Harmonizing Global Metrics for Data Center Energy Efficiency

Global Taskforce Reaches Agreement on Measurement Protocols for PUE – Continues Discussion of Additional Energy Efficiency Metrics

February 28th, 2011

The data center has become an increasingly important part of most business operations in the twenty-first century.   With escalating demand and rising energy prices, it is essential for the owners and operators of these mission critical facilities to assess and improve their performance with energy efficiency metrics. However, even with the global presence of many companies, these metrics are often not applied consistently at a global level.

To address these inconsistencies, a group of global leaders has been meeting regularly to agree on standard approaches and reporting conventions for key energy efficiency metrics. These organizations are: U.S. Department of Energy's Save Energy Now and Federal Energy Management Programs, U.S. Environmental Protection Agency's ENERGY STAR Program, European Commission Joint Research Center Data Centers Code of Conduct, Japan's Ministry of Economy, Trade and Industry, Japan's Green IT Promotion Council, and The Green Grid.

A joint statement in February 2010 highlighted goals and guiding principles for collaboration. In the past year, this work has been expanded to provide greater detail on measurement guidelines and next steps to help bring superior IT productivity metrics to the market. This current document reflects agreements reached as of February 28th, 2011. The group intends to continue collaboration as an ongoing effort to improve Data Center Energy efficiency and Green House Gas Emission efficiencies.

Goal

Share global lessons and practices with an objective of arriving at a set of metrics, indices, and measurement protocols which can be formally endorsed or adopted by each participant organization to improve data center energy efficiency globally. This includes the following specific goals:
        1. Identify an initial set of metrics
        2. Define each metric
        3. Define the process for measurement of each metric
        4. Establish on-going dialog for development of additional metrics

Desired Outcomes

There are several desired outcomes of the Taskforce's activities.

Outcome (1) – Effective energy efficiency metrics that measure the actual IT work output of the data center compared to actual energy consumption. It is of note that in the process to define IT work output, the following interim measurements are being defined and/or validated:

> *Outcome (1.a)* – IT – Measure the potential IT work output compared to expected energy consumption; and measure operational utilization of IT Equipment.
>
> *Outcome (1b)* – Data center facility and infrastructure – Measure the data center infrastructure and efficiency (Power Usage Effectiveness - PUE)

Outcome (2) – Measure renewable energy technologies and re-use of energy to reduce carbon.

Guiding Principles

It is recommended by all that the development of metrics to address Outcomes (1.a), (1.b), and (2), should form a holistic framework to address all aspects of the above desired outcomes.

The Taskforce has finalized discussions and agreed on the following:

Outcome (1.b) – It is recommended that data centers begin to measure PUE according to these principles:

- PUE using source energy is the preferred energy efficiency metric. PUE is a measurement of the total energy of the data center divided by the IT energy consumption.

- The industry should improve the IT measurement capabilities to ultimately enable taking the measurement directly at the IT load (e.g. servers, storage, networking, etc.). The recommendation is to measure the IT energy at the output of the PDU. At a minimum IT energy measurements should be measured at the output of the UPS.

- For a data center, total energy measurement should include all energy sources at the point of utility handoff. Total energy should include all cooling, lighting, and support infrastructure, in addition to IT load.

- Additional detail on measurement guidelines have been added in Appendix A for PUE measurements. The additional detail provides guidelines specific to equitable measurements of PUE with various designs; using multiple energy inputs (including renewable energy), on-site generation, and re-use of energy.

The Taskforce is in agreement on the following concepts, as an interim step toward the desired Outcomes.

Outcome (1.a) – As noted in the desired outcomes, metrics in this area need to address both the potential capability of the IT equipment and the efficiency of which it is employed.

Outcome (2) – As noted in the desired outcomes, metrics in this area need to address on-site generation efficiencies (including renewable energy), re-use of energy, and carbon emissions at the data center site.

Progress to Date and Next Steps

Specific to the holistic framework being sought by the Taskforce, several approaches are currently being evaluated:

- A single metric to evaluate overall data center efficiency (one such approach is DPPE: http://www.greenit-pc.jp/topics/release/pdf/dppe_e_20100315.pdf)

- A multi-parameter framework to evaluate overall data center efficiency (one such approach is The Green Grid Productivity Indicator: http://www.thegreengrid.org/en/Global/Content/white-papers/TGG-Productivity-Indicator)

Other approaches will be evaluated as they are suggested or identified.

