations) in the proposed building (the “Design Building”) compared to a baseline case meeting the minimum requirements of ASHRAE 90.1-2007 (the “Baseline Building”). This is done using a computer model following rules described in Appendix G of ASHRAE 90.1-2007.

\*\*Once the prerequisite has been met, projects can then earn points for additional percentage increases in energy cost reduction up to 18 points (LEED v4) and 19 points (LEED v2009). Table 2 presents the points available under LEED v4 and LEED v2009 for New Construction.

The energy modeling and documentation process is identical for EAp2 and Optimize Energy Performance, Option 1. The exact reduction is established through running of the energy model. -

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<sup>11</sup> LEED credit language for Optimize Energy performance is available at:

<http://www.usgbc.org/node/2614273?return=/credits/new-construction/v4/energy-%26-atmosphere> (LEED v4) and <http://www.usgbc.org/node/1731022?return=/credits/new-construction/v2009/energy-%26-atmosphere> (LEED v2009).

<sup>12</sup> Note that in LEED v 2009, projects with an improvement over baseline of 50% or more may be considered for an additional point under the Innovation in Design Category.

**Table 2: Points for Percentage Improvement in Energy Costs (New Construction) -**

Percent Improvement over Baseline	Points	
	LEED v4	LEED v2009
6%	1	---
8%	2	---
10%	3	---
12%	4	1
14%	5	2
16%	6	3
18%	7	4
20%	8	5
22%	9	6
24%	10	7
26%	11	8
28%	---	9
29%	12	---
30%	---	10
32%	13	11
34%	---	12
35%	14	---
36%	---	13
38%	15	14
40%	---	15
42%	16	16
44%	---	17
46%	17	18
48%	---	19
50%	18	---

**Option 2: ASHRAE Advanced Energy Design Guides (Prescriptive)**

- LEED v4
  - Projects can earn 1-6 points.
  - Projects must 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. ASHRAE 50% Advanced Energy Design Guides are available for:
    - Small to Medium Office Buildings (less than 100,000 square feet)
    - Medium to Large Box Retail Buildings (20,000 to 100,000 square feet)
    - K-12 School Buildings
    - Large Hospitals (over 100,000 square feet)
- LEED v2009
  - Projects can only earn 1 point.
  - Projects must comply with the prescriptive measures of the ASHRAE Advanced Energy Design Guide appropriate to the project scope. Applicable Advanced Energy Design Guides include:
    - Small Office Buildings (less than 20,000 square feet)
    - Small Retail Buildings (less than 20,000 square feet)
    - Small Warehouses and Self Storage Buildings (less than 50,000 square feet)

### **Option 3: Advanced Buildings Core Performance Guide (Prescriptive)**

- LEED v4 only allows projects to earn points by following Option 1 or Option 2.
- Under LEED v2009, compliance with the prescriptive measures of the CPG offers an opportunity for a maximum of 3 points. One point is earned for compliance with the CPG. Up to two additional points are available to projects that implement performance strategies listed in Section 3: Enhanced Performance. For every 3 strategies implemented from this section, 1 point is available.

## **USGBC Methodology for Modeling CHP**

To account for CHP in the energy model required for Option 1 of EAp2 and the Optimize Energy Performance credit USGBC developed the document, *Methodology for Modeling Combined Heat & Power for EAp2/c1 in LEED 2009* (available at: <http://www.usgbc.org/resources/methodology-modeling-combined-heat-amp-power-eap2c1-leed-2009>).<sup>13</sup> The document only applies to on-site CHP systems which can either have the same ownership as the project (Case 1) or different ownership as the project (Case 2).

