“Proposal of OGE, On-site Generation Efficiency Metric, and ECI, Energy Carbon Intensity Metric,”

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グリーンIT推進協議会
Green IT Promotion Council

Proposal for On-site Generation Efficiency Metrics

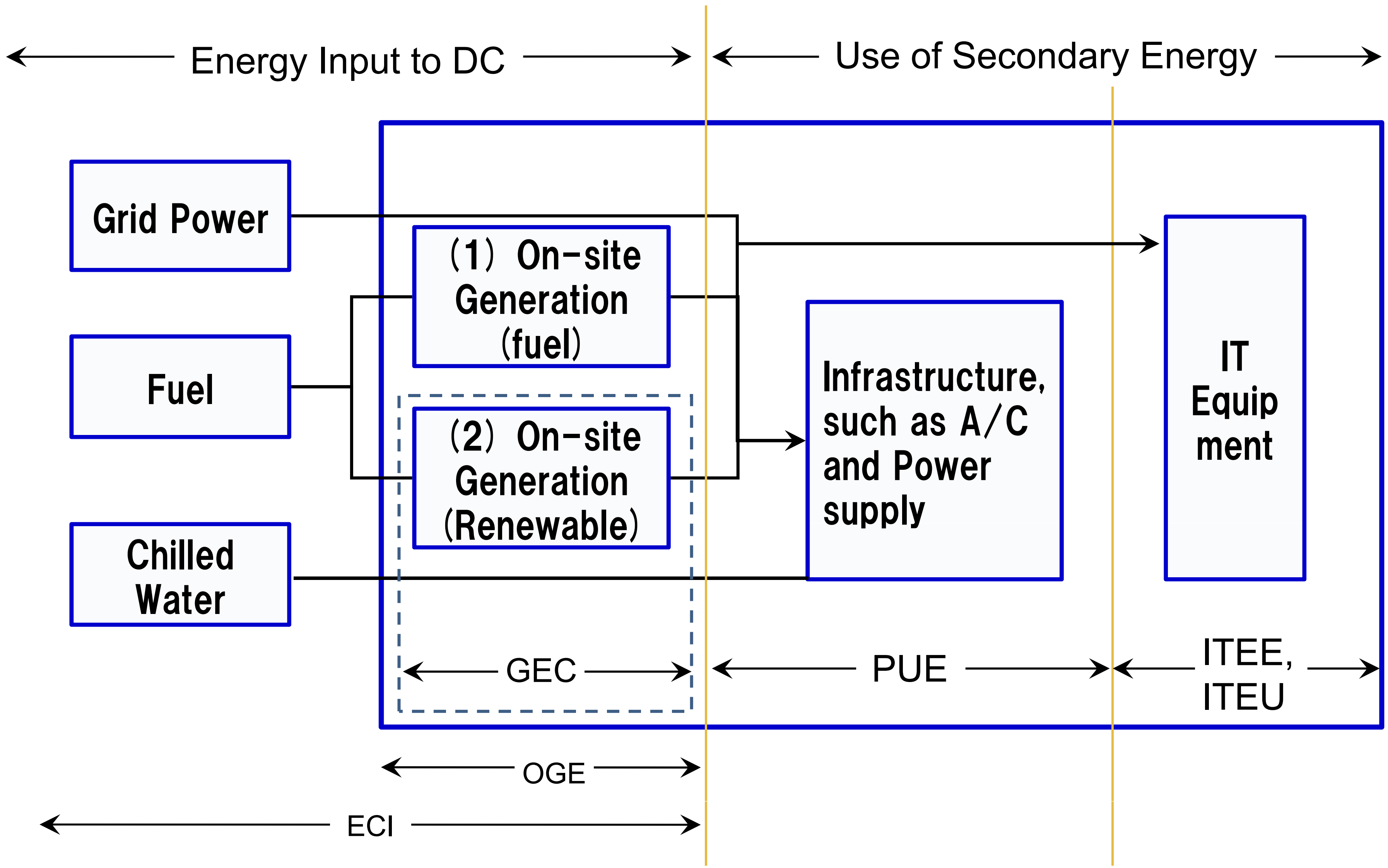
In order to cope with feedbacks to include several energy sources, GIPC will propose OGE or ECI as an expansion of GEC.

