Treatment of District Energy CHP Outputs in LEED® for Building Design and Construction: New Construction and Major Renovations

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Introduction

District energy systems (DES) produce steam, hot water or chilled water at a central plant. The steam, hot water or chilled water is then piped to individual buildings for space heating, domestic hot water heating and air conditioning. The buildings served by the DES can receive these services at lower capital and energy costs than if they produced thermal energy on site.

When a DES includes combined heat and power (CHP), the efficiency of CHP can further reduce energy costs and emissions for buildings served by the DES. Since CHP also produces electricity, it may also be possible to improve the reliability and resiliency of the electricity supply to connected buildings.

In addition to these benefits, buildings connected to a CHP-equipped DES can earn more LEED® points than they could otherwise earn.

As explained in the U.S. Green Building Council's (USGBC's) LEED® v4 Reference Guide,[1] new buildings seeking LEED® certification must meet a "Minimum Energy Performance" prerequisite. In addition, under the "Energy and Atmosphere: Optimize Energy Performance" (OEP) credit,[2] buildings can earn points for superior energy performance beyond the requirement of the prerequisite. The Reference Guide includes guidance for calculating points under the OEP credit for buildings connected to a CHP-equipped DES. This fact sheet summarizes that guidance. Specifically, the fact sheet:

- Presents guidance for meeting the Minimum Energy Performance prerequisite and calculating points under the OEP credit ("OEP points").
- Presents a hypothetical example demonstrating the application of the methodology for determining OEP points. It presents a typical building designed to meet the Minimum Energy Performance prerequisite, and the same building when connected to a CHP-equipped DES.

This fact sheet complements "Treatment of CHP in LEED® for Building Design and Construction: New Construction and Major Renovations," which provides the following information:

- What is CHP?
- Importance of the OEP credit
- CHP's demonstrated point impact
- Summary of the Minimum Energy Performance prerequisite
- Summary of the OEP credit
- USGBC methodology for modeling CHP

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[1] The LEED® v4 Reference Guide for Building Design and Construction is available for purchase at: - http://www.usgbc.org/resources/leed-reference-guide-building-design-and-construction. See "Project Type Variations" - under the Minimum Energy Performance description for the full guidance on how buildings connected to a CHP-equipped - DES can calculate OEP points. -

[2] The OEP credit rewards buildings for enhanced energy efficiency, and is the maximum LEED® point-earning credit (in all - LEED® credit categories). The credit also has the most relevance to CHP within the LEED® Energy and Atmosphere credit - category. -

In October 2015, USGBC and the Green Building Certification Institute (GBCI) kicked off a task group to identify opportunities to strengthen and streamline the relationship between LEED® and PEER®, particularly around district energy. PEER® (Performance Excellence in Electricity Renewal) is intended to improve power system performance and electricity delivery systems, and is managed by GBCI. The task group is currently developing a pilot alternative compliance path that would award LEED® OEP points to buildings connected to a PEER®-certified district energy system.

Options for Meeting Minimum Energy Performance Prerequisite and Earning OEP Points

To meet the Minimum Energy Performance prerequisite and earn OEP points, buildings can choose one of two options:

- Option 1: whole-building energy simulation (using an energy model)
    - ***Buildings connected to a CHP-equipped DES may choose Option 1 to maximize the opportunity to earn OEP points.***
- Option 2: prescriptive compliance (using *ASHRAE 50% Advanced Energy Design Guide* or the *Advanced Buildings Core Performance Guide*).
    - ***This option substantially limits the number of OEP points a building can earn, and does not recognize the efficiency benefits of CHP.***

The option chosen must also be used to calculate points under the OEP credit.

Under Option 1, buildings can choose one of three modeling paths:

- Path 1: ASHRAE 90.1-2010, Appendix G
- Path 2: full DES performance accounting
    - ***This is the only path that recognizes the efficiency benefits of CHP.***[3]
- Path 3: streamlined DES modeling

Guidance for Determining OEP Points (Using Option 1 [Whole-Building Energy Simulation), Modeling Path 2 [Full DES Performance Accounting])

The methodology for determining OEP points for a building connected to a CHP-equipped DES is based on allocating a portion of the CHP system's fuel input and electricity output to the Design Building (i.e., the building being evaluated). This allocation is based on the amount of thermal energy supplied to the Design Building by the DES and the total thermal energy output of the DES.