- In accordance with the Appendix G (Performance Rating Method [PRM]) of ASHRAE 90.1, the parameters of the calculation of the CHP performance are as follows:
  - Case 1 – Same ownership, CHP inside project site boundaries
    - The Baseline Building heating and cooling plant utilizes the backup energy source(s) of the Design, or electricity if no backup source is present or specified.
      - For the electrical output of the CHP system the backup source is purchased electricity.
      - For the CHP thermal output, the backup energy source is the same source of energy used in the building's equipment with the CHP system installed. For example, if waste heat recovery is used to supplement domestic hot water, the backup energy source would be the energy source that powers the onsite boiler (e.g. electric, natural gas, etc.)
      - For CHP systems with no thermal backup, the Baseline Building must utilize purchased electricity to meet all applicable ASHRAE requirements.
    - When all electricity and thermal outputs (heating or cooling) of the CHP are used within the Design Building, the electricity produced is considered "free", as is the produced thermal energy. The input fuel for the CHP and any additional purchased energy is charged to the Design Building.
    - In some cases some electricity generated by the CHP is sold to the grid or an external customer. In such cases, thermal and electrical outputs of the CHP used within the Design Building are treated as above. All electricity sold externally is termed a "process", and both the Design and Baseline Buildings are charged with the input fuel associated with the generation of that electricity. The thermal output associated with the generation of sold electricity and used by the Design Building is considered "free", i.e., no additional fuel is charged to the design building for this thermal output, because none is used to produce it. Revenue, if any, associated with the sale of exported electricity does not reduce the energy costs of the design building for the purpose of calculating the percentage improvement in the design building performance rating.
  - Case 2 – Different ownership, CHP inside project site boundaries
    - The rates charged to a building by a CHP developer or operator for electricity and thermal outputs typically include factors for capital recovery, maintenance, and other non-energy costs. Since these types of costs are not included in the PRM calculation for other energy efficiency equipment and measures within the Design, they are also excluded for the CHP calculation regardless of the ownership of the system.

<sup>13</sup> USGBC indicated this document also applies to LEED v4.

- Essentially the CHP system in Case 2 is treated the same as Case 1, with the input fuel charged to the Design Building (at the prevailing utility rate as it applies to the Design Building) for all CHP outputs used within the building, and charged to both the Design and Baseline Buildings for “process” electricity sold externally.
- As with Case 1, the thermal output associated with the generation of sold electricity and used by the Design Building is considered “free”.

## Observations Based on Research

- The cost basis approach to calculating energy savings under Option 1 does not fully recognize the - environmental benefits of CHP. -
  - The use of a cost metric to evaluate energy savings has been discussed significantly in both ASHRAE public comment and USGBC public comment. In both cases, the cost metric was deemed to be the best overall metric that was currently available for evaluating building energy performance.
- Since the percentage savings requirements of Option 1 of EAp2 and the Optimize Energy Performance credit are based on energy costs rather than energy use, the value of CHP (along with other energy efficiency measures), in terms of earning LEED points, is dependent on the fuel costs (purchased electricity, natural gas, or other) used in the model for the Baseline and Design Buildings.<sup>14</sup> For example, in the case of two identical systems with different spark spreads (i.e., difference between the price of a purchased kWh of electricity and the price of fuel required to produce that electricity in a CHP system), the system with the larger spark spread will earn more points, even though the systems result in the same environmental benefits. (See Exhibit 1 below).
- Projects that export electricity generated by the CHP system achieve lower percentage improvements in cost savings compared to projects that retain all CHP outputs within the project boundary. (See Exhibit 2 below).
- It’s possible that other methodologies could be used to earn points with CHP
  - A LEED Interpretation can always be submitted for consideration if a group or project team would like to provide a creditable path for documenting compliance using an alternate metric or method. These will be evaluated by the USGBC Energy & Atmosphere Technical Advisory Group, which consists of volunteer experts from the energy and engineering community.

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<sup>14</sup> CHP system characteristics such as total system efficiency, power-to-heat ratio, and the performance curve of the electrical generator are also important in determining how CHP can contribute to points earned.

**Exhibit 1: Simple Example of Spark Spread Issue**

Based on energy inputs of CHP system illustrated at: [http://www.epa.gov/chp/basic\\_popup5.html](http://www.epa.gov/chp/basic_popup5.html). Same energy use, but spark spread of Building A is larger than that of Building B

**Building Characteristics**

Building Energy Purchases Before and After CHP		Building A Energy Costs		Building B Energy Costs	
Electricity purchases before CHP	30 units (kWh)	Electricity	\$0.10/kWh	Electricity	\$0.05/kWh
Natural gas purchases before CHP	56 units (kWh)*	Natural Gas**	\$3.50/MMBtu (\$0.0119/kWh)	Natural Gas**	\$3.50/MMBtu (\$0.0119/kWh)
Natural gas purchases with CHP	100 units (kWh)				

\*Assumes Baseline Building has onsite boiler and purchases natural gas in quantities needed to produce 45 units of thermal energy used in building

\*\*Natural gas costs for buildings A & B are assumed to be the same for simplicity.