Metrics	Purpose and scope
On-site Generation Efficiency (OGE)	• OGE represents an on-site energy generation efficiency from all input energy of a Data Center to all secondary energy used in a Data Center relative to standard generation efficiency. • The purpose is to know how effectively or ineffectively CHP, PV or on-site generator etc. is producing secondary energy within a Data Center. DPPE = ITEU x ITEE x 1/PUE x OGE
Energy Carbon Intensity (ECI)	• ECI represents a carbon intensity of all secondary energy used in a Data Center. • The purpose is to know how much carbon a Data Center is consuming per its secondary energy. And to know how well a Data Center is trying to reduce carbon. DPPE = ITEU x ITEE x 1/PUE x 1/ECI

Scope of Evaluation for On-site Generation

Option		Scope of evaluation			Pros	Cons
		On-site generation (fuel)	On-site generation (Renewable)	Grid power, Green energy purchase		
A	Green Energy Coefficient (GEC)	—	○	—	Easy to calculate. To focus on generation of green energy in DC sites.	Need to use an additional metric for evaluation of on-site generation or CHP
B	On-site Generation Efficiency (OGE) [Fuel + Renewable]	○	○	—	Include all on-site generation methods by DC	Difficult to handle grid-power efficiency for fair international comparison
C	On-site Energy-Cargon Intensity (ECI) [absolute]	○	○	○	Widely accepted carbon intensity. Suitable for fair international comparison. Can include green electricity purchase.	DC can't control carbon intensity of the grid power. However, DC can choose power source.