Specific to the Desired Outcomes:

Outcome (1) – Measure the actual IT work output of the data center compared to actual energy consumption. At this time the Taskforce is primarily focusing on Outcome (1.a).

Outcome (1.a) – IT – Measure the potential IT work output compared to expected energy consumption; and measure operational utilization of IT Equipment. Over this past year the Taskforce has reviewed the following metrics and continues to evaluate their applicability through industry trials:

- IT Equipment Efficiency (ITEE) & IT Equipment Usage (ITEU). For further details see the published GIPC material: http://www.greenit-pc.jp/topics/release/pdf/dppe_e_20100315.pdf
- Data Center Energy Productivity (DCeP) Proxies, Bits per kWh Proxy, CPU Utilization Proxies, OS instance Proxy. For further details see The Green Grid published material: http://www.thegreengrid.org/en/Global/Content/white-papers/Productivity%20Proxy%20Proposals%20Feedback%20Interim%20Results

Outcome (1.b) – Data center facility and infrastructure – Measure the data center infrastructure and efficiency (PUE). With the above revised guiding principles, there are no further outstanding PUE related items for discussion at this time.

Outcome (2) – Measure renewable energy technologies and re-use of energy to reduce carbon. Over this past year the Taskforce has begun to review the following metrics. Further work is required to provide guiding principles in this area. The taskforce is working toward new metrics and at this time the following are the metrics under review:

- Energy Reuse Effectiveness (ERE). For further details see The Green Grid published material: http://www.thegreengrid.org/en/Global/Content/white-papers/ERE
- Carbon Usage Effectiveness (CUE). For further details see The Green Grid published material: http://www.thegreengrid.org/en/Global/Content/white-papers/Carbon_Usage_Effectiveness_White_Paper
- On-site Energy Generation Efficiency (OGE) and Energy Carbon Intensity (ECI). For further details see the published GIPC material: http://www.greenit-pc.jp/topics/release/pdf/dppe_e_20110222.pdf

This guidance is meant to provide a status update for the Taskforce's desired outcomes and to help drive a common understanding of energy efficiency metrics. With continued dialog and additional input by a variety of stakeholders, this guidance will be refined and expanded to maximize its impact on both energy consumption and operational efficiency. There is significant interest and work among the bodies represented to proceed with globally accepted metrics and measurement protocols, providing guidance to range from minimum recommendations to best practices.

The Taskforce has met in the U.S., Italy, and Japan and has recently celebrated two years of collaboration. The Taskforce has confirmed to continue the discussion and collaboration around these metrics toward global harmonization of metrics for data center energy efficiency.

Participating Organizations

Each organization is represented on the Taskforce, which convenes regularly to advance the progress of the group. A full group of participants from each organization continues to meet in person every 6 to 12 months, as the Taskforce feels it is appropriate based on progress.

For further details, please contact:
- The Green Grid: gdcmetrics@lists.thegreengrid.org
- U.S. Department of Energy Save Energy Now Program: http://www1.eere.energy.gov/industry/datacenters/contacts.html
- U.S. Environmental Protection Agency's ENERGY STAR Program: www.energystar.gov/datacenters
- European Commission – Joint Research Centre: http://re.jrc.ec.europa.eu/energyefficiency/html/standby_initiative_data_centers.htm
- Ministry of Economy, Trade, and Industry: http://www.meti.go.jp/english/index.html
- Green IT Promotion Council: http://www.greenit-pc.jp

Appendices

Appendix A - PUE Measurement Details

The seemingly simple concept of PUE requires additional detail to ensure that it is applied consistently across data centers. Consistent calculations of PUE facilitate communication of performance among data center owners and operators.

- Total Energy (Data Center Boundary) – Total Energy should be measured at the point of utility hand off to the data center. This may include measurements of electricity, chilled water, natural gas, fuel oil, or other purchases made from a utility. All measurements should be made from the point where the energy is purchased. In the case where natural gas is purchased to produce chilled water or electricity, measurement shall occur of the natural gas purchase and *not* of the secondary energy it produces.
    - Consistent Units – All energy shall be reported using the same units, and the recommended unit of measure shall be kWh. Standard thermal conversion factors shall be used to convert to kWh (e.g. 1 kWh = 3.412 kBtu; 1 GJ = 278 kWh)

- IT Energy – IT Energy shall be measured in kWh. The recommendation is to measure the IT energy at the output of the PDU. At a minimum IT Energy should be measured at the output of the UPS.