The methodology has three steps:

1) - <u>Determine Baseline Building[4] Energy Costs</u>

a) - Using an energy model, determine the electricity load of the Baseline Building (i.e., a building that meets the requirements of ASHRAE 90.1-2010, Appendix G).

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[3] It is recognized that all project teams may not have the information necessary to use Path 2.

[4] The Baseline Building is a building similar in size and function to the Design Building that meets the prescriptive requirements of ASHRAE 90.1-2010, Appendix G.

b) - Determine whether the Baseline Building's electricity load needs adjustment for the purposes of the OEP points calculation using the following steps:[5]

i. - First, determine the amount of electricity from the DES CHP system allocated to the Design Building using one of the following equations:[6]

Simple DES/CHP Arrangement:
Use this approach for CHP plants in which the thermal energy is used for only one district energy heat source (i.e., steam or hot water).[7]

The following equation allocates to the Design Building a portion of the total CHP electricity output based on the proportion of CHP thermal energy that is used by the Design Building.

$$CHP\_ELEC_{BLDG} = (X_{HEAT} \times BLDG_{HEAT}) \times CHP\_ELEC_{TOTAL}$$

where:

CHP_ELEC_{BLDG} = the CHP electricity generation allocated to the building
X_{HEAT} = the fraction of the CHP plant's total thermal energy supplied to the DES (i.e., as steam or hot water)
$BLDG_{HEAT}$ = the fraction of the total district thermal energy provided to the building
CHP_ELEC_{TOTAL} = the total CHP electricity generated at the DES plant

Note: X_{HEAT}, $BLDG_{HEAT}$, and CHP_ELEC_{TOTAL} are determined through actual measurement or modeled.

More Complex DES/CHP Arrangement:
Use this approach for CHP plants in which the thermal energy is used to provide more than one district energy source (e.g., steam, hot water, or chilled water provided by absorption chillers).

The equation below specifically accounts for steam, hot water, and chilled water, and a fourth district energy source if applicable (e.g., a second chilled water loop). If there are more than four district energy sources, additional combinations of Z_{SOURCE} and $BLDG_{SOURCE}$ should be added to the equation as needed.

$$CHP\_ELEC_{BLDG} = [(X_{HEAT\text{-}STEAM} \times BLDG_{HEAT\text{-}STEAM}) + (X_{HEAT\text{-}HW} \times BLDG_{HEAT\text{-}HW}) + (Y_{CHW} \times BLDG_{CHW}) + (Z_{SOURCE} \times BLDG_{SOURCE})] \times CHP\_ELEC_{TOTAL}$$

where:

CHP_ELEC_{BLDG} = the CHP electricity generation allocated to the Design Building
$X_{HEAT\text{-}STEAM}$ = the fraction of the CHP plant's total thermal energy applied to the DES as steam
$BLDG_{HEAT\text{-}STEAM}$ = the fraction of the total district steam provided to the building
$X_{HEAT\text{-}HW}$ = the fraction of the CHP plant's total thermal energy applied to the DES as hot water
$BLDG_{HEAT\text{-}HW}$ = the fraction of the total district hot water provided to the building

[5] Note that the methodology assumes that CHP is the only heat source for the DES. -
[6] The methodology assumes that all of the electricity produced by the CHP system is provided to the buildings served by the - DES, and that it is shared in the same ratio as the thermal energy is shared. -
[7] "Source" is used in the methodology to denote the form of thermal energy in the DES (e.g., steam, hot water, chilled water). -

Y_{CHW}	= the fraction of the CHP plant's total thermal energy applied to the DES as chilled water (with the use of absorption chillers)
$BLDG_{CHW}$	= the fraction of total district chilled water provided to the building
Z_{SOURCE}	= the fraction of the CHP plant's total thermal energy applied to the DES as a fourth district energy source, if applicable (e.g., a second chilled water loop)
$BLDG_{SOURCE}$	= the fraction of the fourth district energy source that is provided to the building
CHP_ELEC_{TOTAL}	= the total CHP electricity generated at the DES plant