Boundary of Evaluation for On-site Generation

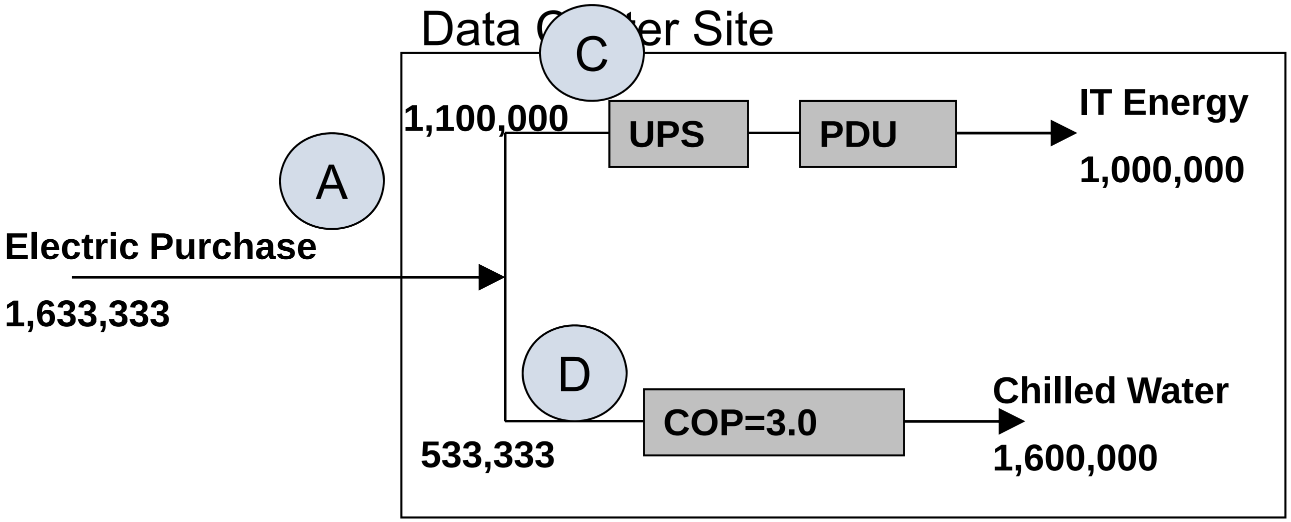


Comparison of GEC/OGE/ECI

	1.Green Energy Coefficent (GEC)	2. On-site Generation Efficiency (OGE)	3.Energy Carbon Intensity (ECI)
Equation	$GEC = \frac{\text{Green Energy generated in DC (kWh)}}{\text{Energy consumed in DC (kWh)}}$	$OGE = \frac{\text{Secondary Energy Used in DC (kWh)}}{\text{Energy Input to DC (kWh)}}$ $= \frac{\text{all electricity + chilled water (kWh)}}{\text{grid electricity + all fuel + district heat}}$ (green electricity[1]) subtracted from the denominator)	$ECI = \frac{\text{Input Energy Carbon to DC (kg-CO2)}}{\text{Secondary Energy Used in DC (kWh)}}$ $= \frac{\sum \text{each energy x Carbon Intensity (kg-CO2)}}{\text{all electricity + chilled water (kWh)}}$
Scope	Electricity generated in DC site without CO2 emission.	On-site generation (fuel) OGE = 1, for all grid power DC OGE > 1, if DC has more efficient generator, CHP or green electric. OGE < 1, if DC has less efficient own generator/CHP OGE = ∞, for all green electric DC	Total carbon intensity ECI = CI of Grid Power, for all grid power DC ECI < CI, if DC has more carbon efficient CHP, or green electric ECI > CI, if DC has less carbon efficient CHP ECI = 0, for all green electric DC (note: CI stands for Carbon Intensity)
Pros	To focus on generation of green energy in DC site.	OGE is good for global comparison of own generation, CHP efficiency. OGE is not affected by either generation efficiency or carbon intensity of grid power.	ECI accounts for both efficiency of CHP and generation of green electric.
Cons	Efficiency of usual on-site generation by fuel is excluded.	Difficult to handle grid-power efficiency for fair international comparison	For solar, wind, and geothermal, the carbon intensity is zero. For grid power, carbon intensity is known. For other energy type, see table from each country.

1) "Green Electricity" of OGE is defined as on-site "Zero Emission Energy" as shown in p. 7.

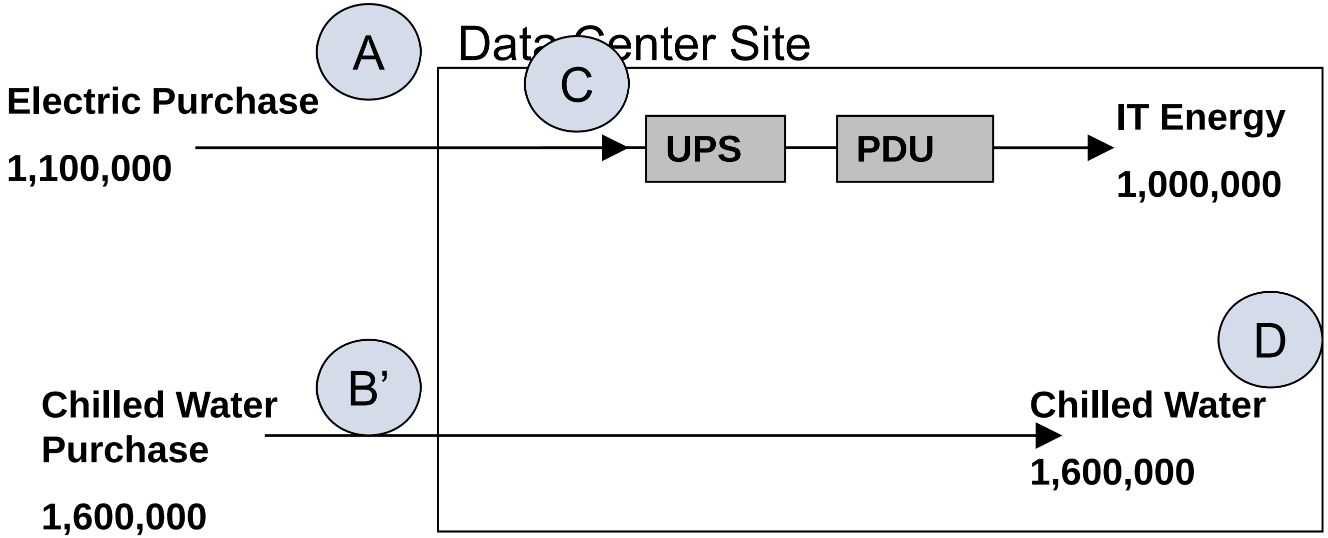
Case A – All Electric Purchase



GEC	OGE	ECI
$GEC = \frac{0}{C+D}$	$OGE = \frac{C + D}{A}$	$ECI = \frac{A \times I\_a}{C + D}$
$= 0$	$= \frac{1{,}100{,}000 + 533{,}333}{1{,}633{,}333}$	$= \frac{1{,}633{,}333 \times 0.4}{1{,}100{,}000 + 533{,}333}$
	= 1.0 [kWh/kWh]	=0.40 [kg-CO2/kWh]

Note: I_a = 0.4 [kg-CO2/kWh] is the carbon intensity of the grid power in Japan.