- Source Energy – Source Energy is a means of assessing the total primary energy use or fuel consumption at a data center. The purpose of source energy is to ensure that data centers that purchase different forms of energy (electricity, natural gas, chilled water) can compare their total consumption equitably. For example, if one data center purchases chilled water from a local utility company while another data center uses electricity to produce chilled water onsite, a factor is required to put the two utility bills in common units for comparison. This factor is called a source energy factor, and it is a factor to reflect the total fuel consumption.

  Because the majority of data centers operate with 100% electricity, this global group recommends source energy factors that are weighted with respect to electricity. In other words, after source factors are developed for each fuel, they are each expressed relative to the source factor for electricity. This convention allows for any electric purchases to be multiplied by a factor of one. Purchases of other fuels are multiplied by their respective factors before being added to the total.

  Weighted energy for each energy type = (Annual energy use * source energy weighting factor)

  The source energy factor is inherently a regional factor because the amount of fuel needed to produce one unit of electricity (or chilled water) will depend on the predominant method of electric (or chilled water) generation in the specific country. Some countries have published values for these conversion factors (such as the EPA ENERGY STAR Program). However, to enable a fair global comparison, this global group recommends that standard, global factors be applied. Global factors represent average values of factors from different regions. While the

global factors are recommended for comparisons across different regions of the world, regional factors may be applied for greater accuracy of comparison within a specific region.
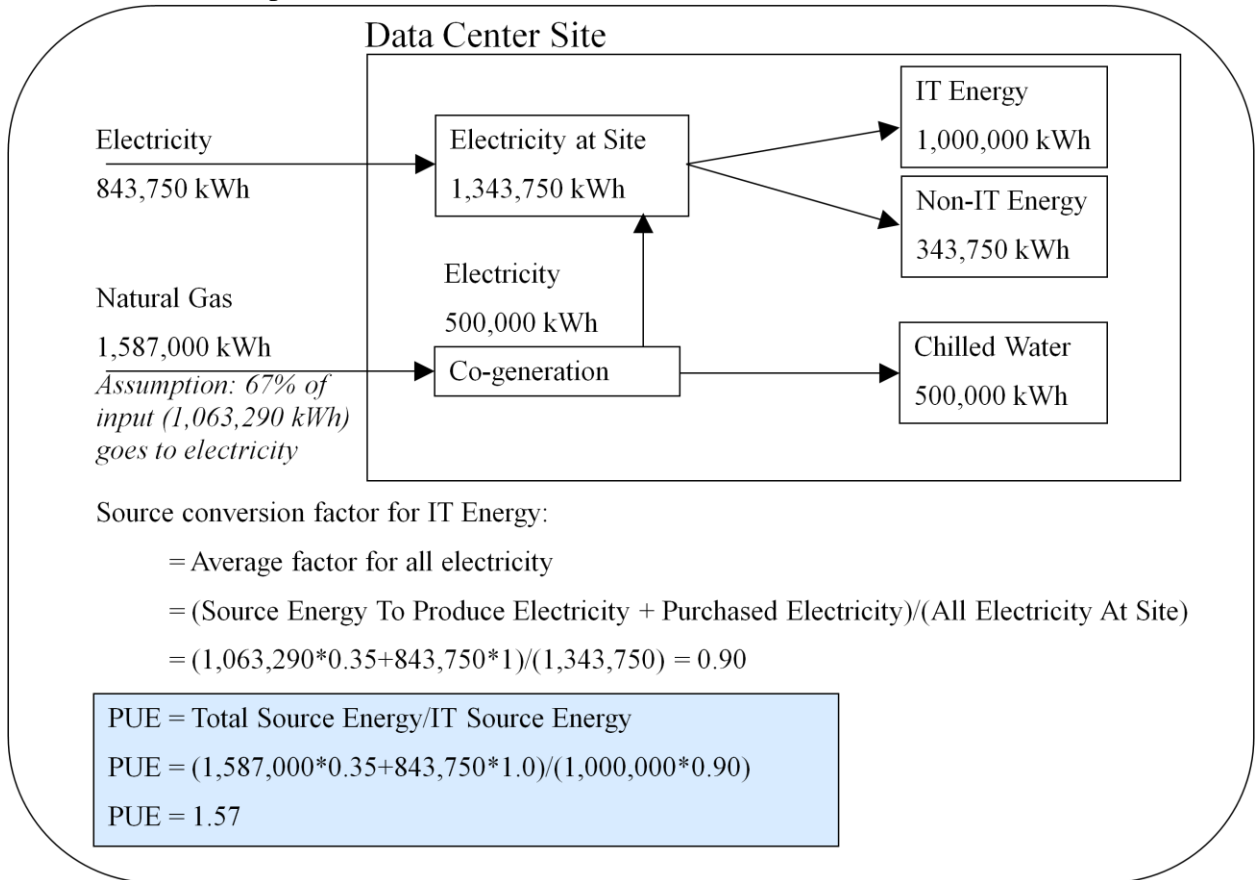
The global average source energy weighting factors shall be:

Energy Type	Weighting Factor
Electricity	1.0
Natural gas	0.35
Fuel oil	0.35
Other fuels	0.35
District chilled water	0.4
District hot water	0.4
District steam	0.4

To express Total Source Energy, each fuel should first be converted into a single common unit (kWh); then each fuel should be multiplied by its weighting factor; finally, the source energy for all fuels can be summed together.

- On-Site Electric Generation – To enable equitable PUE calculations in data center designs that operate on-site electric generation two topics need to be explained:
    - IT Source Energy Conversion Factor
        - To ensure the PUE calculations for a design including on-site electric generation and a design excluding on-site electric generation are equitable, the taskforce has introduced the IT Source Energy Factor. The IT Source Energy Factor enables the data center owner / operator to include the efficiencies of generating chilled water (as in all calculations for PUE), but exclude the efficiencies of generating electricity (as in all calculations for PUE). PUE is not a metric to identify the efficiencies of how electricity is brought to the data center, it is a metric to identify how efficient the electricity is used from the data center control volume to the IT Equipment.

- **Example A: Data center with electric and natural gas (Co-generation) purchase**

Data Center Site

Electricity
843,750 kWh → Electricity at Site 1,343,750 kWh → IT Energy 1,000,000 kWh / Non-IT Energy 343,750 kWh

Natural Gas
1,587,000 kWh
Assumption: 67% of input (1,063,290 kWh) goes to electricity → Co-generation

Electricity 500,000 kWh → (into Electricity at Site)

Co-generation → Chilled Water 500,000 kWh

Source conversion factor for IT Energy:

= Average factor for all electricity

= (Source Energy To Produce Electricity + Purchased Electricity)/(All Electricity At Site)

= (1,063,290*0.35+843,750*1)/(1,343,750) = 0.90

PUE = Total Source Energy/IT Source Energy

PUE = (1,587,000*0.35+843,750*1.0)/(1,000,000*0.90)

PUE = 1.57

- **Cogeneration Input Fuel Assumption**
    - This taskforce has adopted the assumption that 67% of a cogeneration plants' input fuel is allocated to the primary form of generation (electricity in the provided example) and respectively 33% of the primary input fuel is allocated to the secondary form of generation (chilled water in the provided example).
    - This assumption is based on a similar steam based cogeneration study from the U.S. Environmental Protection Agency's Energy Star Program. Differences do exist between the two scenarios, but to solidify the methodology of calculating PUE and to drive consistent and equitable calculations for all design types, this Taskforce is proceeding with the recommendation to adopt this approach. As further data specific to cogeneration examples are provided, the data will be taken into consideration. Provided there is a material change in calculations, the Taskforce will consider updating the recommendations specific to this assumption.
    - Stakeholder feedback is welcome and encouraged to continue the adoption, consistent communication, and equitable calculations for PUE in an effort to improve energy efficiency.

- Energy Re-use – Energy that is re-used shall *not* be subtracted from the total energy use of the data center.
  - If the energy is reused within the datacenter, the value of the reused energy will already be contained within the PUE calculation and needs no special consideration. An example will be reusing waste heat to warm a battery space in a cool climate. The PUE would generally be lower because the HVAC system does not have to add as much energy to heat that battery space, thereby reducing the PUE when energy is measured and PUE calculated.
  - If the energy is reused outside the data center (e.g. re-using heat to warm a lab that is not part of the data center), the PUE of the data center is not affected. While the effort to conserve energy is laudable, it cannot be accounted for in the calculation of the data center PUE because it does not lower the actual total energy need of the data center.