Note: X_{HEAT}, $BLDG_{HEAT}$, Y_{CHW}, $BLDG_{CHW}$, Z_{SOURCE}, $BLDG_{SOURCE}$, and CHP_ELEC_{TOTAL} are determined through actual measurement or modeled.

ii. - If the amount of electricity allocated to the Design Building calculated in Step 1(b)(i) is more than the modeled electricity load for the Design Building, an adjustment to the Baseline Building electricity cost is needed. Step 1(d) below describes the required adjustment.

c) - Calculate the Baseline Building electricity cost by applying the site-appropriate utility rate to the modeled electricity load for the Baseline Building.

d) - If Step 1(b) above determines it to be necessary, adjust the Baseline Building electricity cost by adding the CHP input fuel cost associated with the excess electricity—i.e., the difference between the electricity allocated to the Design Building and the modeled electricity of the Design Building, determined in Step 2(a) below.[8]

i. - The CHP input fuel associated with the excess electricity is determined using the following equation:

$$BaselineBLDG_{FUEL} = (PROCESS\_ELEC_{BLDG} \div CHP\_ELEC_{TOTAL}) \times CHP_{FUEL}$$

with

$$PROCESS\_ELEC_{BLDG} = CHP\_ELEC_{BLDG} - DESIGN\_ELEC_{BLDG}$$

where:

$BaselineBLDG_{FUEL}$	= the excess fuel charged to the Baseline Building
$PROCESS\_ELEC_{BLDG}$	= the amount of allocated CHP electricity in excess of the Baseline Building's modeled annual electricity consumption
CHP_ELEC_{TOTAL}	= the total CHP electricity generated at the DES plant
CHP_{FUEL}	= the total CHP fuel input for electricity generation at the DES plant
CHP_ELEC_{BLDG}	= the CHP electricity generation allocated to the Design Building
$DESIGN\_ELEC_{BLDG}$	= the modeled electricity consumption for the Design Building

Notes:

- *CHP_ELEC_{TOTAL} and CHP_{FUEL} are determined through actual measurement or modeled.*
- *CHP_ELEC_{BLDG} is determined via the equation presented in Step 1(b) above.*

[8] According to the USGBC Reference Guide, adding the CHP input fuel cost associated with the excess electricity to the Baseline Building electricity cost is done to keep the excess cost neutral when calculating the percent improvement in total energy cost between the Baseline and Design Buildings. It appears that making this adjustment would understate the energy cost savings percentage (and potentially OEP points) for the Design Building, compared to a Design Building where the adjustment was not necessary.

- *$DESIGN\_ELEC_{BLDG}$ is modeled.*

ii. - To determine the CHP input fuel cost associated with the excess electricity, apply the site-appropriate utility rate to the additional fuel calculated in Step 1(d)(i) above.

e) - Using an energy model, determine the thermal load of the Baseline Building with one of the following methods:

i. - If the Design Building is situated in a district heating setting, model an onsite heating plant that supplies the Baseline Building's thermal energy needs.[9]

ii. - If the Design Building is situated in a district cooling setting, model an onsite cooling plant that supplies the Baseline Building's thermal energy needs.[10]

f) - Calculate the Baseline Building's thermal energy cost by applying the site-specific utility rate to the modeled thermal energy load determined in Step 1(e).

g) - Calculate total energy cost for the Baseline Building by summing the building electricity and thermal energy costs—i.e., values determined in Step 1(c); Step 1(d), if necessary; and Step 1(f).

2) - <u>Determine Design Building Energy Costs</u>

a) - Using an energy model, determine the electricity and thermal energy loads of the Design Building.

b) - Calculate the CHP fuel input allocated to the Design Building using the following equation.

$$DesignBLDG_{FUEL} = (CHP\_ELEC_{BLDG} \div CHP\_ELEC_{TOTAL}) \times CHP_{FUEL}$$

where:

$DesignBLDG_{FUEL}$ = the CHP fuel input allocated to the Design Building -
CHP_ELEC_{BLDG} = the CHP electricity generation allocated to the Design Building -
CHP_ELEC_{TOTAL} = the total CHP electricity generated at the DES plant -
CHP_{FUEL} = the total CHP fuel input for electricity generation at the DES plant -