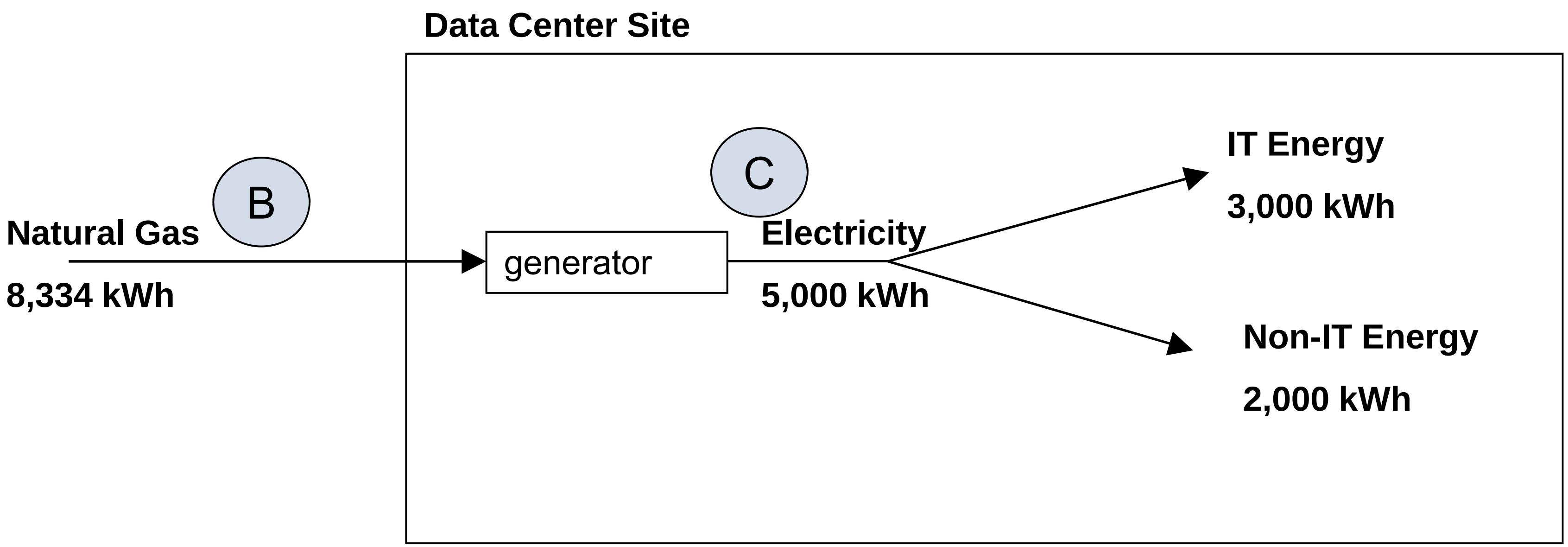
Case B – Electricity & Chilled Water Purchase



GEC	OGE	ECI
$GEC = \frac{0}{C + D \times 0.4}$	$OGE = \frac{C + D \times 0.4}{A + B' \times 0.4}$	$ECI = \frac{A \times I\_a + B' \times I\_b'}{C + D \times 0.4}$
$= 0$	$= \frac{1{,}100{,}000 + 1{,}600{,}000 \times 0.4}{1{,}100{,}000 + 1{,}600{,}000 \times 0.4}$	$= \frac{1{,}100{,}000 \times 0.4 + 1{,}600{,}000 \times 0.205}{1{,}100{,}000 + 1{,}600{,}000 \times 0.4}$
	= 1.0 [kWh/kWh]	=0.44 [kg-CO2/kWh]