- Measuring PUE in a Mixed-use Building
  - The definition of a Mixed-use Building is a facility that has a data center and services not associated with the data center. As an example a Sales team or Marketing team are also housed within a building, but have no direct support responsibilities for the data center.

  - The method for calculating PUE in a mixed use building is the same method for calculating PUE in a dedicated data center except for some ancillary energy loads that <u>can</u> be excluded*:

    - Energy required for shared support spaces: (ancillary energy loads)

      - Shared offices

      - Shared labs

      - Shared cubicles

      - Shared conference rooms

      - Shared elevators

      - Shared lobbies

      - Shared Kitchens / break rooms

      * When excluding any ancillary energy loads this should be declared when reporting PUE.

    - The shared elevator is one example to illustrate the rationale for the above noted exceptions. A data center can be a small portion of one floor located on one level of a multistory building. The data center is located on the 5th floor of a 10 story building. The 5th floor also is mixed-use with many business services and a data center. The effort to implement energy
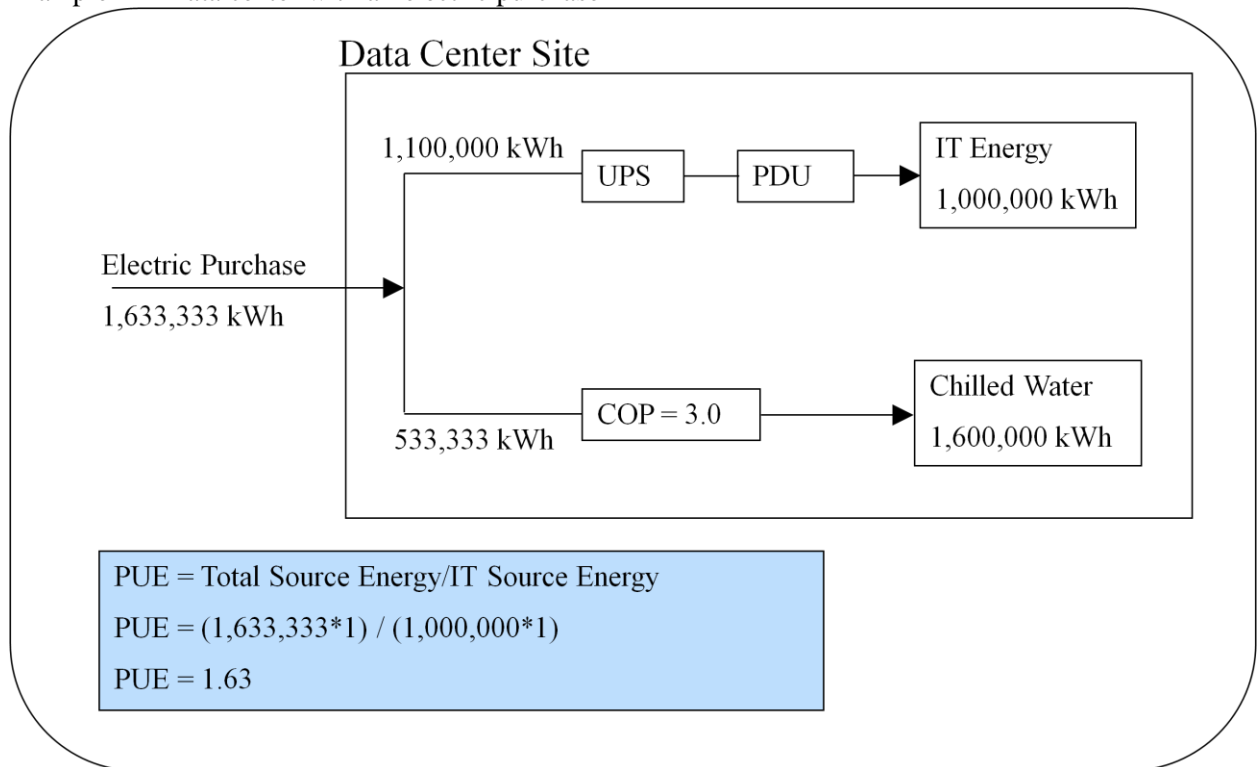
measurements on the shared elevator and the effort to try to quantify how much of that energy should be allocated to the data center traffic on the 5th floor is believed to be a point of diminishing returns. The proportional load for the elevator is insignificant in the PUE calculation.