Notes:

- *CHP_ELEC_{BLDG} is determined in Step 1(b).*
- *CHP_ELEC_{TOTAL} and CHP_{FUEL} are determined through actual measurement or modeled.*

c) - Calculate the cost of the CHP fuel input by applying the cost of CHP fuel to the fuel allocated to the Design Building, as determined in Step 2(b) above.

d) - If the allocation of electricity to the Design Building (CHP_ELEC_{BLDG}) is less than then the Design Building's electricity load, the Design Building will need to purchase electricity to make up the difference. Calculate the cost of the additional electricity needed by applying the site-specific utility rate to the additional electricity needed.

[9] The onsite heating plant must meet requirements outlined in ASHRAE 90.1-2010, Appendix G.
[10] The onsite cooling plant must meet requirements outlined in ASHRAE 90.1-2010, Appendix G.

e) - If the amount of DES thermal energy supplied to the Design Building is less than the Design Building's thermal energy load, the Design Building will need to generate onsite thermal energy to make up the difference. Calculate the cost of the fuel needed to supply the additional thermal energy by applying the site-specific utility rate to the additional fuel needed.

f) - Calculate total energy cost for the Design Building by summing the cost of the CHP fuel input allocated to the Design Building and any additional electricity or thermal energy cost needed to meet the modeled Design Building energy load—i.e., values determined in Step 2(c), Step 2(d), and Step 2(e).

3) - <u>Calculate OEP Points</u>

a) - Calculate the percentage improvement in energy costs of the Design Building compared to the Baseline Building.

b) - Determine if the Minimum Energy Performance prerequisite is met (in LEED® v4, the Design Building must demonstrate a 5 percent improvement in energy costs compared to the Baseline Building).

c) - If the Minimum Energy Performance prerequisite is met, determine OEP points earned according to Table 1.

Table 1: OEP Points for Percentage Improvement in Energy Costs (New Construction, LEED® v4)

Percent Improvement over Baseline	OEP Points
6%	1
8%	2
10%	3
12%	4
14%	5
16%	6
18%	7
20%	8
22%	9
24%	10
26%	11
29%	12
32%	13
35%	14
38%	15
42%	16
46%	17
50%	18

Example Calculation

This section presents a hypothetical example that applies the calculation methodology summarized in this paper to demonstrate the value of connecting to a CHP-equipped DES (compared to meeting energy loads with purchased utility electricity and onsite thermal energy production).

The example chosen is a 195,000-square-foot, full-service hotel located in upstate New York.[11]

Although the example is hypothetical, the EPA CHP team considers all the CHP and DES values to be reasonable based on its experience.

Three cases are evaluated:

- **Case A (Baseline Building):** This case represents the Baseline Building in the analysis. It shows the energy loads for the hotel, assuming it meets the requirements of ASHRAE 90.1-2010.
- **Case B (Design Building, no DES):** Design case in which the hotel implements energy savings measures that result in 5 percent savings in both electric and thermal loads (and consequently 5 percent savings in total energy cost). Under this case, the hotel meets its energy loads by purchasing utility electricity and natural gas to operate an onsite boiler. The assumed 5 percent reduction in energy costs means that the Design Building meets the Minimum Energy Performance prerequisite.
- **Case C (Design Building, DES):** Design case in which the hotel implements the same energy savings measures in Case B (resulting in 5 percent savings in electric and thermal loads), but instead of purchasing utility electricity and producing all its thermal energy with an onsite boiler, the hotel connects to a CHP-equipped DES to help meet its electricity and thermal loads (and if necessary it purchases utility electricity and boiler fuel to meet remaining energy loads).

<u>Data and Calculations</u>

The following tables present the data used in the example and the associated calculations needed to determine OEP points for the two Design Building cases (Cases B and C).

- **Table 2: Energy Loads for Cases A, B, and C.** This table presents the annual electric and thermal loads for the hotel in each of the three cases.
- **Table 3: District Energy System Information.** This table presents the parameters associated with the DES selected for the example.
- **Table 4: Electricity and Natural Gas Prices.** This table presents the utility electricity and delivered natural gas prices used in the example.
- **Table 5: Energy Use Calculations.** This table presents the energy use values and calculations for the three cases needed to determine OEP points.
- **Table 6: LEED® Optimize Energy Performance Point Determination.** This table presents the OEP points earned for each of the two Design Building cases (Cases B and C).