Note: I_a = 0.4 [kg-CO2/kWh] and I_b' = 0.205 [kg-CO2/kWh] are the carbon intensity of the grid power (A) and chilled water (B') in Japan, respectively.
I_b' = 0.057 [t-CO2/GJ] x 0.0036[GJ/kWh]

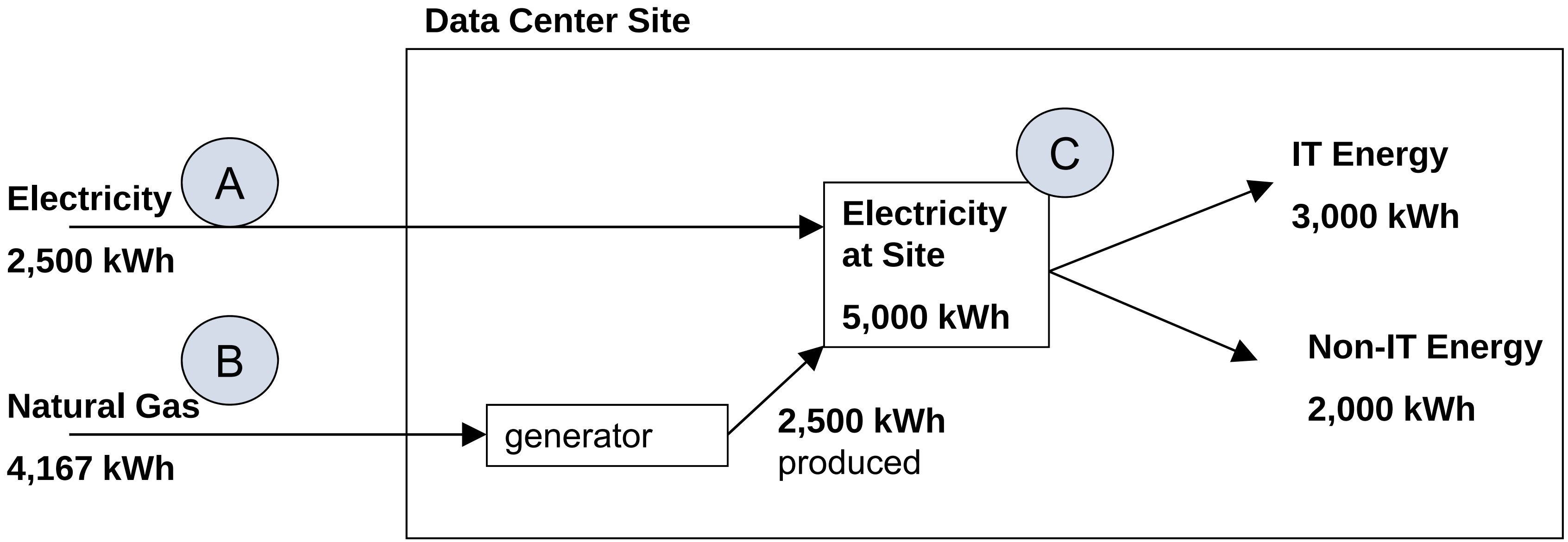
Case C – Natural Gas Purchase



GEC	OGE	ECI
$GEC = \frac{0}{C}$	$OGE = \frac{C}{B \times 0.35}$	$ECI = \frac{B \times I\_b}{C}$
$= 0$	$= \frac{5{,}000}{8{,}334 \times 0.35}$	$= \frac{8334 \times 0.18}{5{,}000}$
	= 1.7 [kWh/kWh]	=0.30 [kg-CO2/kWh]

Note: I_b = 0.18 [kg-CO2/kWh] are the carbon intensity of natural gas in Japan.
I_b = 0.0139 [t-C/GJ] x (44/12) x 0.0036[GJ/kWh]
UPS/PDU loss neglected?