**Energy Cost Calculations**

	Building A	Building B
Electricity cost without CHP (Baseline)	\$3 (30 x \$0.10)	\$1.50 (30 x \$0.05)
NG cost without CHP (Baseline)	\$0.67 (56 x \$0.0119)	\$0.67 (56 x \$0.0119)
Total cost without CHP (Baseline)	\$3.67	\$2.17
NG Cost with CHP (Design)	\$1.19 (100 x \$0.0119)	\$1.19 (100 x \$0.0119)
<b>% Cost Reduction of Design over Baseline</b>	<b>67.6%</b>	<b>45.2%</b>

Despite using the same quantity of energy, Building A shows a cost reduction of 67.6% with CHP compared to 45.2% for Building B. This is due to Building A having a higher cost of purchased electricity and therefore a higher spark spread as compared to Building B. Because Building A can show a greater percent reduction in costs compared to Building B it would be able to earn more LEED points.

**Exhibit 2: Simple Example of Export Electricity Issue**

Based on CHP system depicted at: [http://www.epa.gov/chp/basic\\_popup5.html](http://www.epa.gov/chp/basic_popup5.html).

Example shows that if a given building chooses to size their CHP system to export electricity, that building achieves a lower percent cost savings (design compared to the baseline) than it would if it sized the CHP system to only produce the amount of electricity needed for the building.

Fuel input for analysis = 1 MMBtu

Natural gas cost = \$4/MMBtu

Electricity cost = \$29.31/MMBtu (\$0.10/kWh)

Case A – No Electricity Export			Case B – 10 Units Electricity Export		
<b>Design Building</b>			<b>Design Building</b>		
CHP Fuel Input (MMBtu)	100		CHP Fuel Input (MMBtu)	133.33	CHP system has 30% electrical efficiency so to produce extra 10 units for export an extra 33.33 units of energy are needed as fuel input - per methodology, both Baseline and Design charged with the input fuel associated with the generation of export electricity
Building Electricity Use (MMBtu)	30		Building Electricity Use (MMBtu)	30	
Building Thermal Use (MMBtu)	45		Building Thermal Use (MMBtu)	45	Extra fuel input to the CHP can result in excess thermal energy production, but for purposes of example that extra output is discarded
Export Electricity (MMBtu)	0		Export Electricity (MMBtu)	10	
CHP Fuel Input Cost (\$)	\$400	Input fuel cost for CHP system	CHP Fuel Input Cost (\$)	\$533.32	Input fuel cost for CHP system
<b>Baseline Building</b>			<b>Baseline Building</b>		
Purchased Electricity (MMBtu)	30		Purchased Electricity for Power Used Onsite (MMBtu)	30	
Purchased Thermal Fuel (MMBtu)	56	80% efficient boiler	Fuel Use Associated with 10 Units of Export Electricity (MMBtu)	33.33	An extra 33.33 units of fuel input is needed to produce the 10 units of export electricity in the CHP system - per methodology, both Baseline and Design charged with the input fuel associated with the generation of export electricity
Cost of Purchased Electricity (\$)	\$879.25		Purchased Thermal Fuel (MMBtu)	56	80% efficient boiler
Cost of Purchased Thermal Fuel (\$)	\$224		Cost of Purchased Electricity (\$)	\$879.25	
Total Cost (\$)	\$1,103.25	(Cost of purchased elect. for power used onsite) + (cost of purchased thermal fuel for boiler)	Cost of Fuel Use Associated with 10 Units of Export Electricity (\$)	\$133.32	
			Cost of Purchased Thermal Fuel (\$)	\$224	
			Total Cost (\$)	\$1,236.57	(Cost of purchased elect. for power used onsite) + (cost of fuel associated with production of 10 units of export elect.) + (cost of purchased thermal fuel for boiler)
<b>% Cost Savings Over Baseline</b>	<b>63.74%</b>		<b>% Cost Savings Over Baseline</b>	<b>56.87%</b>	