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[11] Upstate New York is categorized as a cold climate. Energy loads for a 195,000-square-foot hotel located in a cold climate are developed/presented in the EPA CHP Partnership report *CHP in the Hotel and Casino Market Sectors,* available at http://www.epa.gov/sites/production/files/2015-07/documents/chp_in_the_hotel_and_casino_market_sectors.pdf.

Table 2: Energy Loads for Cases A, B, and C -

Factor	Case A (Baseline Building)	Case B (Design Building, No DES)	Case C (Design Building, DES)
Annual electric load (thousand kWh) ($ELEC\_LOAD_{HOTEL}$)	2,960	2,812	2,812
Annual thermal load (MMBtu) ($THERM\_LOAD_{HOTEL}$)	19,660	18,677	18,677

Table 3: District Energy System Information -

Factor	Value	Notes/Equations
CHP system size (MW)	10	
CHP system prime mover	NG combustion turbine	
CHP system power-to-heat ratio (PH)	0.65	
CHP electric efficiency ($ELEC_{EFF}$)	27.3%	
Total CHP electricity generated at the DES plant (kWh) (CHP_ELEC_{TOTAL})	83,220,000	Assumes CHP system operates 95% of year. = (10 MW) × (1,000 kW/MW) × (0.95) × (8760 hours/year)
Annual thermal output of CHP system (MMBtu) (CHP_THERM_{TOTAL})	436,841	= [(CHP_ELEC_{TOTAL}) ÷ PH] × (0.003412 MMBtu/kWh) = [(83,220,000 kWh) ÷ 0.8] × (0.003412 MMBtu/kWh)
Total CHP fuel input for electricity generation at the DES plant (MMBtu) (CHP_{FUEL})	1,040,098	= [(CHP_ELEC_{TOTAL}) ÷ ($ELEC_{EFF}$)] × (0.003412 MMBtu/kWh) = [(83,220,000 kWh) ÷ 0.33] × (0.003412 MMBtu/kWh)
Fraction of the CHP plant's total thermal energy applied to the DES (X_{HEAT})	0.95	95% of the CHP system's thermal output is input to the DES
Fraction of the total district thermal energy provided to the building ($BLDG_{HEAT}$)	0.025	2.5% of the total DES thermal energy is provided to the hotel
CHP thermal provided to hotel (MMBtu) (CHP_THERM_{HOTEL})	10,375	Total amount of the CHP system's thermal energy that is provided to the hotel for use = (CHP_THERM_{TOTAL}) × (X_{HEAT}) × ($BLDG_{HEAT}$) = (354,933 MMBtu) × (0.95) × (0.025)

Table 4: Electricity and Natural Gas Prices -

Factor	Value
Electricity price ($/kWh)*	$0.1535
Natural gas price ($/MMBtu)**	$7.96

* Electricity price is EIA's average retail commercial rate for the state of New York: http://www.eia.gov/electricity/sales_revenue_price/pdf/table4.pdf.

** Gas price is the average of EIA's New York retail commercial and industrial prices: http://www.eia.gov/dnav/ng/ng_pri_sum_a_EPG0_PCS_DMcf_a.htm.