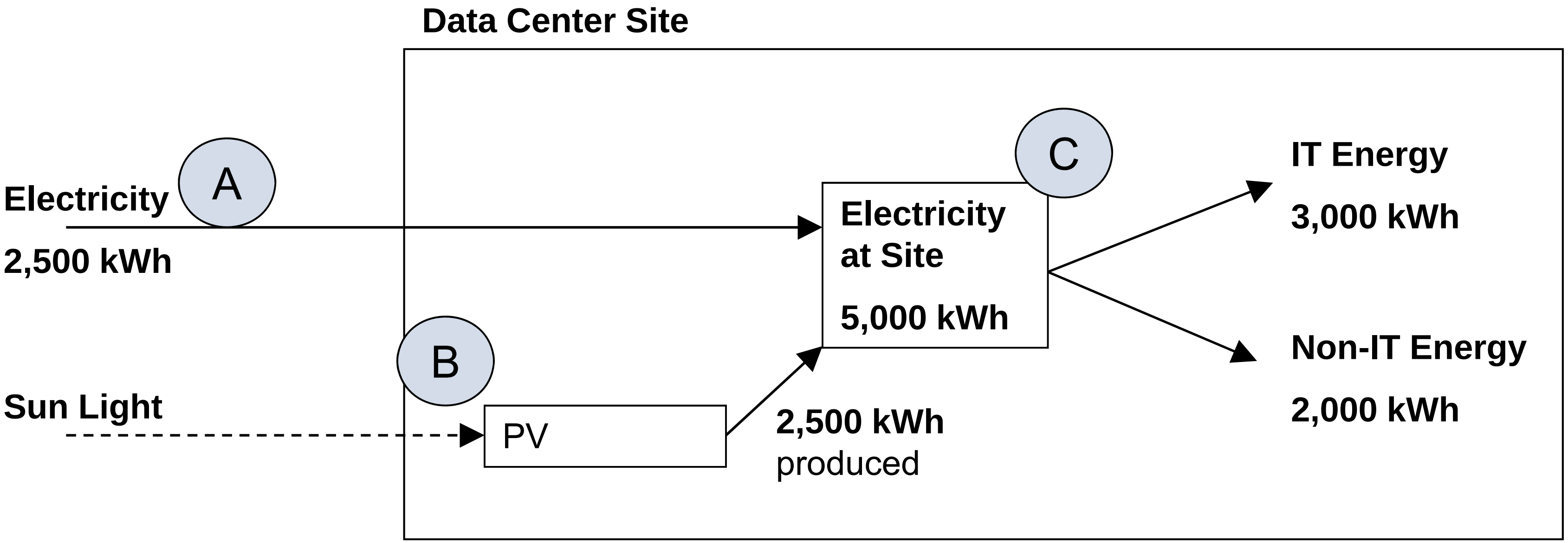
Case D – Electric & Natural Gas Purchase



GEC	OGE	ECI
$GEC = \frac{0}{C}$	$OGE = \frac{C}{A + B \times 0.35}$	$ECI = \frac{A \times I\_a + B \times I\_b}{C}$
$= 0$	$= \frac{3{,}000 + 2{,}000}{2{,}500 + 4{,}167 \times 0.35}$	$= \frac{2{,}500 \times 0.4 + 4{,}167 \times 0.18}{5{,}000}$
	= 1.3 [kWh/kWh]	=0.35 [kg-CO2/kWh]

Note: I_a = 0.4 [kg-CO2/kWh] and I_b = 0.18 [kg-CO2/kWh] are the carbon intensity of the grid power (A) and natural gas (B), respectively.
I_b = 0.0139 [t-C/GJ] x (44/12) x 0.0036[GJ/kWh]