- ▪ Energy consumption of all dedicated space is to be included. As an example if there are offices or cubicles that are dedicated to the data center operations, the energy consumption should be included. Provided the above direction is followed, PUE reporting of data centers within mixed-use buildings follow the same nomenclature as PUE reporting of dedicated data centers.
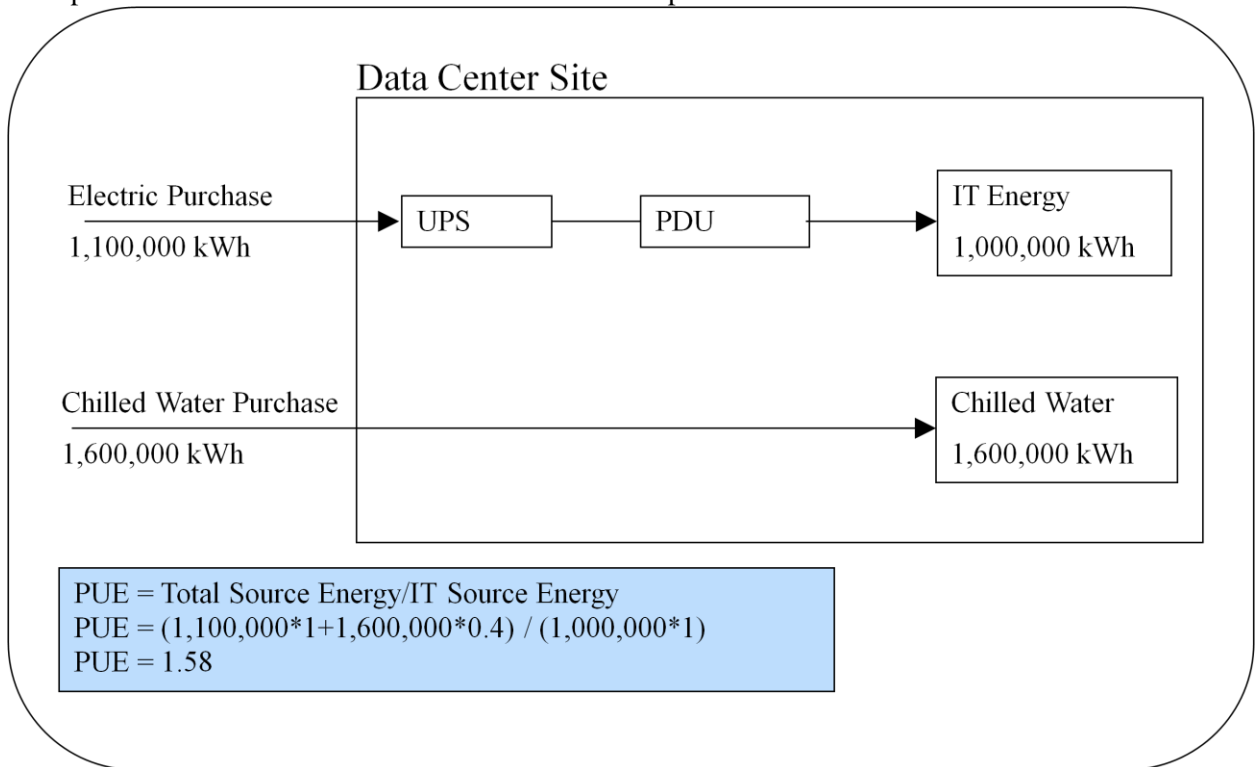
Appendix B – PUE Illustrative Calculation Examples

The following illustrative examples have been provided to demonstrate a few data center designs and the corresponding approach to calculate PUE by the above recommendations:

- • Example B – Data center with all electric purchase

- Example C – Data center with electric and chilled water purchase

Data Center Site

Electric Purchase
1,100,000 kWh → UPS → PDU → IT Energy 1,000,000 kWh

Chilled Water Purchase
1,600,000 kWh → Chilled Water 1,600,000 kWh

PUE = Total Source Energy/IT Source Energy
PUE = (1,100,000*1+1,600,000*0.4) / (1,000,000*1)
PUE = 1.58

- Example D – Data center with natural gas purchase

Data Center Site

Natural Gas
8,334 kWh → Generator → Electricity 5,000 kWh → IT Energy 3,000 kWh
→ Non-IT Energy 2,000 kWh

Source conversion factor for IT Energy:

= Average factor for all electricity

= (Source Energy to produce electricity + Purchased Electricity)/(All Electricity At site)

= (8,334*0.35+0*1)/(5,000) = 0.58

PUE = Total Source Energy/IT Source Energy

PUE = (8,334*0.35)/(3,000*0.58)

PUE = 1.67
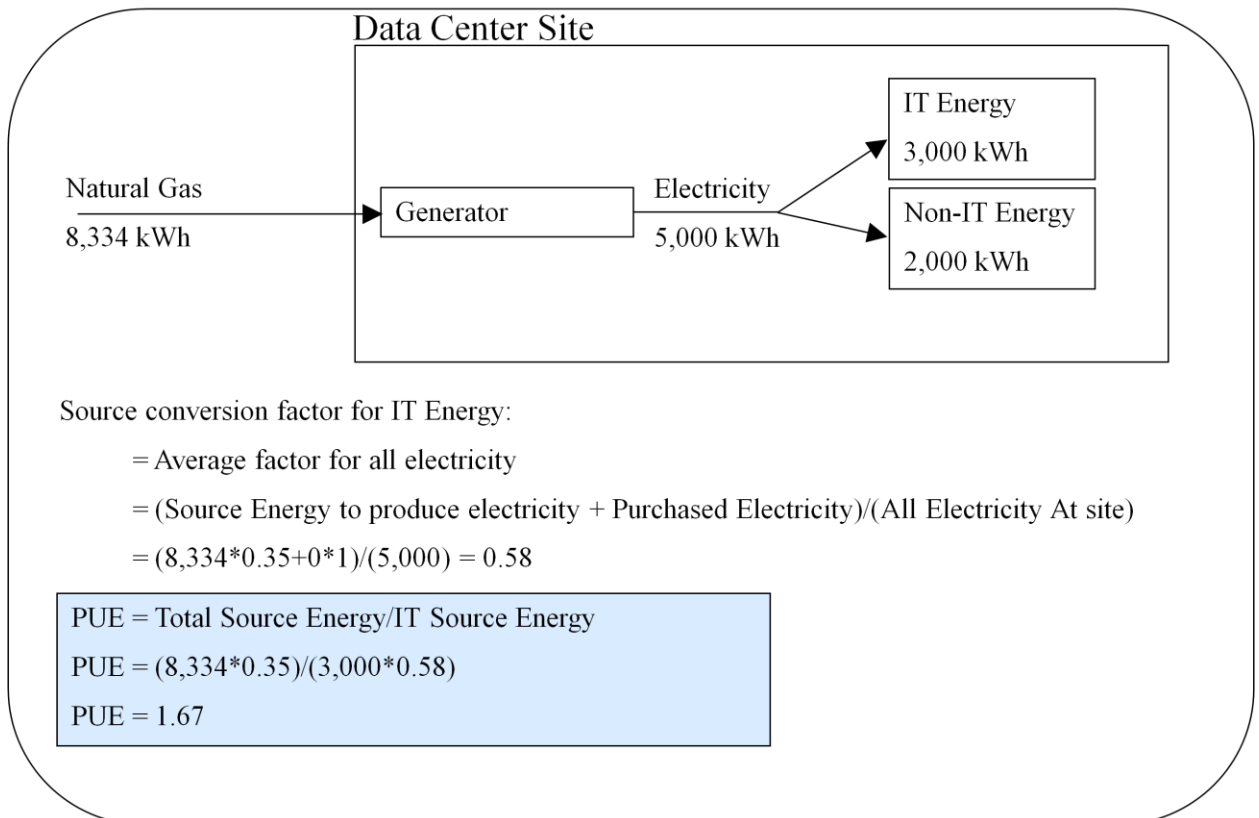
- Case E – Data center with electric and natural gas purchase

Data Center Site

Electricity
2,500 kWh

Electricity at Site
5,000 kWh

IT Energy
3,000 kWh

Non-IT Energy
2,000 kWh

2,500 kWh
produced

Natural Gas
4,167 kWh

Generator

Source conversion factor for IT Energy:

= Average factor for all electricity

= (Source Energy to produce electricity + Purchased Electricity)/(All Electricity At site)

= (4,167*0.35+2,500*1)/(5,000) = 0.79

PUE = Total Source Energy/IT Source Energy

PUE = (4,167*0.35+2,500)/(3,000*0.79)

PUE = 1.67