Table 5: Energy Use Calculations

Factor	Case A (Baseline Building)	Case B (Design Building, no DES)	Case C (Design Building, DES)	Step from Methodology	Notes/Equations
Annual electricity load for hotel (kWh) ($ELEC\_LOAD_{HOTEL}$)	2,960,000	2,812,000	2,812,000	1(a) [Case A] 2(a) [Cases B and C]	Values taken from Table 2. For Cases B and C, annual electricity load is 5% less than Case A. Values for Cases B and C are $DESIGN\_ELEC_{BLDG}$.
Annual thermal load for hotel (MMBtu) ($THERM\_LOAD_{HOTEL}$)	19,660	18,677	18,677	1(e) [Case A] 2(a) [Cases B and C]	Values taken from Table 2. For Cases B and C, annual thermal load is 5% less than Case B.
CHP electricity generation allocated to the Design Building (kWh) (CHP_ELEC_{BLDG})	NA	NA	1,976,475	1(b) [Case C]	$= (X_{HEAT} \times BLDG_{HEAT}) \times CHP\_ELEC_{TOTAL}$ $= (0.95) \times (0.025) \times (83{,}220{,}000 \text{ kWh})$ The allocation of electricity from the DES CHP to the Design Building is based on the fraction of CHP thermal energy provided to the DES and the fraction of total DES thermal energy provided to the hotel. In this example, the electricity allocated to the Design Building (1,976,475 kWh) is less than the modeled electricity load for the Design Building (i.e., 2,812,000 kWh), so no adjustment to the Baseline Building electricity cost is required.

Factor	Case A (Baseline Building)	Case B (Design Building, no DES)	Case C (Design Building, DES)	Step from Methodology	Notes/Equations
CHP fuel input allocated to the Design Building (MMBtu) ($DesignBldg_{FUEL}$)	NA	NA	24,702	2(b) [Case C]	$= [(CHP\_ELEC_{BLDG}) \div (CHP\_ELEC_{TOTAL})] \times (CHP_{FUEL})$ = [(1,976,475 kWh) ÷ (83,220,000 kWh)] × (860,444 MMBtu)
Purchased electricity needed to meet electricity load (kWh)	NA	NA	835,525	2(d) [Case C]	$= (ELEC\_LOAD_{HOTEL}) - (CHP\_ELEC_{BLDG})$ = (2,812,000 kWh) – (1,976,475 kWh) The allocation of electricity from the DES to the Design Building is not enough to meet all of the hotel's electricity load, so some purchased utility electricity is needed.
Onsite boiler fuel needed to meet thermal load (MMBtu)	24,575	23,346	10,378	2(e) [Case C]	$= [(THERM\_LOAD_{HOTEL}) - (CHP\_THERM_{HOTEL})] \div 0.8$ = [(18,677 MMBtu) – (8,430 MMBtu)] ÷ 0.8 The amount of thermal energy provided by the DES is not enough to meet all of the hotel's thermal load, so an onsite boiler is needed to provide the additional thermal energy required. The onsite boiler is assumed to have 80% efficiency.

Table 6: LEED® Optimize Energy Performance Point Determination -

Factor	Case A (Baseline Building)	Case B (Design Building, No DES)	Case C (Design Building, DES)	Step from Methodology
Purchased electricity cost ($)	$454,360.00	$431,642.00	$128,253.09	1(c) [Case A] 2(d) [Cases B and C]
CHP input fuel allocation cost	NA	NA	$196,630.45	2(c) [Case C]
Boiler NG cost ($)	$195,617.00	$185,836.15	$82,605.16	1(f) [Case A] 2(e) [Cases B and C]
Total cost	$649,977.00	$617,478.15	$407,488.70	1(g) [Case A] 2(f) [Cases B and C]
% cost savings from baseline	**NA**	**5.00%**	**37.31%**	**3(a) [Cases B and C]**
OEP points*	**NA**	**0****	**14**	**3(c) [Cases B and C]**

* Table 1 above shows the OEP points awarded for achieving energy cost savings compared to the Baseline Building.
** 5% energy cost savings satisfies the Minimum Energy Performance prerequisite, but does not result in any OEP points earned for the hotel.

Discussion

In this hypothetical example, based on assumptions that are reasonable in our experience, the hotel achieves 37.31 percent energy cost savings and 14 OEP points by connecting to a CHP-equipped DES to supply a portion of its electricity and thermal energy needs (Case C). By not connecting to the CHP-equipped DES, the hotel only achieves 5 percent energy cost savings and fails to earn any OEP points.

CHP produces the same amount of energy using less fuel than separate heat and power (SHP) (i.e., purchased utility electricity and onsite boiler fuel). Buildings connected to a well-designed, CHP-equipped DES take advantage of CHP's enhanced efficiency, and are able to achieve higher energy cost savings compared to a Baseline Building (and thus OEP points) than buildings that choose to meet their energy loads with SHP.