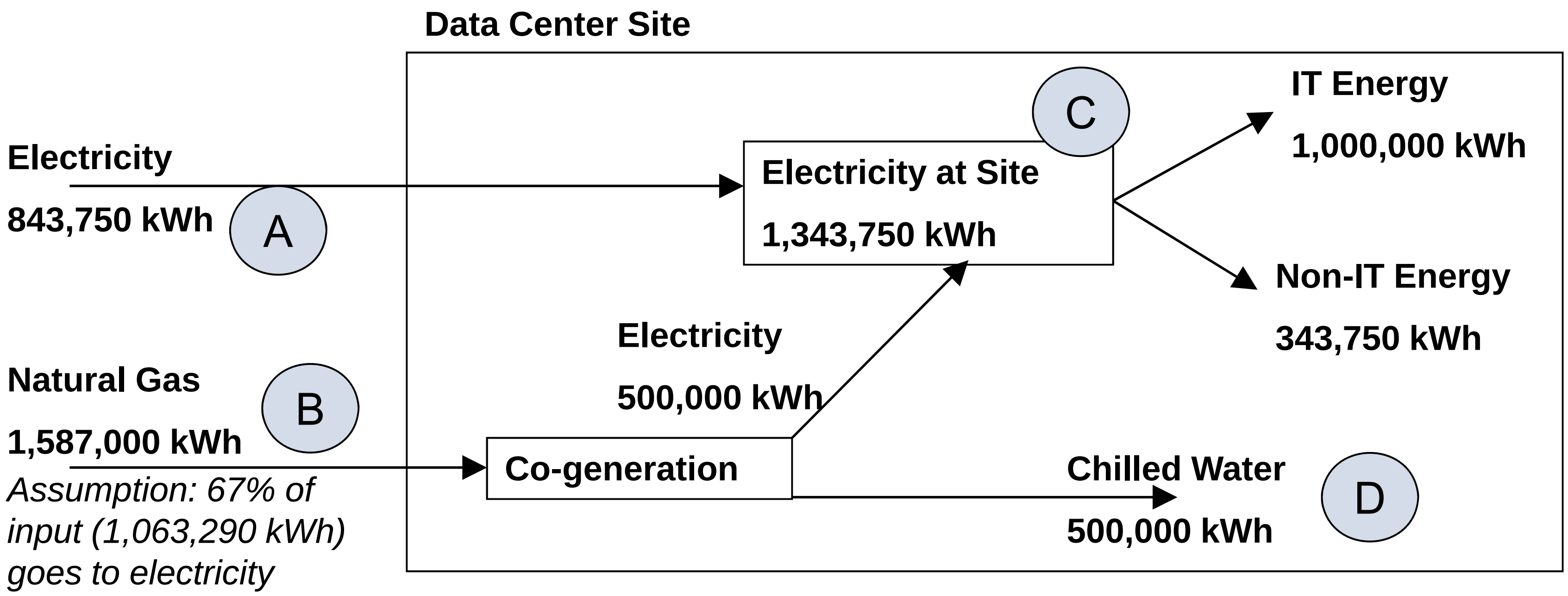
Case D' – Electric & Photovoltaic (PV)



GEC	OGE	ECI
$GEC = \frac{B}{C} = \frac{2{,}500}{5{,}000} = 0.5$	$OGE = \frac{C}{A + B} = \frac{5{,}000}{2{,}500 + 0} = 2.0$ [kWh/kWh]	$ECI = \frac{A \times I\_a + B \times I\_b}{C} = \frac{2{,}500 \times 0.4 + 2{,}500 \times 0}{5{,}000} = 0.20$ [kg-CO2/kWh]

Note: I_a = 0.4 [kg-CO2/kWh] and I_b = 0.18 [kg-CO2/kWh] are the carbon intensity of the grid power (A) and natural gas (B), respectively.
I_b = 0.0139 [t-C/GJ] x (44/12) x 0.0036[GJ/kWh]

Case E – Electricity & Natural Gas (Cogeneration) Purchase



GEC

$$GEC = \frac{0}{C + D \times 0.4}$$

$$= 0$$

OGE

$$OGE = \frac{C + D \times 0.4}{A + B \times 0.35}$$

$$= \frac{1{,}343{,}750 + 500{,}000 \times 0.4}{843{,}750 + 1{,}587{,}000 \times 0.35}$$

$$= 1.1\ [kWh/kWh]$$

ECI

$$ECI = \frac{A \times I\_a + B \times I\_b}{C + D \times 0.4}$$

$$= \frac{843{,}750 \times 0.4 + 1{,}587{,}000 \times 0.18}{1{,}343{,}750 + 500{,}000 \times 0.4}$$

$$= 0.404 [kg\text{-}CO2/kWh]$$

Note: I_a = 0.4 [kg-CO2/kWh] and I_b = 0.18 [kg-CO2/kWh] are the carbon intensity of the grid power (A) and natural gas (B), respectively.
I_b = 0.0139 [t-C/GJ] x (44/12) x 0.0036[GJ/kWh]